On the necessity of hippocampus in lexical-semantic mapping in language processing

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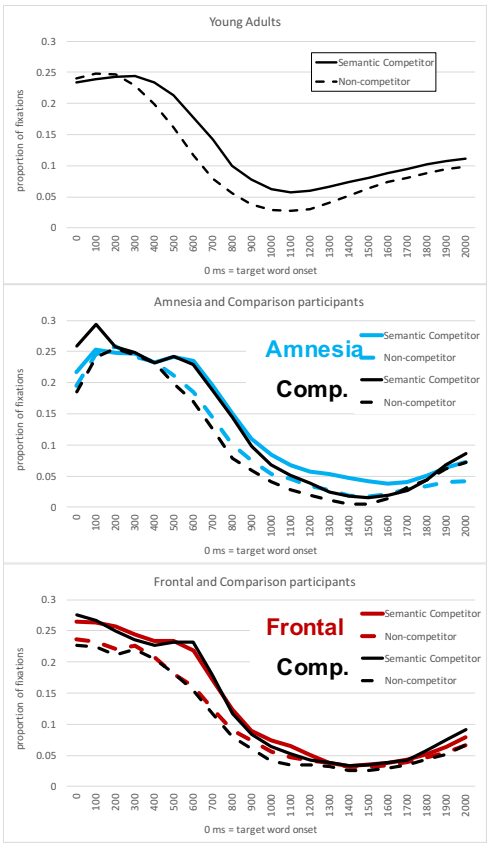
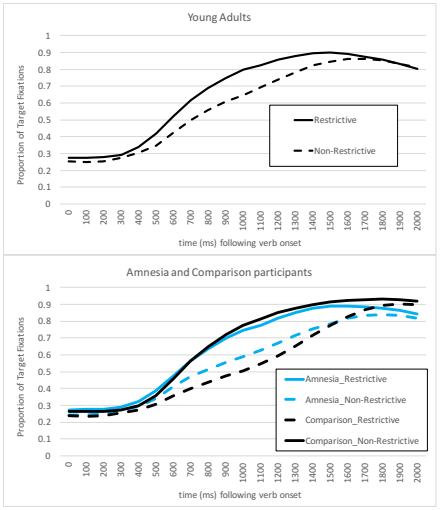
Recent findings suggest hippocampus contributes to the online processing of language[1]. We ask if hippocampus is necessary for lexical-semantic mapping in online sentence processing. Semantic knowledge is grounded in experiences that give rise to meaning[2]. Evidence for a role for hippocampus in semantics comes from a study of direct hippocampal recordings that finds increased hippocampal theta oscillations for semantically constraining sentences, pointing to a critical role for hippocampus in the use of semantics to relate words in sentence processing[3]. Converging evidence from fMRI points to left-hippocampal engagement during a semantic interference naming paradigm[4]. Work with patients with bilateral hippocampal damage reports impairments in semantic feature generation[5]. We test patients with bilateral hippocampal damage to examine the **necessity** of hippocampus for lexical-semantic mapping.

E1 examines lexical-semantic mapping in spoken word recognition[6,7]. If hippocampal damage impairs this process, activation of semantic competitors following a spoken word should be attenuated in patients with hippocampal damage. Scenes contain 4 pictures (target, critical item, and 2 unrelated), and participants (P) heard a spoken target word. The key manipulation is whether the critical item (e.g., mouse) is or is not semantically related to the target word (related target=cat; unrelated target=bed). Ps were: 18 healthy young adult (YA) controls; Ps with bilateral hippocampal damage and dense amnesia (N=5) and matched healthy controls (N=5). We also tested brain-damaged control (BDC) Ps with frontal lobe damage (N=5), and a separate group of healthy controls matched to the frontal BDC Ps (N=5). Gaze was analyzed as a binary measure of fixations to critical item (mouse) in a series of 10ms time-bins from 180-1300ms following the target word (e.g. *cat*) using a *dynamic-GLMM* (Cho et al., 2018), which takes into account dependencies in fixations across time using autocorrelations, and includes Ps and items as crossed random effects. **Results:** As predicted, in YAs the effect of condition was significant with many more fixations to the critical item in the related vs. unrelated condition (z= -7.24, p<.0001). Amnesia and Comparison Ps also had a significant condition effect (z= -6.48, p<.0001) that did not interact with group (p=.57). For Frontal Ps and their comparisons, the condition effect was significant (z= -2.97, p<.01) and did not interact with group (p=.59).

E2 tests sentences like "*She will hunt (find) the deer*", where the direct object (DO) was strongly predicted by the verb[8] (*hunt*=restrictive), or not (*find*=non-restrictive). Scenes had 4 pictures: the DO and 3 unrelated objects. The task was to click the DO. Ps were 16 YAs, Ps with bilateral hippocampal damage (N=5) and matched healthy controls (N=10). Gaze was analyzed from 180-1700ms using dynamic-GLMM. **Results:** As predicted, YAs made more DO fixations in Restrictive vs. Non-Restrictive condition (z=10.33, p<.001). In amnesia and healthy comparison Ps a significant condition effect (z's>8.0) did not signif. differ across group (z's<1.8).

Conclusion: Two studies find no evidence for impaired lexical-semantic mapping in spoken language processing following bilateral hippocampal damage, pointing to a lack of **necessity** for hippocampus in this process. How can we reconcile these findings given previous evidence for hippocampal contributions to semantics in comprehension[3], production[4], and feature generation[5]? One explanation is that hippocampus contributes to the lifelong tuning of lexical-semantic knowledge. Such a mechanism may predict graded effects, with close and frequent semantic relations (tested here) remaining intact. Our findings capture the role of hippocampus in engaging lexical-semantic associations during the processing of ordinary sentences, in a population with isolated hippocampal damage and dense amnesia. The results clearly show that at least for relatively common words and concepts, hippocampus is not necessary for engaging the lexical-semantic network in online sentence processing.





Experiment 1 **Experiment 2**

LEFT panel: Exp1: Time-course of fixations to the critical item (e.g. mouse) following a semantically related spoken target word (e.g. cat) or an unrelated target word (e.g. bed) for young adults, amnesia and comparison participants, and frontal and comparison participants. Time (ms) on the x-axis is following target word onset.

RIGHT panel: Exp2: Time-course of fixations to the direct object (e.g. deer) following the onset of the verb in sentences like "*She will hunt (find) the deer".* Plotted are data for young adults, and amnesia and comparison participants.

References

1. Brown-Schmidt, S., & Duff, M. C. (2016). Memory and common ground processes in language use. *Topics in cognitive science*, 8(4), 722-736.
2. Glenberg, A. M. (1997). What memory is for. Behavioral and brain sciences, 20(1), 1-19.
3. Piai, V., et al., (2016). Direct brain recordings reveal hippocampal rhythm underpinnings of language processing. *PNAS*, 113(40), 11366-11371.
4. de Zubicaray, G., et al. (2014). A perfusion fMRI investigation of thematic and categorical context effects in the spoken production of object names. *Cortex*, 54, 135-149.
5. Klooster, N. B., & Duff, M. C. (2015). Remote semantic memory is impoverished in hippocampal amnesia. *Neuropsychologia*, 79, 42-52.
6. Yee, E., & Sedivy, J. C. (2006). Eye movements to pictures reveal transient semantic activation during spoken word recognition. *JEP:LMC*, 32(1), 1.
7. Huettig, F., & Altmann, G. T. (2005). Word meaning and the control of eye fixation: Semantic competitor effects and the visual world paradigm. *Cognition*, 96(1), B23-B32.
8. Nozari, N., Trueswell, J. C., & Thompson-Schill, S. L. (2016). The interplay of local attraction, context and domain-general cognitive control in activation and suppression of semantic distractors during sentence comprehension. *Psychonomic bulletin & review*, 23, 1942-1953.