Language Plasticity: Genes, Brain, Cognition, Computation

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Neural Evidence for Cortical Consolidation After a Period of Offline Sleep

Nicole Landi[1,2], Jeffrey Malins[1], Stephen Frost[1], James Magnuson[1,2], Jay Rueckl[1,2], W.E. Mencl[1] & Kenneth Pugh[1,2]

[1]Haskins Laboratories & [2]University of Connecticut

UCONN UNIVERSITY OF CONNECTICUT

Haskins Laboratories

INTRODUCTION

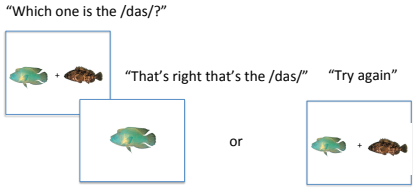
fMRI studies of word learning, via both simple in-scanner repetition and out of scanner training have shown modulation of LH language regions and the hippocampus (Sandak et al. 2004; Breitenstein et al. 2005), including variation in patterns as a function of reading skill (Pugh et al. 2008).

Recent fMRI studies of consolidation have found that after a period of sleep consolidation, newly learned words showed patterns of activation that were more similar to activation patterns for existing words (Davis et al. 2009), and further that these effects were modulated by whether participants were learning word forms alone, or form-meaning pairings (Takashima et al. 2014).

Findings from studies of learning and consolidation of new words support the dual memory systems account, which posits an initial period of sparse encoding in the hippocampus followed by a period of sleep-associated cortical consolidation.

The current fMRI study extends previous neural investigations of word learning and consolidation work by using a visual world training task, and exploring the relationship between language & learning skill and consolidation effects.

METHODS: Learning Task



Behavioral Performance

	Block	Acc	RT	N
Initial learning (Day 1)	1	77%	1801	48
	2	91%	1557	48
	3	94%	1469	32
	4	94%	1327	15
	5	95%	1333	9
	6	97%	1186	4
Refresher (Day 2)	1	96%	1299	48
	2	98%	1190	47
New Learning (Day 2)	1	87%	1652	48
	2	96%	1426	47
	3	97%	1464	13
	4	99%	1462	2
	5	95%	1415	1
	6	99%	1637	1

METHODS: Behavioral

N = 48 adults, 22 males; mean age = 20.92 (2.88)

Behavioral Assessments: Standardized battery of reading and language measures

Behavioral Training

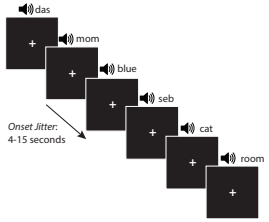
Learning Task: Paired associate learning of auditorily presented non-words to rare fish or rocks/minerals.

Day 1 (4pm): Train to 90% accuracy or 7 blocks, each with 24 items paired with fish pairs. Each target was heard 3 times within a block (72 total).

Day 2 (10am): Refresher of previously trained pairs (2 blocks). In addition, training on a new set of 24 items again to 90% or 7 blocks.
Eyetracking data was also collected during all training.

Day 2 (3pm) MR Scan: Participants heard (1) consolidated items (2) unconsolidated items (3) novel non-words (4) existing words

METHODS: fMRI task

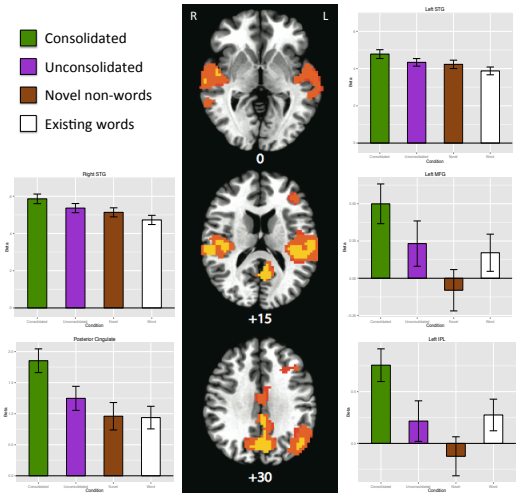


- Fast event-related design
- Six runs each (4:36min); all conditions present in all runs
- 40 total trials/run 80% non-color items: 20% real words, 20% trained unconsolidated 20% trained consolidated, 20% novel non-words
- Participants pressed one button for color words (20%) and another for all other stimulus types

fMRI Analysis Methods
Data were collected on a Siemens Trio 3T
Single subject data were processed using the AFNI suite of programs. Data were submitted to a multiple regression analysis (*3dDeconvolve*) with explanatory variables separately representing the five auditory stimulus conditions with nuisance regressors representing movement (3 rotation and 3 translation parameters).
Group analysis was performed using *3dANOVA2* to test for a main effect of type (trained consolidated, trained unconsolidated, novel non-words, and existing words), a main effect of repetition (first vs. second presentation), and the interaction between these two factors.

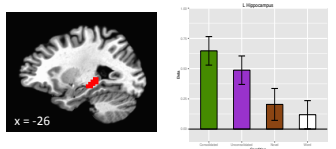
fMRI RESULTS: Groupwise Effects

Main Effect of Stimulus Type: Whole Brain



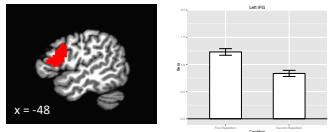
voxelwise p = .005 (cluster corrected at p = .05)

Main Effect of Stimulus Type: Medial Temporal Lobe ROI



voxelwise p = .005 (small volume correction at p = .05)

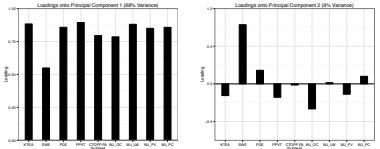
Main Effect of Repetition: Whole Brain



voxelwise p = .005 (cluster corrected at p = .05)

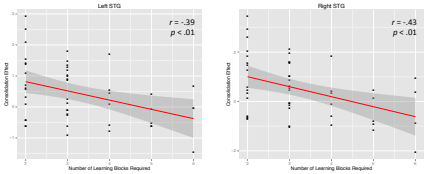
fMRI RESULTS: Individual Differences

Language factor scores derived from PCA



Scores for PC #1 negatively correlated with number of learning blocks required to reach criterion (r = -.38, p < .01)

Number of Learning Blocks Required to Reach Criterion Correlated with Size of Consolidation Effect in Bilateral STG



CONCLUSIONS

Initial results indicate that training plus consolidation for novel items produces greater activation in the STG (bilaterally), the L. IPL, the L. MFG and in in the posterior cingulate relative to trained but not consolidated items, untrained words and untrained non-words; the magnitude of this difference appears larger for untrained non-words in some regions (MFG, IPL).

In addition to our cortical effects, the L. hippocampus, showed a similar pattern of results (increased amplitude for consolidated items, relative to all other items).

Further, we replicated previous findings of repetition suppression in the IFG, for all stimulus types.

With respect to skill, we found that both learning rate and language function was associated with our consolidation effect in STG, such that faster learners (higher language function), show increased consolidation effects.

CONTACT

Nicole Landi, PhD; Nicole.landi@uconn.edu
www.haskins.yale.edu; http://landi.lab.uconn.edu/

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