Kognitionspsychologie II: Session 3

Neural basis of emotions

Loreen Tisdall, FS 2025

Version: March 17, 2025

Semester overview

#	Date	Topic	Slides	Instructor
1	18.02.2025	Emotion: What is an emotion?	pdf	Mata
2	25.02.2025	Emotion: What is an emotion? (continued)	pdf	Mata
3	18.03.2025	Emotion: Neural bases		Tisdall
4	25.03.2025	Emotion: Regulation		Mata
5	01.04.2025	Emotion: Well-being		Mata
6	08.04.2025	Motivation: What is motivation?		Mata
7	15.04.2025	Motivation: Extrinsic vs intrinsic motivation		Mata
8	29.04.2025	Motivation: Neural bases		Tisdall
9	06.05.2025	Motivation: Cooperation and morality		Theisen
10	13.05.2025	Applications		Mata
11	20.05.2025	Wrap-up and Q&A		Mata
12	03.06.2025	Exam (DSBG Neubau)		
13	03.06.2025	Repeat Exam (Biozentrum)		

Learning Objectives

- Learn about **neural model**(s) of basic (and not so basic) emotions
- Learn about methods to **meta-analyze** neuroimaging studies, and their shortcomings (and possible solutions ;))
- Engage with the evidence supporting **locationist versus constructivist approaches** to the neural basis of emotions
- Get a first intuition of how **brain maturation** supports the development of emotion control / regulation from childhood to early adulthood

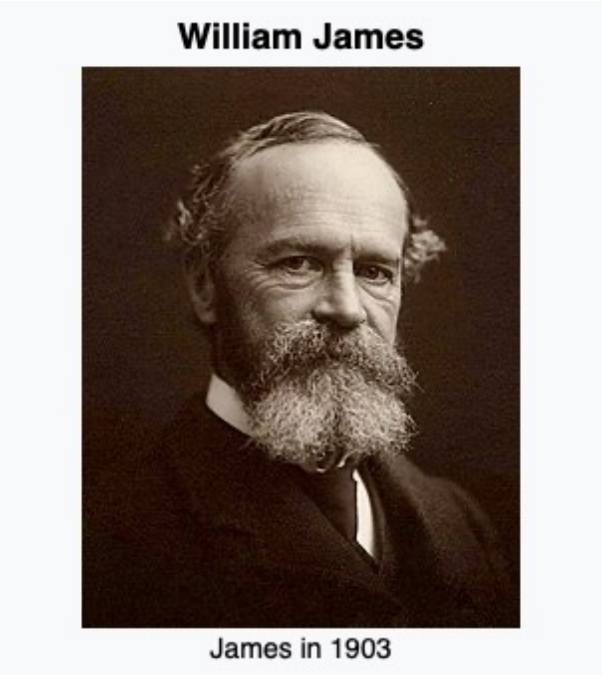
Recap: What is emotion?

Image created with AI (Bing), January 31, 2024

"It is widely agreed that emotion refers to a collection of psychological states that include subjective experience, expressive behavior (e.g., facial, bodily, verbal), and peripheral physiological responses (e.g., heart rate, respiration). It is also widely agreed that emotions are a central feature in any psychological model of the human mind. **Beyond these two points of agreement, however, almost everything else seems to be subject to debate**."

Gross, J.J, & Barrett, L.F. (2011). *Emotion generation and emotion regulation: One or two depends on your point of view*. Emotion Review, 3, 8–16.

The neural basis of emotion



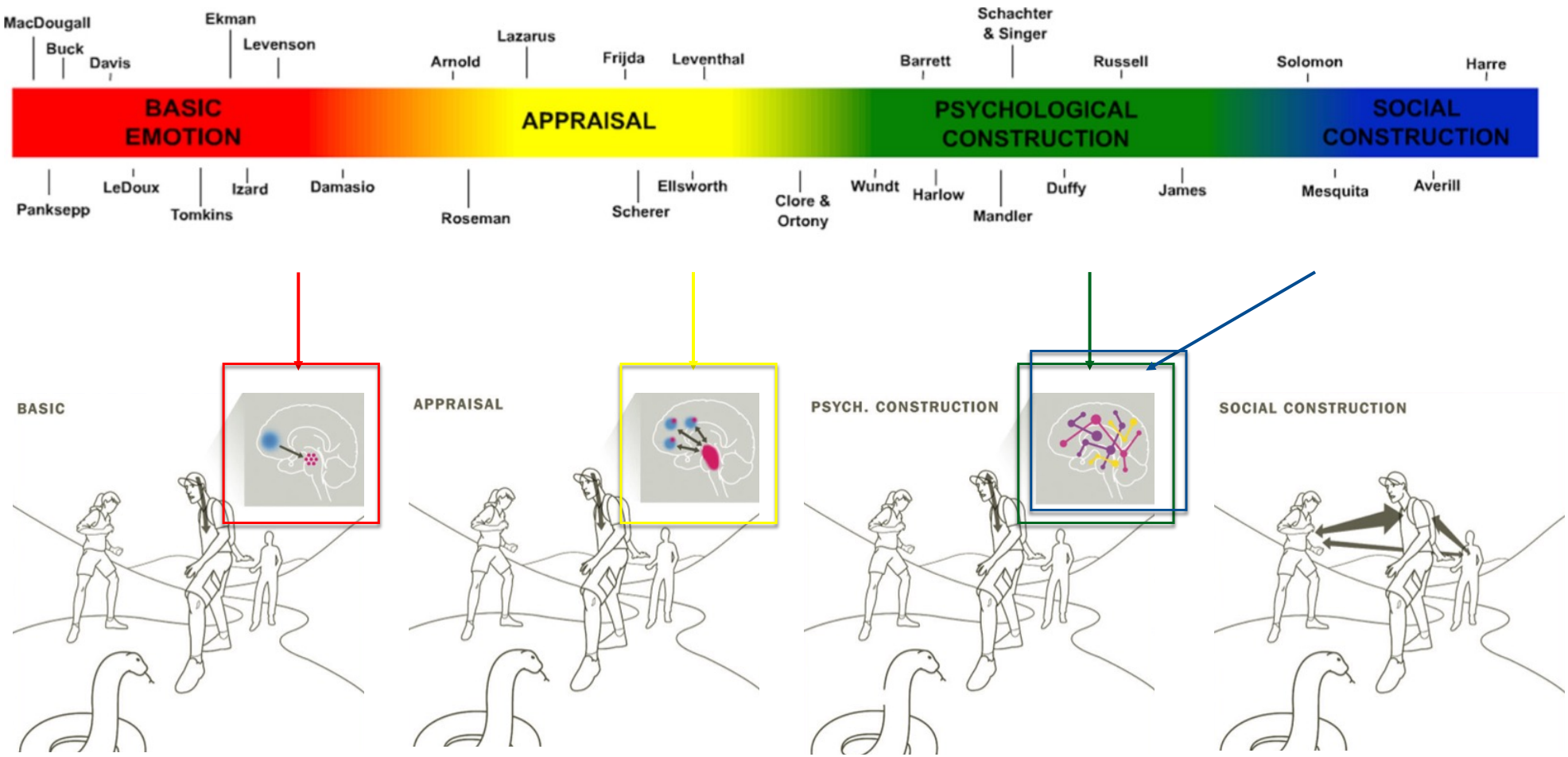
https://en.wikipedia.org/wiki/William_James

" […] of two things concerning the emotions, one must be true. Either separate and special centres, affected to them alone, are their brain-seat, or else they correspond to processes occurring in the motor and sensory centres already assigned."

(William James, 1890, in Lindquist et al., 2012)

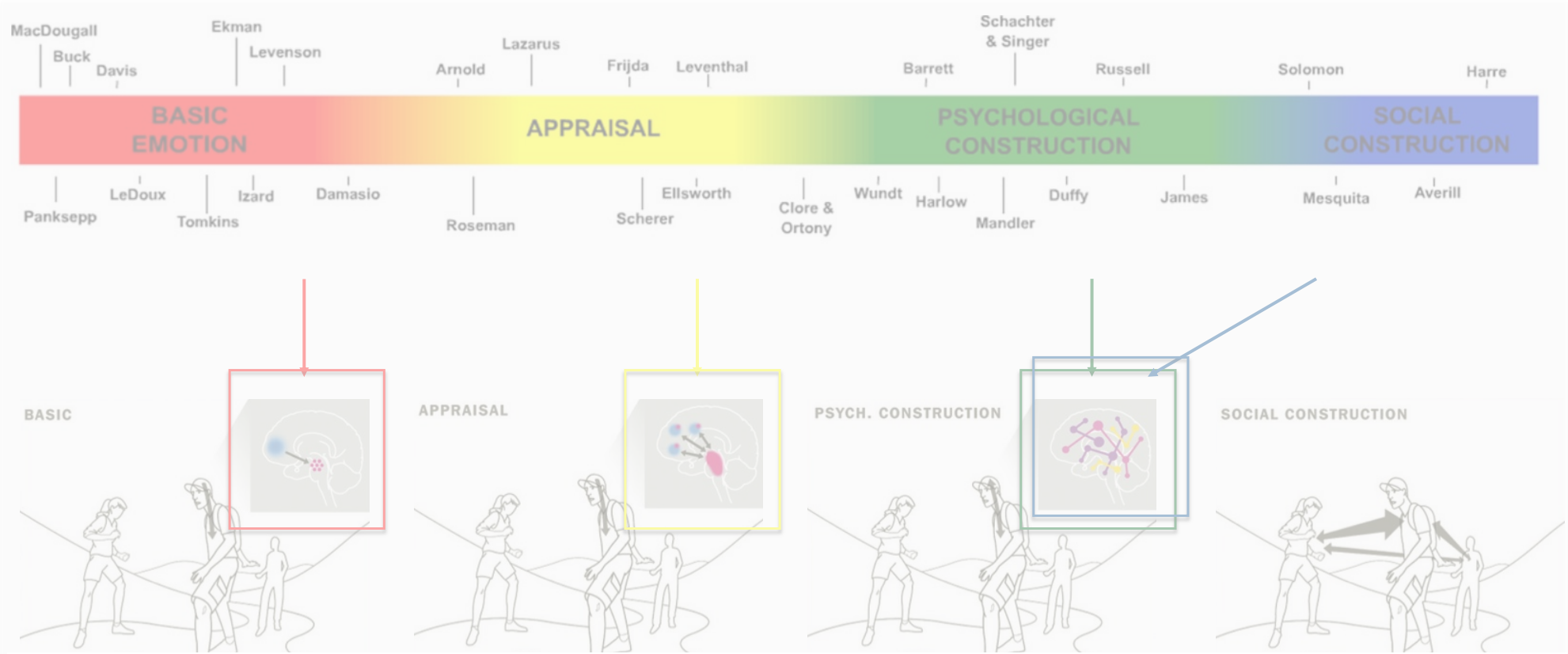
***Lindquist et al. (2012). *The brain basis of emotion: a meta-analytic review*. Behavioral and brain sciences, 35(3), 121-143.

Recap: Four perspectives on emotion



Gross, J.J, & Barrett, L.F. (2011). *Emotion generation and emotion regulation: One or two depends on your point of view*. Emotion Review, 3, 8–16.

Recap: Four perspectives on emotion



In affective neuroscience, this is framed as the "locationist vs. psychological constructionist" debate

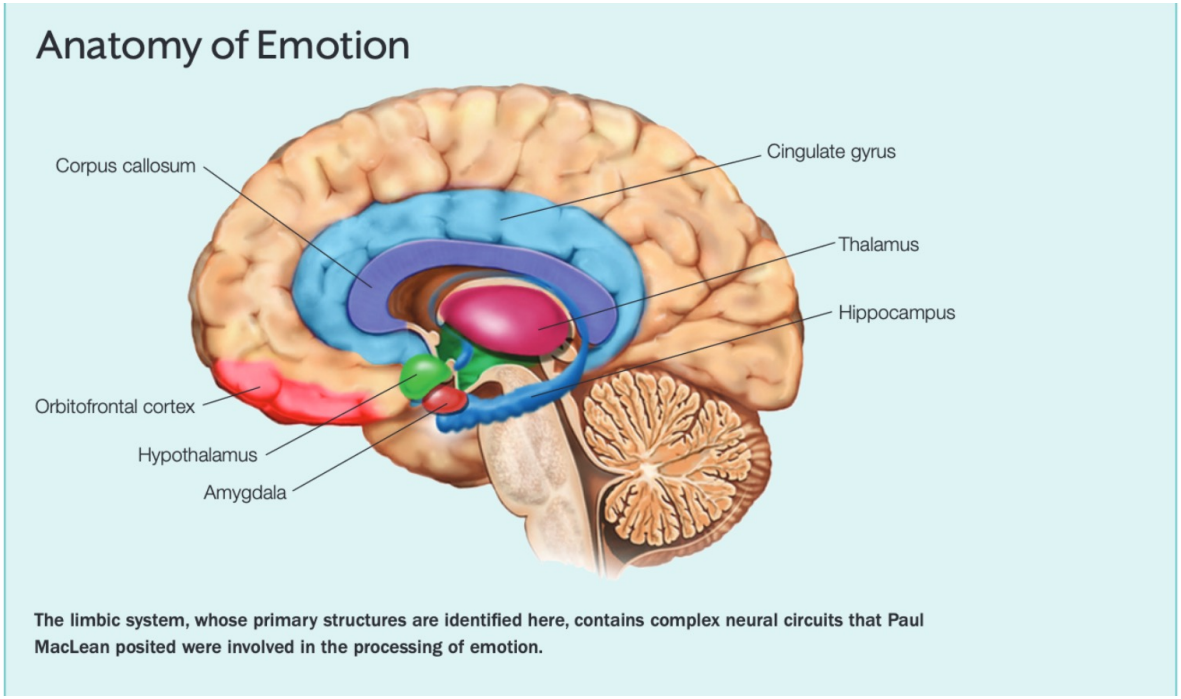
Gross, J.J, & Barrett, L.F. (2011). *Emotion generation and emotion regulation: One or two depends on your point of view*. Emotion Review, 3, 8–16.

Anatomical orientation: The "emotional" brain

Core structures of the limbic system

(NOTE: contentious!)

- Limbic lobe
- Thalamus
- Hypothalamus
- Amygdala
- Hippocampus
- OFC
- Basal ganglia



The limbic system, whose primary structures are identified here, contains complex neural circuits that Paul MacLean posited were involved in the processing of emotion.

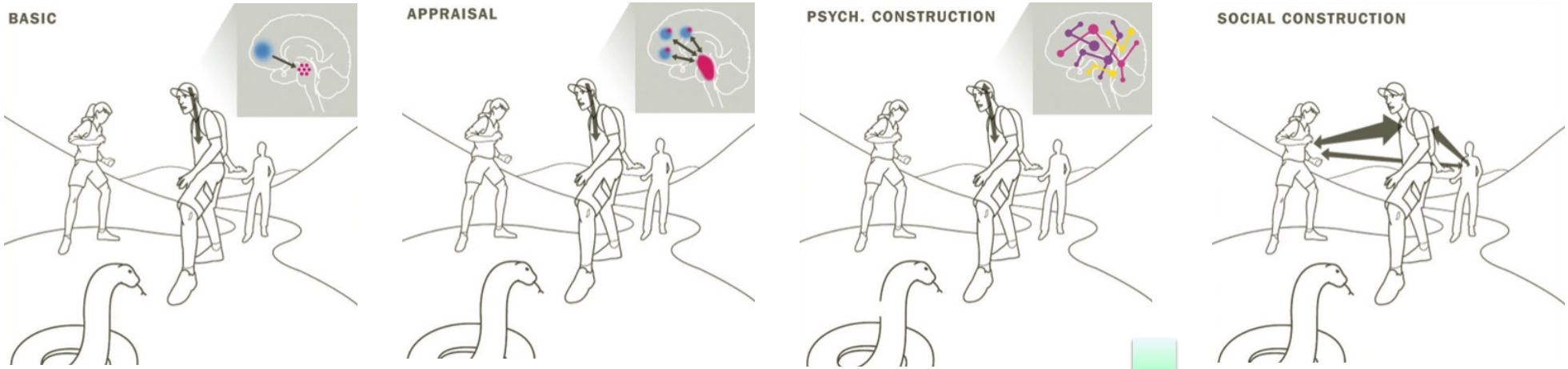
Gazzaniga, M.S., Ivry, R.B., & Mangun, G.R. (Eds.). (2019). Emotion. In Gazzaniga, M.S., Ivry, R.B., & Mangun, G.R. (Eds.), *Cognitive Neuroscience. The biology of the mind* (5th ed., pp. 427-473). W.W. Norton & Company.

Locationist vs. constructionist account

	Locationist ***→ natural kind / modal model of emotions***	**Psychological constructionist** ***→ conceptual act model***
Core assumptions	• The body and brain respect the category emotion and individual categories within • Emotion categories refer to states with endowed motivational characteristics that drive cognition and behavior • States are biologically basic and cannot be broken down further	• The body and brain do not respect emotion categories • Emotions are "situated conceptualizations", that is, psychological events that emerge out of more basic psychological operations that are not specific to emotion • Emerge when people make meaning out of sensory input (e.g., from the body) using their experience, expectations, etc. • Emotion = "core affect" (mental representation of bodily changes) + "conceptualization" (using experience to make meaning out of current sensation) + "emotion words" + "executive attention"
Implications for the neural basis	• Emotional experience is rooted in dedicated brain mechanisms • Each emotion is supported by dedicated, innate neural circuits: discrete emotion categories consistently and specifically correspond to single distinct (architecturally defined) brain regions	• Discrete emotion categories are constructed from more general brain networks ("psychological primitives") which are not specific to emotion • Categorization (or conceptualization) is a fundamental process in the human brain • Realized in a set of brain regions that reconstitutes prior experiences for use in the present ("episodic memory network")

***Lindquist et al. (2012). *The brain basis of emotion: a meta-analytic review*. Behavioral and brain sciences, 35(3), 121-143.

Locationist vs. constructionist account



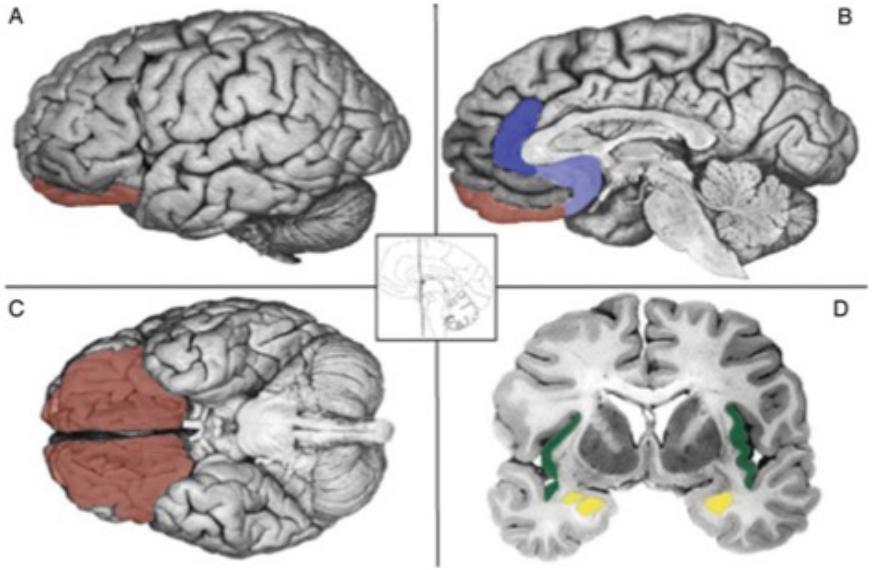
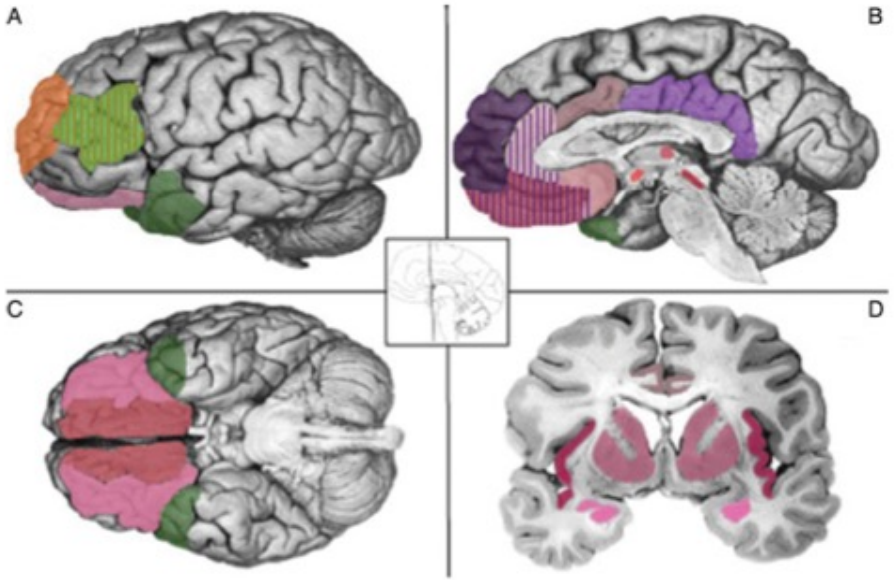
See snake → Bodily arousal (core affect) → Contextual interpretation → Emotion constructed (e.g., fear, curiosity, excitement) → Behavioral response

See snake → Cognitive appraisal → (Threat? Yes → Amygdala activation, No → No fear) → Physiological response → Behavioral response → Conscious fear experience

See snake → Amygdala activation → Physiological response → Behavioral response → Conscious fear experience

Gross, J.J, & Barrett, L.F. (2011). *Emotion generation and emotion regulation: One or two depends on your point of view*. Emotion Review, 3, 8–16.

Locationist vs. constructionist account

Locationist Hypotheses of Brain – Emotion Correspondence	**Psychological Constructionist Hypotheses of Brain–Emotion Correspondence**
	
Fear = amygdala (yellow); *Disgust* = insula (green); *Anger* = OFC (rust); *Sadness* = ACC (blue)	***Core affect*** = amygdala, insula mOFC, lOFC, ACC, thalamus, hypothalamus, PAG (pink); ***Conceptualization*** = vmPFC, dmPFC, mTL (e.g., hippocampus), PCC (purple); ***Emotion words*** = vlPFC, aTL (green); ***Executive attention*** = dlPFC, vlPFC (orange)

***Lindquist et al. (2012). *The brain basis of emotion: a meta-analytic review*. Behavioral and brain sciences, 35(3), 121-143.

Locationist vs. constructionist account: A meta-analysis

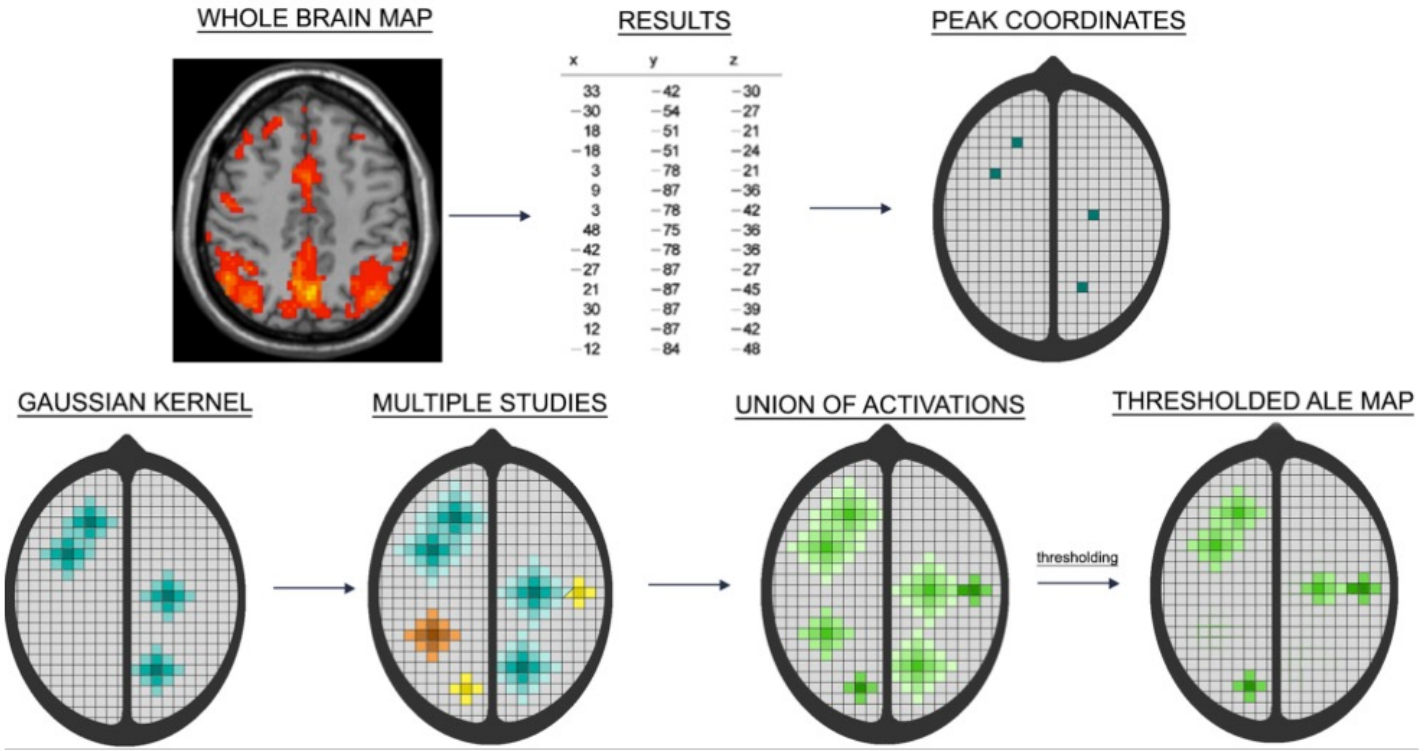
- Analysis of PET or fMRI studies targeting the experience or perception of discrete emotions (240 contrasts of anger, sadness, fear, disgust, and happiness from 91 studies published 1993 through the end of 2007)
- Statistically significant peaks of activation within each contrast were included (changes in neural activation relative to neutral baseline)
- Contrasts of emotion experience (i.e., after emotion induction) and perception (e.g., recognition, listening to voices or viewing faces/bodies) were analysed separately (prior meta-analytic evidence found differences in brain regions supporting experience and perception of emotion)
- Studies included healthy adults only

***Lindquist et al. (2012). *The brain basis of emotion: a meta-analytic review*. Behavioral and brain sciences, 35(3), 121-143.

Locationist vs. constructionist account: A meta-analysis

Question: How does one meta-analyze functional neuroimaging studies?

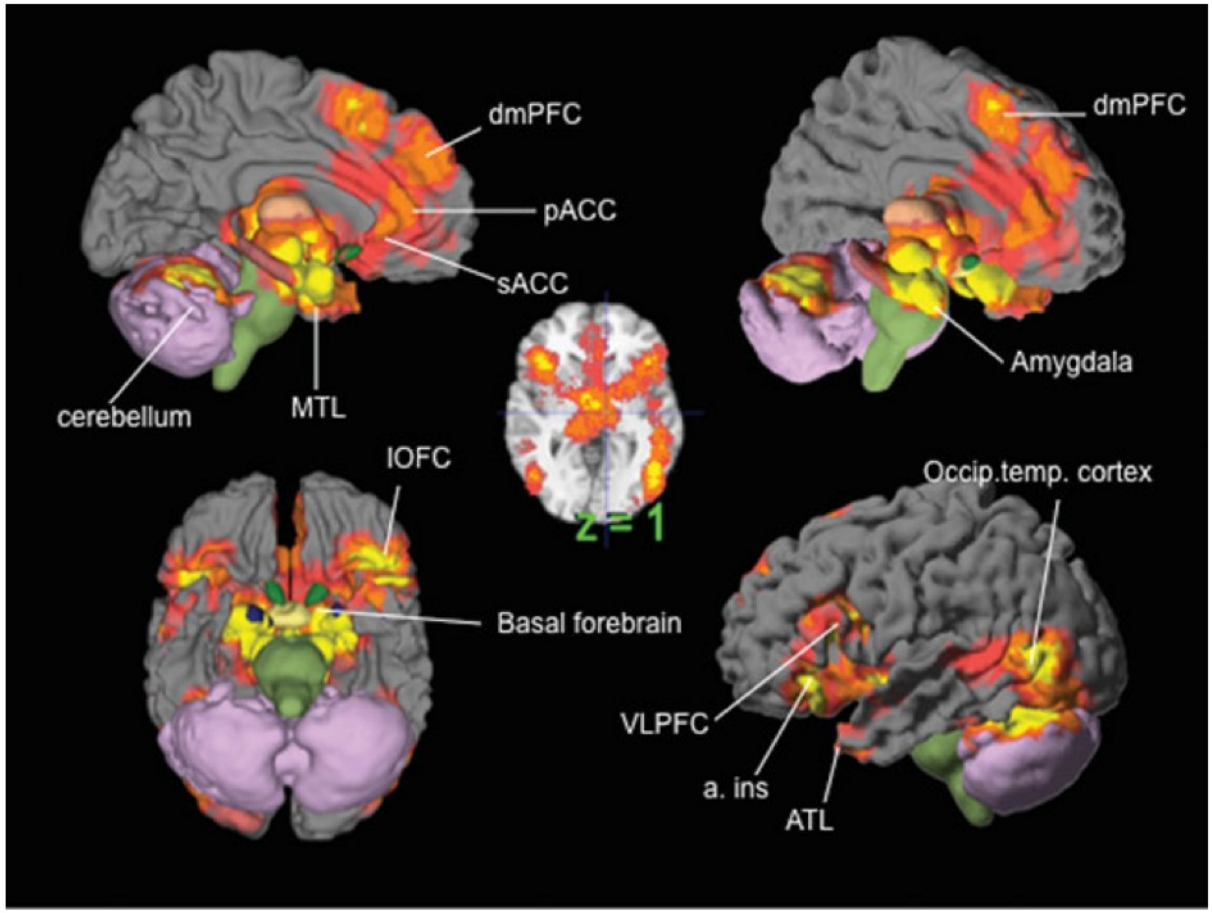
Answer: Activation Likelihood Estimation (ALE)



Acar, F., Seurinck, R., Eickhoff, S. B., & Moerkerke, B. (2018). *Assessing robustness against potential publication bias in Activation Likelihood Estimation (ALE) meta-analyses for fMRI*. PloS one, 13(11), e0208177.

Locationist vs. constructionist account: A meta-analysis

Results (1): Neural reference space for studies of discrete emotions (anger, fear, sadness, disgust, happiness)

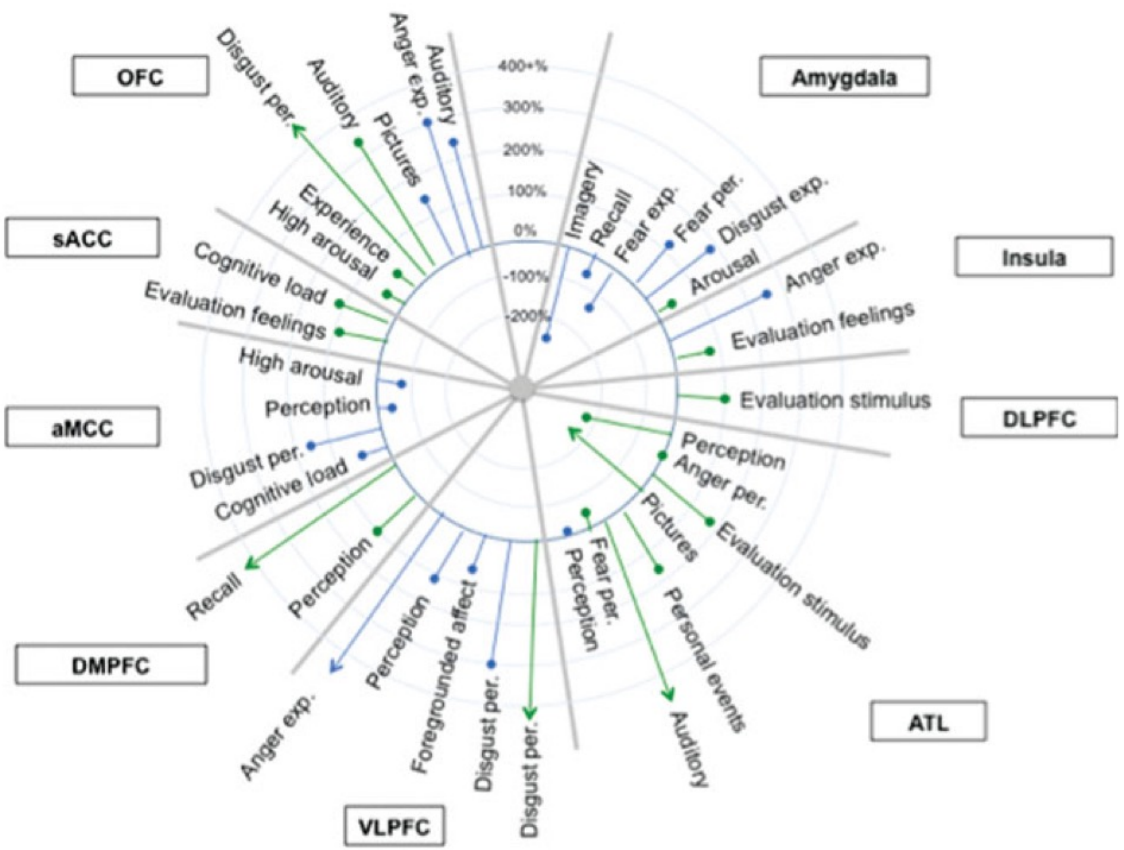


This reference space is consistent with the regions hypothesized to support the psychological constructionist perspective on brain-emotion correspondence.

***Lindquist et al. (2012). *The brain basis of emotion: a meta-analytic review*. Behavioral and brain sciences, 35(3), 121-143.

Locationist vs. constructionist account: A meta-analysis

Results (2): No functional specificity in amygdala activation for fear

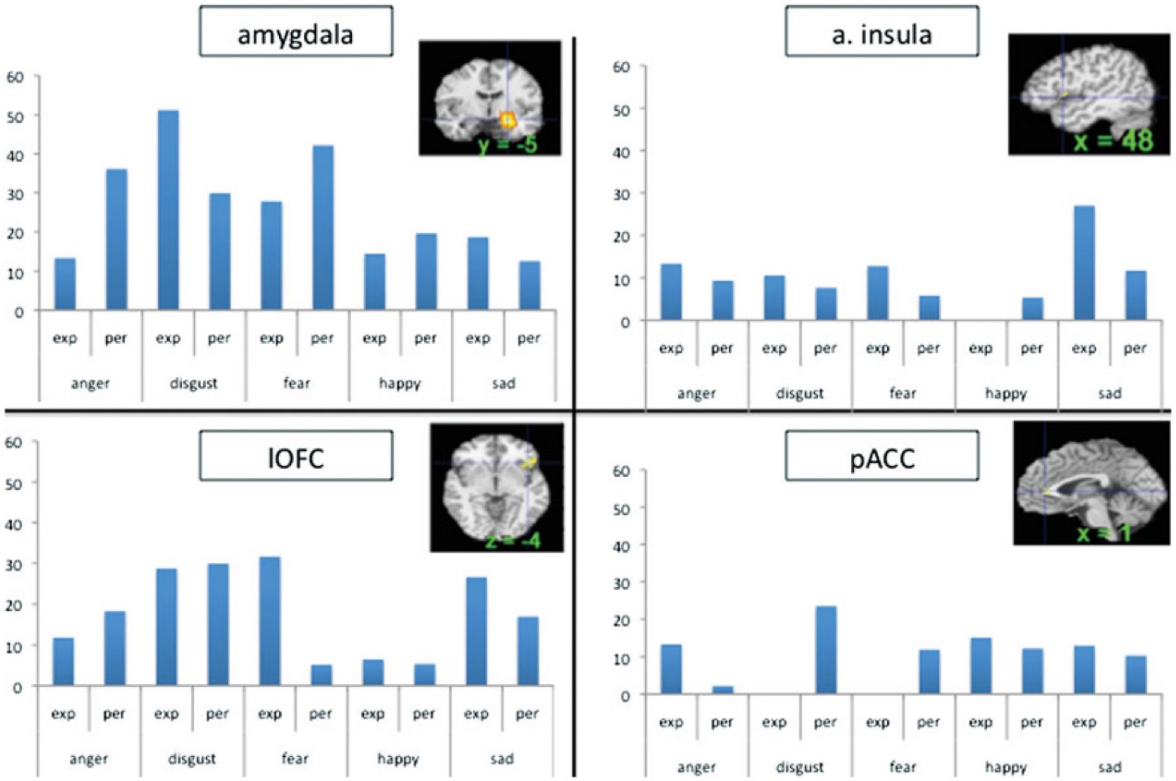


- More likely to see increased activity in left (blue) amygdala when participants were perceiving instances of fear or experiencing instances of disgust than when perceiving or experiencing any other emotion categories → amygdala responds to salient perceptual stimuli!
- Increases in activity in the right (green) amygdala were likely when participants were experiencing or perceiving instances of any highly arousing emotion category.
- No increase in activity in the left amygdala when participants were focusing on their internal state (i.e., when emotion experience was induced via recall of a personal event and mental imagery) → amygdala responds preferentially to salient exteroceptive (vs. interoceptive) sensations!

***Lindquist et al. (2012). *The brain basis of emotion: a meta-analytic review*. Behavioral and brain sciences, 35(3), 121-143.

Locationist vs. constructionist account: A meta-analysis

Results (3a): Consistency versus specificity of brain activation for discrete emotions



- Many brain regions are consistently activated in the context of emotions.
- There seems to be some functional selectivity.
- The findings do not support functional specificity.

***Lindquist et al. (2012). *The brain basis of emotion: a meta-analytic review*. Behavioral and brain sciences, 35(3), 121-143.

Locationist vs. constructionist account: A meta-analysis

Results (3b): Consistency versus specificity of brain activation for discrete emotions

Table 3. *Summary of Brain Regions Showing Consistent Increases in Activation During Mental States and Methodological Manipulations*

	Variable	Area
Mode	*Experience of emotion*	**R. lOFC**
	Perception of emotion	**DMPFC/dACC** **R. hippocampus** **L. VLPFC** **R. peristriate** **R. occipitotemporal**
Affect	*High arousal emotions*	**R. amygdala** **R. lOFC** **PAG**
	Unpleasant emotions	**L. peristriate**
Emotion	*Anger experience*	**L a. ins.*** **L. a. ins.** **L. lOFC** **L. VLPFC** **L. ATL**
	Anger perception	**L. VLFPC*** R. entorhinal cortex R. DLPFC R. parastriate R. occipitotemporal R. supplementary motor area
	Disgust experience	**L. amygdala*** R. amygdala L. entorhinal cortex **R. lOFC** **L. occipitotemporal***
	Disgust perception	**R. lOFC*** R. a. ins **aMCC** **L. VLPFC** **R. VLPFC*** **R. peristriate** **R. occipitotemporal**
	Fear experience	**PAG** **R. peristriate** R. parastriate **R. occipitotemporal*** L. middle temporal
	Fear perception	**L. amygdala** **L. entorhinal cortex** **R. entorhinal cortex** **L. hippocampus** **R. middle temporal**
	Happiness experience	**L. peristriate**
	Sadness experience	L. entorhinal cortex DMPFC R. middle temporal R. putamen

(*continued*)

Table 3 (*Continued*)

	Variable	Area
		PAG
Method Types	*Recall*	**pACC** **DMPFC/aMCC**
	Auditory	**R. lOFC** **R. VLPFC** **R. ATL**
	Imagery	**R. occipitotemporal** **R. middle temporal**
	Visual	**R. peristriate** **L. occipitotemporal**
Stimuli	*Pictures*	**L. lOFC** **R. peristriate** **R. occipitotemporal**
	Faces	**L. VLPFC**
	Films	**DMPFC/aMCC** **L. peristriate** **R. occipitotemporal** **R. middle temporal**
Other Psychological Variables	*Evaluation of feelings*	**R. a. ins** **sACC**
	Evaluation of stimulus	**R. ATL** **R. DLPFC** **PAG** **L. peristriate**
	Foregrounded affect	**L. occipitotemporal** **L. VLPFC** **L. peristriate**
	Cognitive load	**sACC** **aMCC**

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- There seems to be some functional selectivity.
- The findings do not support functional specificity.

***Lindquist et al. (2012). *The brain basis of emotion: a meta-analytic review*. Behavioral and brain sciences, 35(3), 121-143.

What is love? A meta-analysis

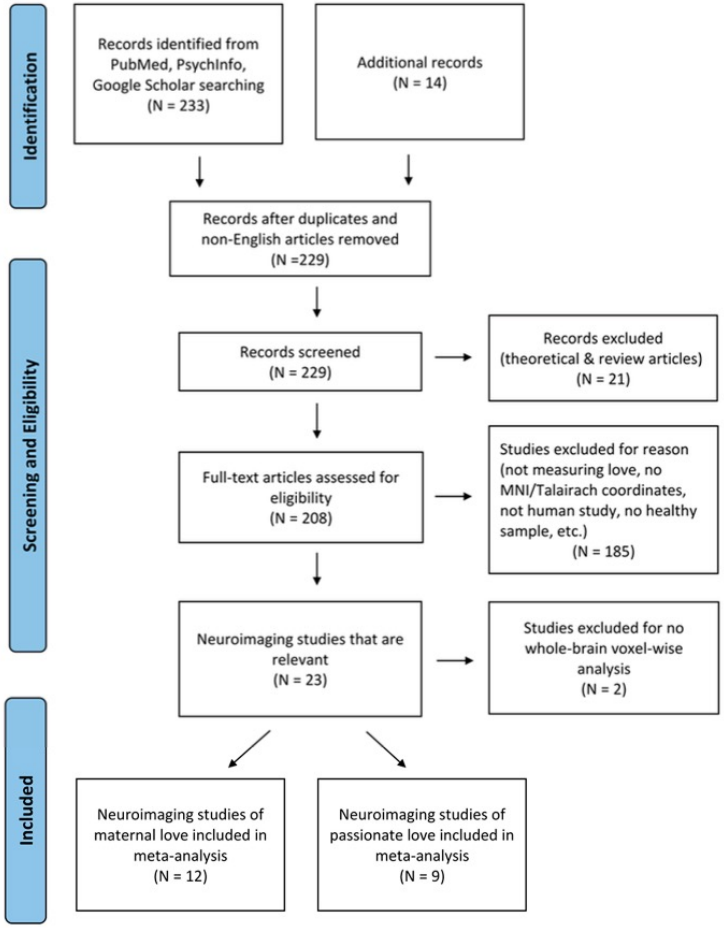


Table 1. (**A**): Details of included studies on maternal love. (**B**): Details of included studies of passionate love.

(A)

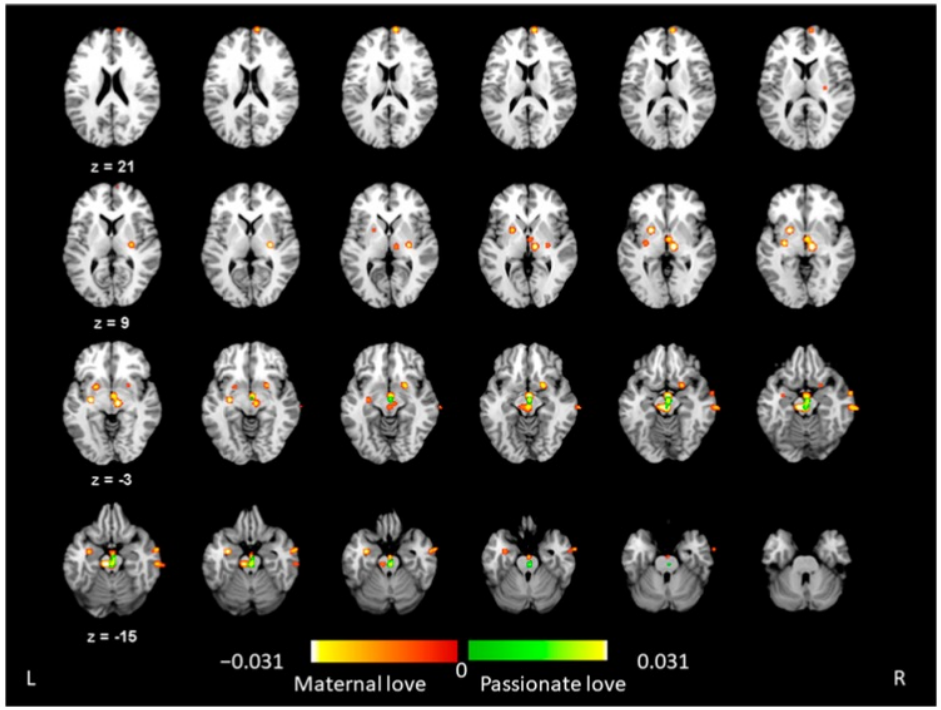
First Author	Year	Categories of Love	Numbers of Participants	Mean Age of Participants' Own Child	Mean Age of Participants	Experimental Stimuli	Contrasts	Numbers of Foci
Lorberbaum [27]	2002	Maternal	10	6.18 weeks	30.55	Cry sound and white noise (auditory)	Infant cry > Rest	80
Bartles [22]	2004	Maternal	20	24.4 months	34	Pictures (visual)	Own child > Acquainted child	28
Nitschke [28]	2004	Maternal	6	3–5 months	No report	Pictures of faces (visual)	Own infant > Unfamiliar infant	6
Leibenluft [29]	2004	Maternal	7	5–12 years	32.9	Pictures of faces (visual)	Own child > Familiar child	36
Ranote [30]	2004	Maternal	10	25.6 months	26	Video Clip (visual-auditory)	Own infant > Unknown infant	3
Noriuchi [31]	2008	Maternal	13	16.5 months	31.1	Video Clip (visual-auditory)	Own infant > Other infant	81
Lenzi [32]	2009	Maternal	16	9.5 months	33.7	Pictures of faces (visual)	Own child > Acquainted child	7
Strathearn [33]	2008	Maternal	28	6.7 months	30.2	Pictures of faces (visual)	Own infant > Unknown infant	67
Strathearn [34]	2009	Maternal	30	7 months	No report	Pictures of faces (visual)	Own infant > Unknown infant	46
Atzil [35]	2011	Maternal	23	4–6 months	22–37	Pictures of faces (visual)	Own infant > Unfamiliar infant	21
Barret [36]	2012	Maternal	22	3 months	25–35	Pictures of faces (visual)	Own infant > Unfamiliar infant	32
Wan [37]	2014	Maternal	20	6.2 months	32	Video Clip (visual-auditory)	Own infant > Unknown infant	40

(B)

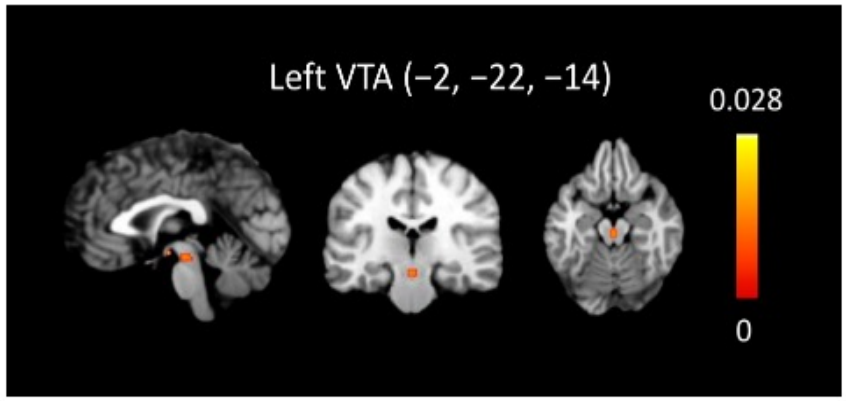
First Author	Year	Categories of Love	Numbers of Participants (Female)	Mean Age of Participants	Experimental Stimuli	Contrasts	Numbers of Foci
Bartels & Zeki [21]	2000	Passionate	17 (11)	24.5	Pictures of faces (visual)	Lover > Familiar friend	13
Aron [38]	2005	Passionate	17 (10)	20.6	Picture (visual)	Lover > Familiar friend	8
Ortigue [39]	2007	Passionate	36 (36)	20.1	Words (visual)	Lover > Familiar friend Lover > Noun	14 4
Kim [40]	2009	Passionate	10 (5)	21.1	Pictures of faces (visual)	Lover > Familiar friend	29
Zeki [41]	2010	Passionate (opposite and same sex)	24 (12)	26.3	Pictures of faces (visual)	Lover > Familiar friend	11
Stoessel [42]	2011	Passionate	12 (6)	24.08	Picture (visual)	Lover > Erotic pictures	16
Xu [43]	2011	Passionate (Chinese participants)	18 (10)	21.61	Pictures of faces (visual)	Lover > Familiar friend	8
Xu [44]	2012	Passionate	18 (0)	25.11	Picture (visual)	Lover > Familiar friend	10
Acevedo [26]	2012	Passionate (long-term)	17 (10)	52.85	Pictures of faces (visual)	Lover > Familiar acquaintance Lover > Close friend	30 26

Shih, H. C., Kuo, M. E., Wu, C. W., Chao, Y. P., Huang, H. W., & Huang, C. M. (2022). *The neurobiological basis of love: a meta-analysis of human functional neuroimaging studies of maternal and passionate love*. Brain Sciences, 12(7), 830.

What is love? A meta-analysis



"The ALE results showed significant activation of the brain regions in the left ventral tegmental area (VTA), right thalamus, left substantia nigra, and the left putamen for maternal love, but in the bilateral VTA for passionate love."
"The meta-analytic neuroimaging evidence suggests the greater involvement of cognitive–affective regulation in maternal attachment and the greater desire to combine liking and wanting in romantic love behaviors."



"The conjunction analysis highlights the functional convergence of the VTA across the two types of human love, indicating a shared neurobiological mechanism of maternal and passionate love with evolutionary roots."

(NOTE: results not significant using stringent correction methods for multiple testing!!!)

Shih, H. C., Kuo, M. E., Wu, C. W., Chao, Y. P., Huang, H. W., & Huang, C. M. (2022). *The neurobiological basis of love: a meta-analysis of human functional neuroimaging studies of maternal and passionate love*. Brain Sciences, 12(7), 830.

Your turn!

Image created with AI (Bing), October 2024

Which of the core assumptions of psychological constructionist approaches do these meta-analyses not address?

Discuss with your neighbour(s)
~2 minutes

Addressing issues of causality and temporality

Lesion studies (e.g., Weiskrantz, 1956):

amygdala lesion

inferior temporal lesion

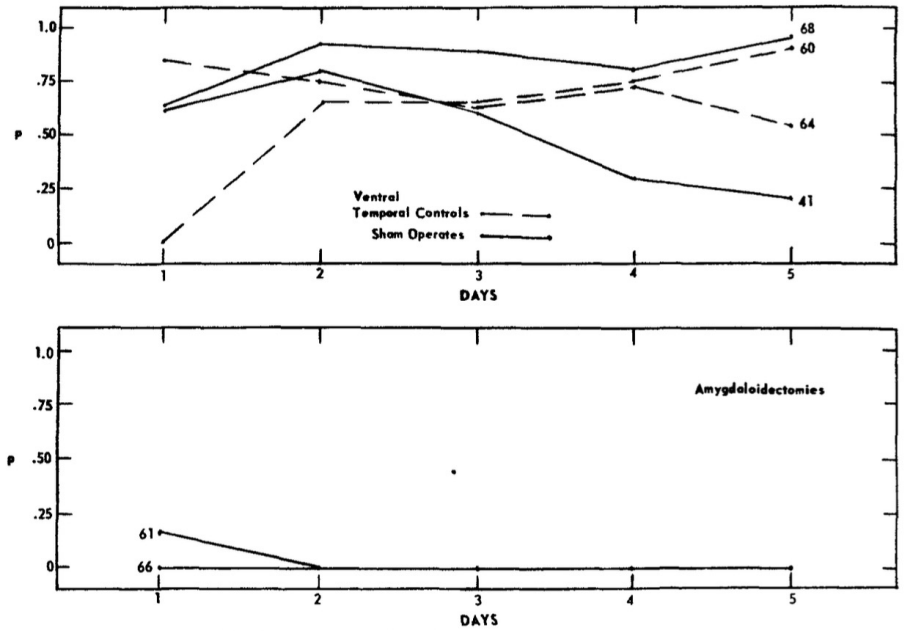


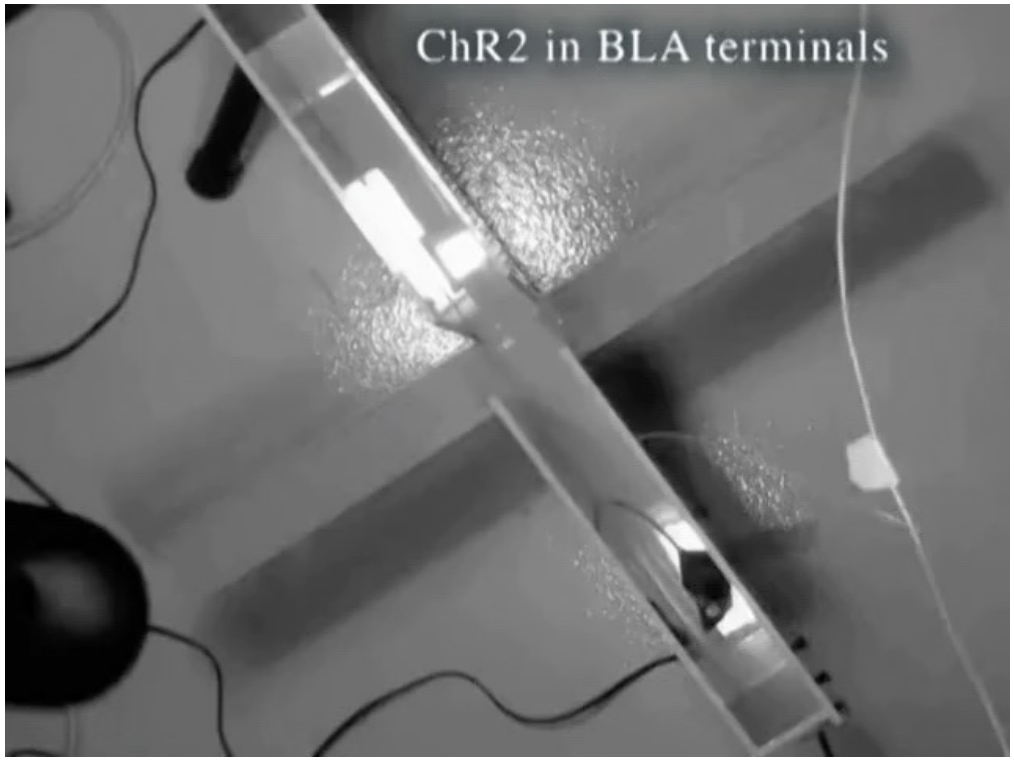
FIG. 5. Proportions of avoidance responses to experimenter.

"[…] marked increase in tameness and a weakening or disappearance of fear responses to previously aversive stimuli by amygdala [lesion] animals"

Weiskrantz, L. (1956) Behavioral changes associated with ablation of the amygdaloid complex in monkeys. *Journal of Comparative Physiology and Psychology, 49*, 381–391.

Addressing issues of causality and temporality

Optogenetic studies (e.g., Tye et al., 2012):



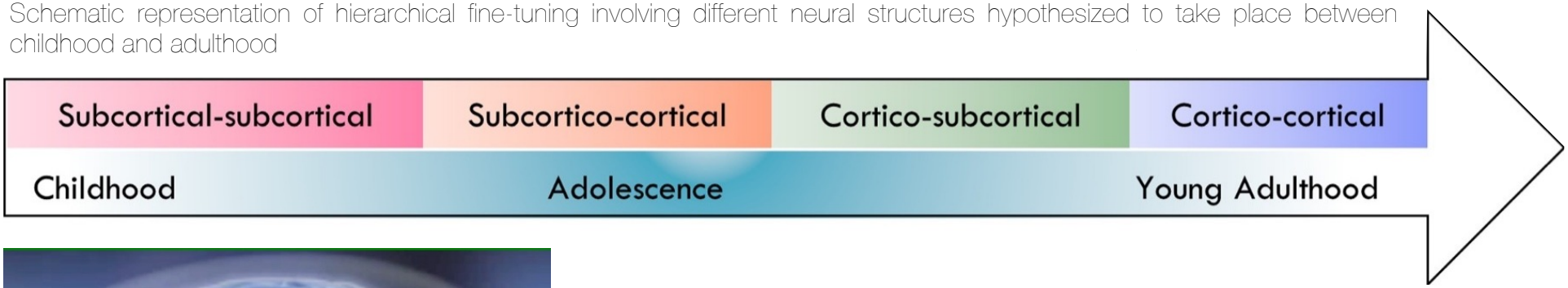
→ Optogenetics
a biological technique which involves the use of light to control cells in living tissue, typically neurons, that have been genetically modified to express light-sensitive ion channels. It is a neuromodulation method that uses a combination of techniques from optics and genetics to control and monitor the activities of individual neurons in living tissue—even within freely-moving animals—and to precisely measure these manipulation effects in real-time.

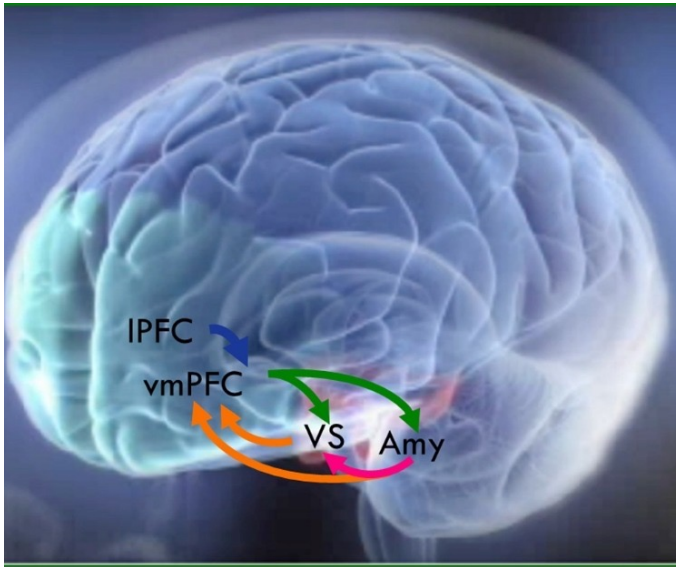
"[…] temporally precise optogenetic stimulation of basolateral amygdala (BLA) terminals in the central nucleus of the amygdala […] exerted an acute, reversible anxiolytic effect"

Tye, K. M., Prakash, R., Kim, S. Y., Fenno, L. E., Grosenick, L., Zarabi, H., ... & Deisseroth, K. (2012). Amygdala circuitry mediating reversible and bidirectional control of anxiety. *Nature, 471*(7338), 358-362.

Emotional development

Schematic representation of hierarchical fine-tuning involving different neural structures hypothesized to take place between childhood and adulthood





The ventral striatum (VS) is implicated in learning and prediction of positive outcomes and receives inputs from the basolateral amygdala (Amy). The amygdala is important in learning the emotional significance of cues in the environment, and can facilitate ventral striatum activity through its direct inputs from the basolateral nucleus, leading to motivated action. The ventromedial prefrontal cortex (vmPFC) has been implicated in fear and emotion regulation. This region has dense projections to the (inhibitory) cells in the amygdala and to the ventral striatum (VS) that modulate emotive behaviors. Cortico-cortical connections include pathways between lateral prefrontal cortex (lPFC), implicated in higher cognitive functions, and medial prefrontal regions, involved in emotion and social interactions. These connections may serve as an interface between cognitive and emotional processes.

Current developmental models propose that there is a **hierarchical fine-tuning** that takes place across childhood and adolescence **as a function of biological maturation and experience**; this process represents a potential **mechanism for the observed changes in emotional reactivity and regulation across childhood and adolescence** (e.g., patterns of self-control and risk taking).

Casey, B. J., Heller, A. S., Gee, D. G., & Cohen, A. O. (2019). Development of the emotional brain. *Neuroscience Letters, 693*, 29–34. http://doi.org/10.1016/j.neulet.2017.11.055

Summary

- Meta-analysis of functional neuroimaging studies increases reliability and generalizability by identifying consistent brain activation patterns across diverse studies, while also allowing the examination of moderators such as stimulus features (e.g., emotional valence, complexity) and modalities (e.g., visual, auditory). But, issues of causality may require different approaches (e.g., lesion studies, optogenetics).

- Current models of emotional experience and regulation encompass a number of neural structures with only a few being core emotional regions and most being associated with other aspects of cognitive processing (e.g., memory, decision-making).

- This stance makes clear the somewhat arbitrary distinction between emotional and cognitive processing (cognition is not value free!), and supports a psychological constructionist perspective.

- The hierarchical fine-tuning and maturation of connections between different brain regions throughout childhood, adolescence and early adulthood support the progressive development of cognitive functions, emotional regulation, and behavioral control, enabling more efficient information processing, decision-making, and adaptive responses to complex environmental demands.

Key (mandatory) reading

- Lindquist, K. A., Wager, T. D., Kober, H., Bliss-Moreau, E., & Barrett, L. F. (2012). *The brain basis of emotion: a meta-analytic review*. Behavioral and brain sciences, 35(3), 121-143. https://www.cambridge.org/core/services/aop-cambridge-core/content/view/80F95F093305C76BA2C66BBA48D4BC8A/S0140525X11000446a.pdf/the-brain-basis-of-emotion-a-meta-analytic-review.pdf

BEHAVIORAL AND BRAIN SCIENCES (2012) **35**, 121–202
doi:10.1017/S0140525X11000446

The brain basis of emotion:
A meta-analytic review

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Abstract: Researchers have wondered how the brain creates emotions since the early days of psychological science. With a surge of studies in affective neuroscience in recent decades, scientists are poised to answer this question. In this target article, we present a meta-analytic summary of the neuroimaging literature on human emotion. We compare the locationist approach (i.e., the hypothesis that discrete emotion categories consistently and specifically correspond to distinct brain regions) with the psychological constructionist approach (i.e., the hypothesis that discrete emotion categories are constructed of more general brain networks not specific to those categories) to better understand the brain basis of emotion. We review both locationist and psychological constructionist hypotheses of brain–emotion correspondence and report meta-analytic findings bearing on these hypotheses. Overall, we found little evidence that discrete emotion categories can be consistently and specifically localized to distinct brain regions. Instead, we found evidence that is consistent with a psychological constructionist approach to the mind: A set of interacting brain regions commonly involved in basic psychological operations of both an emotional and non-emotional nature are active during emotion experience and perception across a range of discrete emotion categories.

Keywords: Discrete emotion; emotion experience; emotion perception; meta-analysis; neuroimaging; psychological construction

1. Introduction

William James framed the question of emotion–brain correspondence when he wrote, "of two things concerning the emotions, one must be true. Either separate and special centres, affected to them alone, are their brain-seat, or else they correspond to processes occurring in the motor and sensory centres already assigned" (James 1890/1998, p. 473). In this target article, we statistically summarize the last 15 years of neuroimaging research on emotion in an attempt to determine which of these alternatives is correct. We examine the utility of two different models of emotion that have each existed since the beginning of psychology.

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