Relations Between Hippocampal Subregion Volumes and Emotion Regulation in Young Children

Benjamin E. Weinberg, Jessica Stern, Jude Cassidy, Tracy Riggins

University of Maryland, College Park

Introduction

Background:

- Emotion regulation is the adaptive ability to modulate one's own emotions to achieve desirable social, cognitive, and environmental outcomes (Eisenberg & Spinrad, 2004; Graziano et al., 2007)
- Evidence suggests that emotion regulation can impact cognition, particularly memory, and vise versa (McGaugh, 2018; Pessoa, 2018)
  - These relations may arise due to overlapping neural substrates, as the hippocampus and amygdala play pivotal roles in both emotion and cognition, as well as their interaction (Pessoa, 2010; Phelps, 2004)
- However, these links are under-investigated in development
  - In a recent paper, we reported that empathic responding was related to hippocampal, but not amygdala volumes in young children (Stern et al., in press)
  - Both memory and emotion regulation were proposed to be possible mechanisms linking empathic responding with hippocampal volume

Present Study:

- The goal of this study was to explore relations among parent-reported emotion regulation, memory, hippocampal and amygdala volumes in typically developing young children

Methods

Participants:

- 85 participants (46 male) ages 4-8 years (M = 6.28, SD = 1.06) who provided complete emotion regulation, memory, and neuroimaging data (n = 60, 30 male) were recruited from a larger study on memory development (Riggins et al., 2018)

Measures:

- Parents reported their child's ability to regulate emotion using the Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997)
  - 24 items split across 2 subscales:
    - Emotional Regulation (ER; 8 items), ex.: "Responds positively to neutral or friendly overtures by peers."
    - Lability/Negativity (L/N; 15 items); ex.: "Is easily frustrated."
  - Items scored on a 4-point Likert-type scale ranging from "never" to "almost always"
- Memory was assessed via multiple measures [adapted from literature]:
  - Primacy Discrimination (Matthews & Fozard, 1970)
  - Temporal Order Recall (Bauer et al., 2013)
  - Source Memory Task (Drummey & Newcombe, 2002)
- Magnetic resonance imaging (MRI) conducted to provide brain region volumes
  - A standard resolution (.9mm^3), T1-weighted whole brain structural scan was acquired during neuroimaging and processed using FreeSurfer (v5.1)
  - Hippocampal and amygdala volumes in left and right hemisphere were obtained, along with gray matter volume
  - Hippocampus was divided into subregions (head, body, and tail)

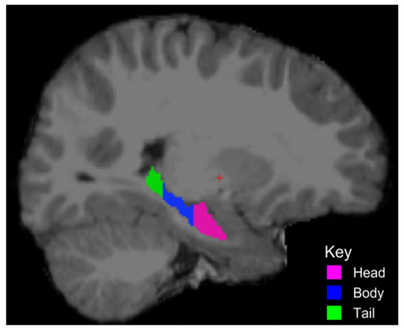
Results

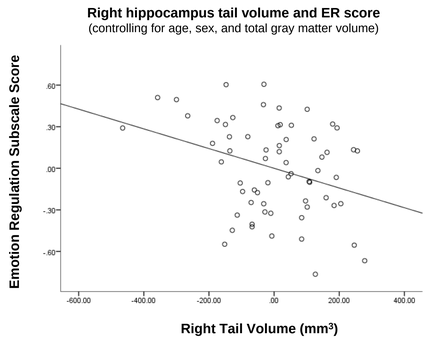
Table 1.

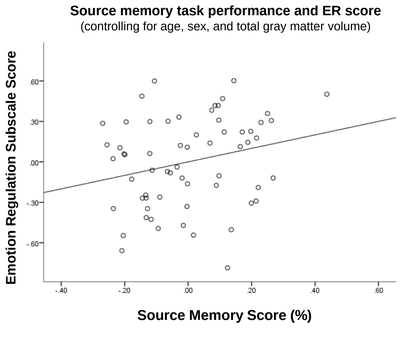
Bivariate correlations between children's emotion regulation, memory, brain volumes, and covariates

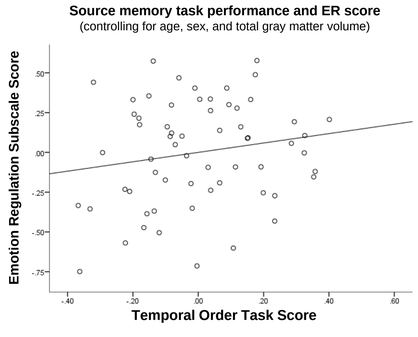
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Age															
2	Sex[1]	-0.112														
Emotion Regulation Measures																
3	Emotion Regulation score	-.306**	0.149													
4	Lability/Negativity score	-0.06	-0.178	-.531**												
Memory Measures																
5	All adjacent pairs	0.376**	0.065	0.090	-0.169											
6	Primacy score	0.269**	-0.069	0.082	-0.146	0.257**										
7	Source memory correct	0.380**	-0.094	0.061	-0.108	0.154	0.326**									
Amygdala Volumes																
8	Left amygdala volume	.185*	-.219*	-0.056	-0.089	0.180	0.019	0.143								
9	Right amygdala volume	.231*	-.235*	0.035	-0.058	.211*	0.116	0.156	.740**							
Hippocampal Volumes (Adjusted for ICV)																
10	Left head volume	.350**	-.249*	-0.135	0.004	0.151	0.060	0.098	0.368**	0.264**						
11	Left body volume	-0.121	0.018	0.023	0.210*	-0.078	0.064	-0.166	0.060	0.238*	-.438**					
12	Left tail volume	-0.042	-0.098	-0.130	0.058	-0.084	0.111	0.007	-0.101	0.020	0.086	0.128				
13	Right head volume	0.330**	-.310**	-0.045	-0.168	0.029	0.035	0.164	0.361**	0.273**	0.681**	-.270**	0.052			
14	Right body volume	-0.009	-0.053	0.012	0.240*	0.104	0.121	-0.055	0.200*	0.311**	-.190*	0.665**	-0.072	-.353**		
15	Right tail volume	0.047	-0.109	-.321**	0.077	-0.111	-0.066	-0.019	0.090	0.099	0.115	0.185*	0.687**	0.215*	0.020	
Intra-Cranial Volume (ICV)																
16	Intra-cranial volume	0.194*	-.394**	0.011	0.027	0.175	0.008	0.050	0.510**	0.635**	0.334**	0.285**	0.040	0.321**	0.379**	0.185*

Note. *p < .05, **p < .01, ***p < .001; Sex is coded 1, 2: 1 = Male, 2 = Female.









After controlling for age, sex, and intracranial volume, 5 of 46 relevant analyses met significance criteria:

- Parent-rated ER scores negatively correlated with right hippocampal tail volume, $r(55) = -.264$, $p = .024$
  - Positive correlations between ER and memory task performance approached significance, specifically for the temporal order, $r(55) = .178$, $p = .093$, and source memory tasks, $r(55) = .204$, $p = .064$
- Parent-rated L/N scores negatively correlated with right hippocampal head volume, $r(55) = -.222$, $p = .048$
  - Parent-rated L/N scores positively correlated with right hippocampal body volume, $r(55) = .232$, $p = .041$, in addition to left hippocampal body volume, $r(55) = .236$, $p = .038$
- Primacy memory positively correlated with left hippocampal tail volume, $r(55) = .230$, $p = .043$
  - Correlations between primacy memory and left hippocampal body volume, $r(55) = .202$, $p = .065$, as well as right hippocampal body volume, $r(55) - .185$, $p = .084$, approached significance
- No significant correlations between memory or emotion regulation and amygdala volumes emerged

Discussion

Findings:

- Emotion regulation, as measured by parent-reported ER and L/N, was associated with hippocampal volume in typically developing young children
  - Interestingly, the direction of L/N and hippocampal volume associations varied across different hippocampal subregions; specifically, significant associations were predominantly within right hippocampus subregions
  - Left hippocampus may be more involved in autobiographical memory recall (Burgess et al., 2002)
- Relations between parent-reported emotion regulation and memory performance were present but failed to meet traditional levels of significance
- Memory task performance was positively associated with hippocampus subregion volumes, but not amygdala volume
  - Possibly the result of immaturity or reduced neuroplasticity; brain-memory links could occur along many pathways and be less specialized in young children
  - Overall consistent with Stern et al. (in press) which found similar associations between empathy and hippocampus volumes but not amygdala volumes

Limitations:

- High SES sample; emotion regulation may be less impactful (Troy et al., 2017)
- Small sample size due to incomplete participant data

Future Directions:

- Compare memory performance and brain region volumes/maturation in a sample encompassing adults and children
- Use memory tasks covering a more diverse span of memory types (e.g. autobiographical memory)
- Further investigate relations between hippocampus and amygdala volumes, memory, emotion regulation, and empathic responding

Selected References

Bauer, P., Dikmen, S., Heaton, R., Mungas, D., Slotkin, J., & Beaumont, J. (2013). III. NIH Toolbox Cognition Battery (CB): Measuring episodic memory. *Monographs of the Society for Research in Child Development, 78*(4), 34–48.

Burgess, N., Maguire, E. A., & O'Keefe, J. (2002). The human hippocampus and spatial and episodic memory. *Neuron, 35*(4), 625-641.

Drummey, A. B., & Newcombe, N. S. (2002). Developmental changes in source memory. *Developmental Science, 5*(4), 502-513.

Eisenberg, N. & Spinrad, T.L. (2004). Emotion-related regulation: sharpening the definition. *Child Development, 75*(2) 334-339.

Graziano, P. A., Reavis, R. D., Keane, S. P., & Calkins, S. D. (2007). The role of emotion regulation in children's early academic success. *Journal of School Psychology, 45*(1), 3-19.

Mathews, M. E., & Fozard, J. L. (1970). Age differences in judgments of recency for short sequences of pictures. *Developmental Psychology, 3*, 208-217.

McGaugh, J. L. (2018). Emotional arousal regulation of memory consolidation. *Current Opinion in Behavioral Science, 19*, 55-60.

Pessoa, L. (2010). Emotion and cognition and the amygdala: From "what is it?" to "what's to be done?". *Neuropsychologia, 48*, 3416-3429.

Pessoa, L. (2018). Understanding emotion with brain networks. *Current Opinion in Behavioral Science, 19*, 19-25.

Phelps, E. A. (2004). Human emotion and memory: interactions of the amygdala and hippocampal complex. *Current Opinion in Neurobiology, 14*, 198–202.

Riggins, T., Geng, F., Botdorf, M., Canada, K., Cox, L., & Hancock, G. R. (2018). Protracted hippocampal development is associated with age-related improvements in memory during early childhood. *NeuroImage, 174*, 127–137.

Shields, A. & Cicchetti, D. (1997). Emotion regulation among school-age children: The development and validation of a new criterion Q-sort scale. *Developmental Psychology, 33*(6), 906-916.

Stern, J. A., Botdorf, M., Cassidy, J., & Riggins, T. (in press). Empathy and hippocampal volume in young children [Special issue]. *Developmental Psychology*.

Troy, A. S., Ford, B. Q, McRae, K., Zarolia, P., & Mauss, I. B. (2017). Change the things you can: Emotion regulation is more beneficial for people from lower than from higher socioeconomic status. *Emotion, 17*(1), 141-154.

Acknowledgements

The authors would like to thank the families that participated in this research study and to the Neurocognitive Development Lab for their assistance with data collection.

Support for this research was provided by NICHD under Grant HD079518 (TR).

For questions or comments, please contact: bweinberg0928@gmail.com