Instantiating new objects into the discourse: the role of hippocampus and prefrontal cortex

Zachary Ekves[1,2], Pedro M. Paz-Alonso[3], Nicholas C. Hindy[4], Sarah Solomon[5], Gerry T. M. Altmann[1,2]

University of Connecticut[1], Connecticut Institute for the Brain and Cognitive Sciences[2], Basque Center on Cognition, Brain, and Language[3], University of Louisville[4], University of Pennsylvania[5]

Object-State Representation

- Successful sentence comprehension often involves tracking objects that undergo a change in state
- Subsequent processing can then refer to that changed object or a new one of the same type

  "The man will chop the tomato. And then he will smell the/another tomato."
- Left IFG is implicated in selecting between competing representations for reference during state change processing (Hindy et al., 2012; Solomon et al., 2015)
- **What is the content of these representations that are being selected?**

Hippocampus and Memory

- Hippocampus implicated in situation specific (episodic) memory (Eichenbaum et al., 2012; McClelland et al., 1995)
- Hippocampus involved in integrating information during language processing (Duff & Brown-Schmidt, 2012)
- Prefrontal and hippocampal connectivity guides memory retrieval and consolidation (Oztekin et al., 2009; Preston & Eichenbaum, 2013)
- Hippocampus is subdivided, with anterior regions biased towards global representation, and posterior regions towards local representation (Poppenk et al., 2013)

Questions

1. Are distinct hippocampal segments sensitive to object-state change and object instantiation/ reference in language processing?
2. Are there differences in co-activation ("*functional connectivity*") between hippocampal segments and other regions-of-interest (ROIs) involved in sentence processing?

Token Instantiation Sentences

Same Token, Minimal Change

The man will weigh the tomato. And then he will smell the tomato.

Same Token, Substantial Change

The man will chop the tomato. And then he will smell the tomato.

Different Token, Minimal Change

The man will weigh the tomato. And then he will smell another tomato.

Different Token, Substantial Change

The man will chop the tomato. And then he will smell another tomato.

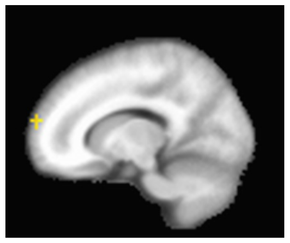
Results: Same Token, Substantial Change > Different Token, Substantial Change

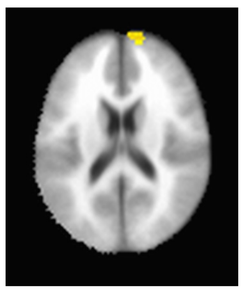
ROI-to-ROI

LIFG <–> R Hippocampal Body: t(23) = 2.23, p = .04, uncorrected

Seed-to-Whole Brain

Hippocampus (L Body, L Tail, R Body seeds) <–> R Medial Superior Frontal Gyrus; p < .05 uncorrected





Discussion

Referring back to substantially changed objects, compared to another token of the same type related to increased connectivity:

Connectivity between LIFG and R Hippocampal Body: potentially related to selection of appropriate state in episodic memory

R Medial Superior Frontal Gyrus-Hippocampus: frontal region implicated in inhibitory control (Floden & Stuss, 2006)

Token-State Switch Sentences

And Then, Minimal Change

The man will weigh the tomato. And then he will smell the tomato.

And Then, Substantial Change

The man will chop the tomato. And then he will smell the tomato.

But First, Minimal Change

The man will weigh the tomato. But first he will smell the tomato.

But First, Substantial Change

The man will chop the tomato. But first he will smell the tomato.

But First shifts attention to a different object state than what's in focus (cf. Different Token in previous experiment)

Results: But First, Substantial Change > And Then, Substantial Change

ROI-to-ROI

LIFG <–> L Hippocampal Body: t(15) = -2.24, p = .04, uncorrected

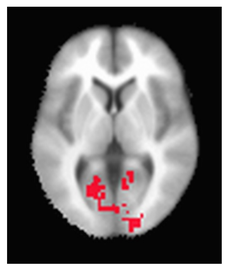
Seed-to-Whole Brain

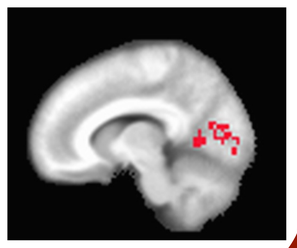
Right Hippocampal Head <–> posterior (Cuneus, Lingual gyrus) cluster; p < .05, uncorrected

Discussion

Cuneus/Lingual Gyrus implicated in encoding and retrieval in working memory and long term memory (Ranganath et al., 2003)

Connectivity with hippocampus could be related to encoding specific features to an object state being referenced





Summary

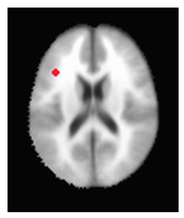
Hippocampus to LIFG connectivity greater when referring to previously mentioned objects, compared to new objects, after they have been substantially changed: may be indicative of a "selection" role of LIFG in selecting the relevant object state from episodic memory, and in turn, the relevant feature set

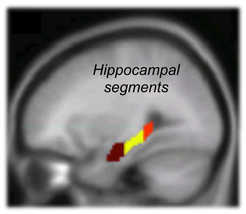
ROI Selection

7 spherical 7-voxel ROIs:

LIFG(1): Centered at peak voxel of Same,Substantial-Same,Minimal contrast

Hippocampus(6): bilateral ROIs centered at head, body, and tail, based on automated segmentation from Freesurfer structurals (Lerma-Usabiaga et al., 2016)





Methods

Data reanalyzed from Solomon et al. (2015), Hindy et al. (2012) in collaboration with Sharon Thompson-Schill. ***Solomon:*** **Participants**: 24 right-handed, native English speakers, ages 18-41 (M = 22.6) **Functional Acquisition**: 120 experimental trials (6 original conditions) across 5 runs, TR=3000ms, TE=30ms, FOV=192x192mm, flip angle=90°, 42 axial slices and 3mm^3 voxels, 3-15s jittered fixation between trials **Hindy: Participants:** 16 right-handed, native English speakers, ages 18-28 **Functional Acquisition:** 120 experimental trials (4 conditions) across 5 runs, TR=3000ms, TE=30ms, 44 axial slices, 3mm^3 voxels, 3-15 jittered fixation between trials. **Functional Connectivity**: Beta Series Correlation (Rissman, Gazzaley, & D'Esposito, 2004)

Future Work

Future studies will use visual analogs of these manipulations (e.g. cartoons showing change):
will both explore the degree to which the effects observed here are language specific as opposed to more general event processing, as well as the hippocampal gradient of abstraction for language vs visually situated scenes

Corresponding author: zachary.ekves@uconn.edu