Developmental differences in hippocampal contribution to episodic memory in 4- to 8-year-old children

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Introduction

- In school-aged children and adolescents, fMRI studies of encoding have shown developmental changes in the activation of hippocampus and its connectivity with other brain regions such as prefrontal cortex (Güler & Thomas, 2013; Ghetti, DeMaster, Yonelinas, & Bunge, 2010; Menon, Boyett-Anderson, & Reiss, 2005; Ofen et al., 2007).
- Recently, studies have indicated that hippocampal subregions (head, body, or tail) may play different roles in memory formation or retrieval.
  - Age differences have been reported in activation of hippocampal subregions during retrieval (Sastre et al., 2016). For example, 8- to 9-year-old children did not activate any hippocampal subregion; in contrast, high performing adults activated only hippocampal head to retrieval contextual details.
- Due to demands of the scanning environment, fMRI has not yet examined age-related changes in the neural correlates of encoding in early childhood.
- Our previous ERPs study has indicated that there are developmental changes in encoding between the age of 4 and 8 years (Geng, Kelsey, & Riggins, under review). However, due to the low spatial resolution of ERPs, it is unknown whether there are developmental changes in the activation of hippocampal subregions during encoding across early childhood. The goal of the present study is to address this gap.

Method

Participants

- A total of 62 children completed the imaging session and memory task.
  - Participants were excluded due to too few trials left for analysis (< 10, *n*=7), too much motion(censored scans ≥ 30% or mean FD ≥ 0.50, *n*=17), or missing data (*n*=3).
- Data from 35 participants (14 male) aged 4-8 years (M= 6.97 ± 1.23 years) were included in the present analyses. Children were divided via a median split into young (n = 18, Mean age = 6.02 years, Age range = 4.19-7.19 years, SD = 0.86) and old groups (n = 17, Mean age = 7.97 years, Age range = 7.24-8.91 years, SD = 0.58).
- One participant in young group was lost for fMRI analysis due to failure in making individual mask.

Memory Assessment

- During encoding, fMRI data were collected while children viewed and were instructed to remember 120 stimuli and cartoon characters they were paired with. After getting out of the scanner, children were asked to make item and source memory judgments on 160 stimuli during retrieval.
  - Subsequent recognition memory: subsequent hit items vs. subsequent miss items
  - Subsequent recollection memory: subsequent source correct items vs. subsequent source incorrect items

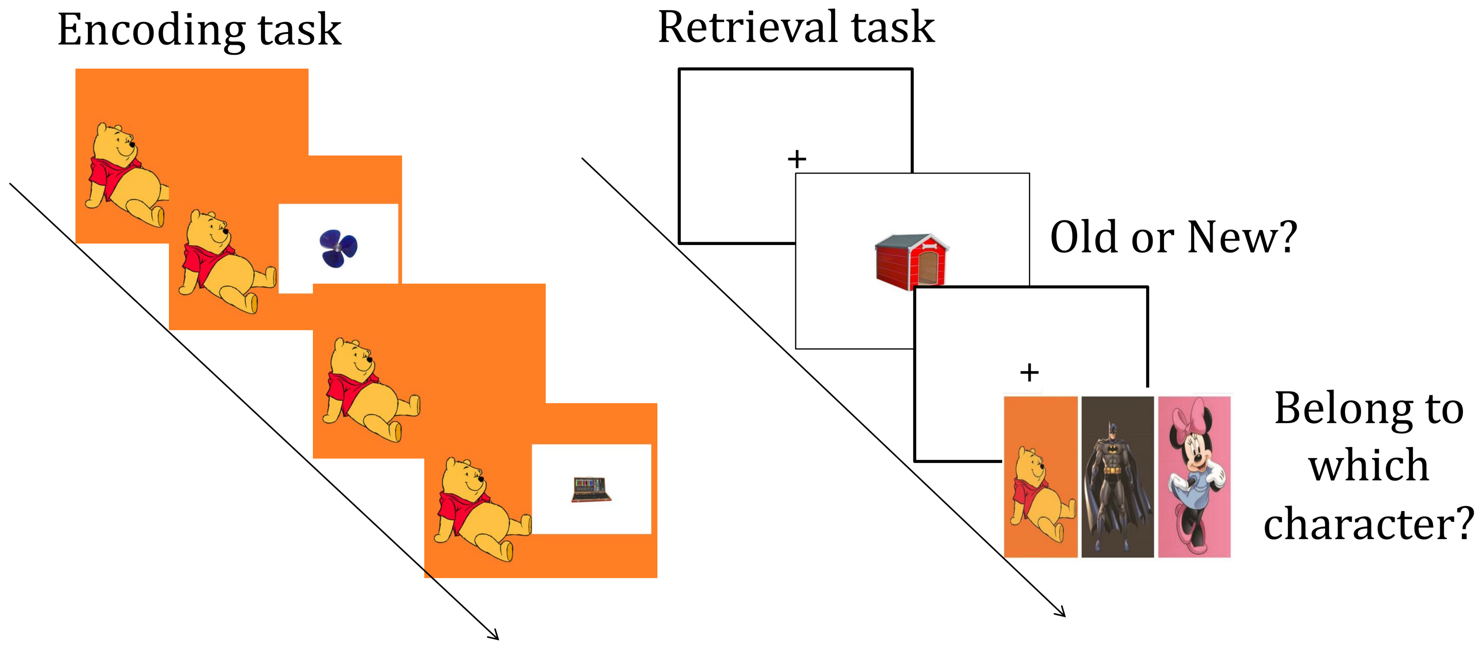

Figure 1. Illustration of encoding and retrieval tasks

MRI Data Collection and Analyses

- MRI data were collected at the Maryland Neuroimaging Center using a 32-channel coil in a Siemen's 3T scanner.
- Functional and anatomical data were preprocessed using SPM8.
- Statistical analyses were carried out in AFNI (Cox, 1996).
  - Multiple regression analysis was carried with three regressors of interest: items subsequently remembered with correct source, items subsequently remembered with incorrect source, and items subsequently forgotten.
  - The six motion correction curves were included as covariates of no interest in the model.
- ROI analyses were carried out using individual hippocampus head, body, and tail from left and right hemisphere as seed regions.
  - Hippocampal subregions were dervied from Freesurfer 5.1 and edited using Freesurfer v5.1 (surfer.nmr.mgh.harvard.edu; Fischl, 2012)and Automatic Segmentation Adapter Tool (ASAT, nitrc.org/projects/segadapter; Wang et al., 2011)

Results – Memory Performance

Table 1. Behavioral performance for each age group

	Young	Old	Difference
hit%	0.45 (0.17)	0.51 (0.14)	*t* = 1.22, *p* = .23
FA%	**0.13 (0.18)**	**0.02 (0.02)**	***t* = 2.56, *p* = .02**
Source%	0.52 (0.12)	0.57 (0.13)	*t* = 1.20, *p* = .24
dprime	**1.32 (0.73)**	**2.05 (0.40)**	***t* = 3.65, *p* = .001**

Results – Activation of hippocampal subregions

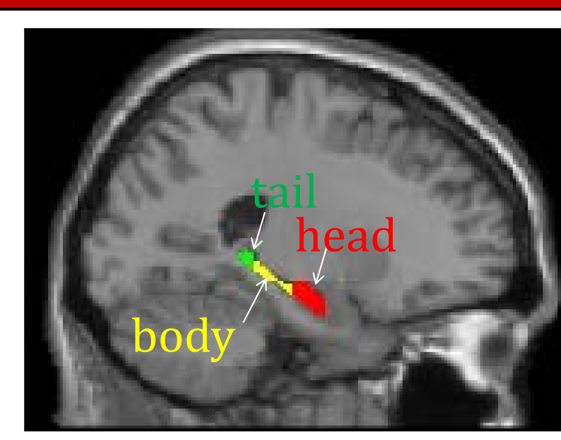

Figure 2. An example of hippocampal subregions

Repeated measures ANOVA analyses were carried out with within-subject factors (Conditions: subsequent hit vs. miss, or subsequent source correct vs. subsequent source incorrect; Hemisphere: left vs. right; Subregions: head, body, or tail) and a between-subject factor (Age: young vs. old).

Subsequent recognition memory

Condition × Hemisphere × Subregion (F (2, 66) = 3.22, $p < .05$)

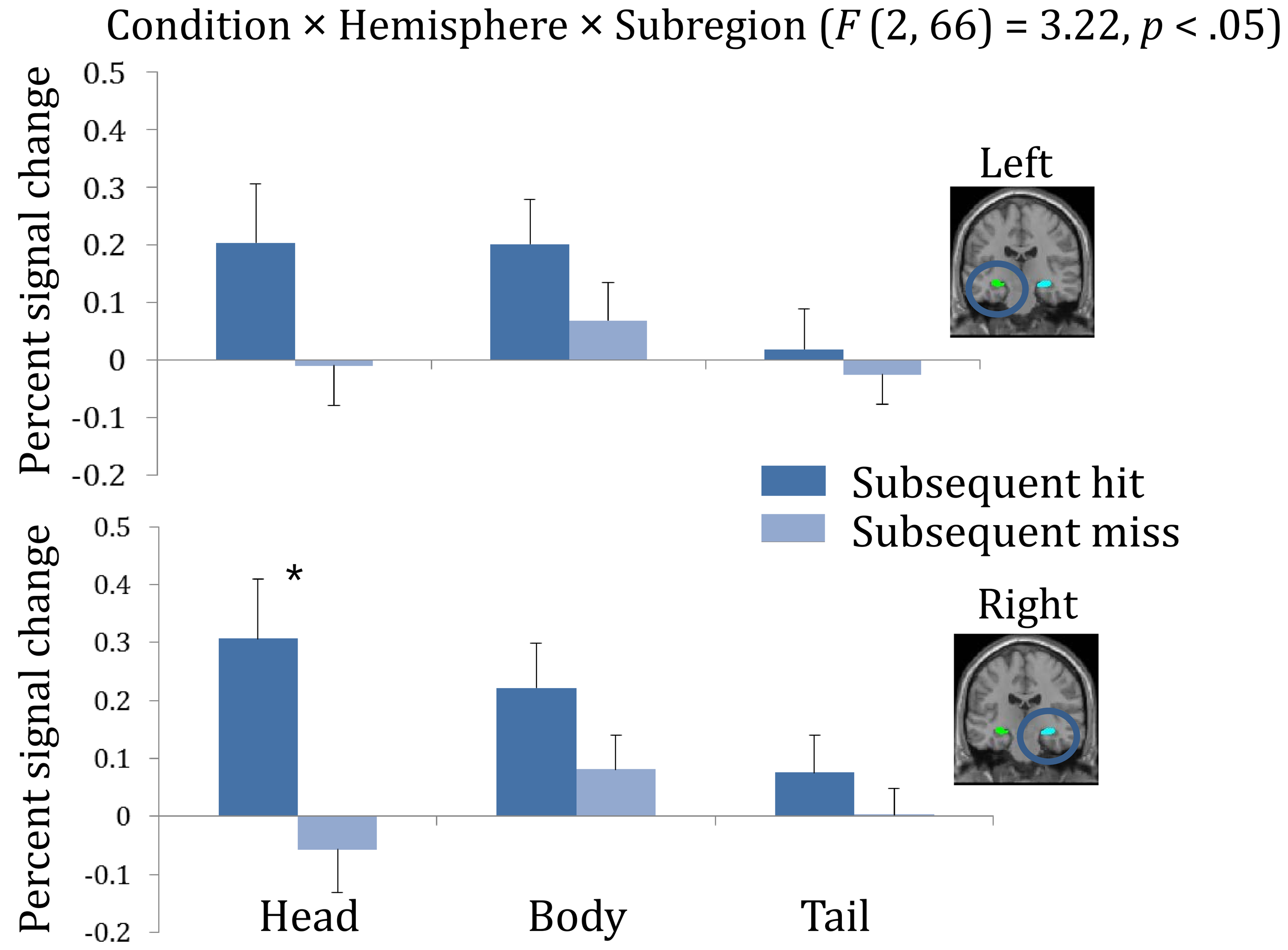

Figure 3. Results of analyses for the comparison between hit and miss conditions (* < .05).

Results – Activation of hippocampal subregions

Subsequent recollection memory

Condition × Hemisphere × Subregion (F (2, 66) = 3.35, $p < .05$)

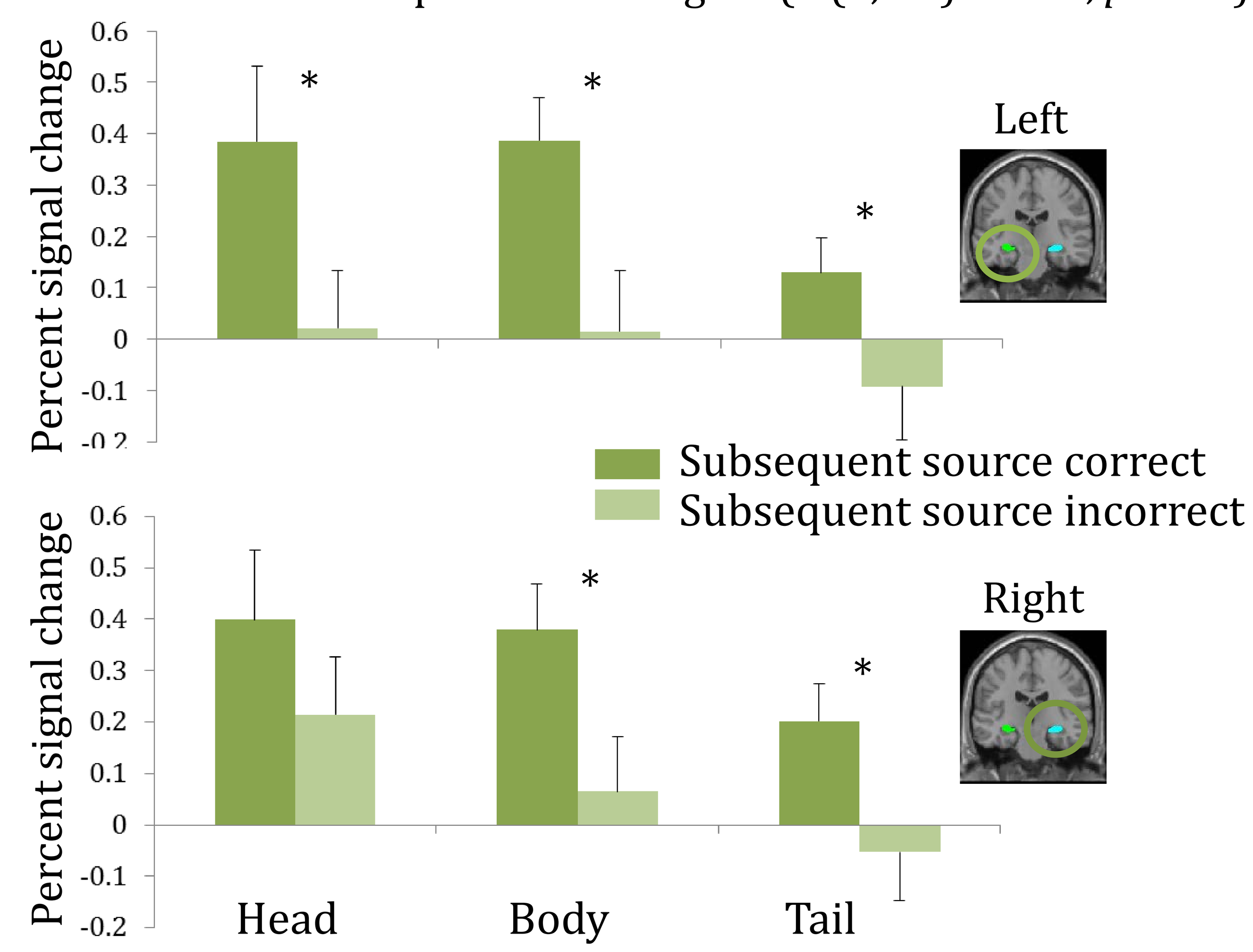

Figure 4. Results of analyses for the comparison between source correct and incorrect conditions (* < .05).

Discussion

- The findings support previous work suggesting the role of hippocampus in memory formation.
- All hippocampal subregions except left hippocampal head showed differential activation for subsequent source correct items vs. subsequent source incorrect items. However, Ghetti et al. (2010) did not find such difference in 8- to 9-year-old children.
  - Possible explanations: age difference (4- to 8-year-old vs. 8- to 9-year-old); mask difference (individual hippocampal subregion mask with ASAT correction vs. whole hippocampus mask without ASAT correction).
- There were no developmental changes in the activation of hippocampal subregions during encoding between the age of 4 and 8 years.
  - Developmental changes may exist in some other brain regions such as prefrontal cortex as suggested by Often et al. (2007).

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