BRAIN NETWORKS FOR RETRIEVAL OF ATTENDED AND UNATTENDED LANGUAGE TARGETS IN THE HUMAN AUDITORY SYSTEM

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Introduction

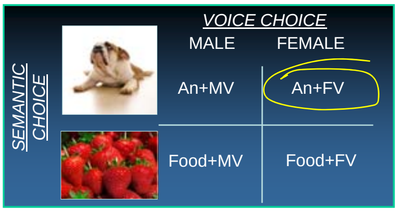
❑ fMRI (Functional Magnetic Resonance Imaging) is a relatively new technology that measures changes in brain hemodynamics.
❑ Activation is detected as changes in blood oxygen level, but these changes have been shown to reflect neural activity.
❑ Advantages of the UA's 3-Tesla magnet:
- non-invasive; no radiation involved
- no radioactive isotopes are needed
- short scan times
- high spatial resolution

❑ The role of attention is a critical factor in understanding how the human brain processes language.
❑ Exactly how attention and memory mechanisms are related is still an area of active debate in cognitive neuroscience.
❑ Attention & memory studies that involve fMRI have used mostly visual tasks to isolate the patterns of neural activation in the brain that result from varying attention demands.
❑ The purpose of this study was to use fMRI analysis along with an auditory language (attention) task, and a memory (retrieval) task to help isolate the attention and memory systems in the brain that are specifically engaged in processing spoken language.
❑ Recognition, a type of declarative memory, consists of two components:
- familiarity ("Did I hear that word before?")
- recollection ("Do I remember the details?")

❑ The medial temporal lobe (MTL) in the human brain is believed to be important in declarative memory, but it remains unclear how familiarity and recollection are processed in MTL structures, especially in the auditory domain.

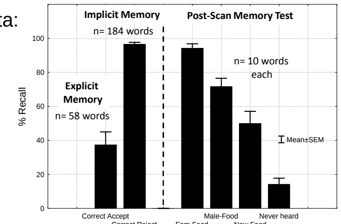
Study Design

❑ Subjects wore headphones inside the scanner, and they listened to a list of single nouns belonging to one of four categories:



❑ Inside the scanner, subjects were instructed to remember ONLY the An+FV words (explicit targets). During the recall phase, they had to press one button for explicit targets, and another button for all other words (non-target distractors).
❑ However, after the scan, they were given a surprise memory test to guage whether they could remember the non-targets as well (implicit encoding).
❑ Subjects received more examples of the non-target words to see if they could be forced to remember these distractors in addition to the targets.
❑ Behavioral data indicate that this strategy worked!

Memory Data:
(n=12 subjects;
$p < 0.01$)



Model of DECLARATIVE MEMORY

Recognition

I have encountered this before.

I also remember the details.

1) familiarity — item only — *perirhinal & entorhinal*

2) recollection — item + context — *hippocampus*

IMPLICIT (Food +MV) → ?
IMPLICIT (An+MV) → right item / ?
IMPLICIT (Food + FV) → ? / right context
EXPLICIT (An + FV) → ?

WHAT AREAS OF THE BRAIN ARE INVOLVED IN RECALL OF TARGETS vs. DISTRACTORS?

Results

❑ PREDICTIONS:
1. We expected that recall of target stimuli would specifically engage hippocampus, while recall of non-target (implicitly-encoded) stimuli would instead involve parahippocampal regions.
2. We also expected differential activity for recall of the implicitly-encoded words according to the strength of the observed memory for each category:
Food+FVoice > Food+MVoice > "New" Food+FVoice

❑ Entorhinal cortex = BA 28
❑ Dorsal entorhinal area = BA 34
❑ Perirhinal cortex = BA 35 and 36

STATISTICAL PARAMETRIC MAPS (by CONDITION)

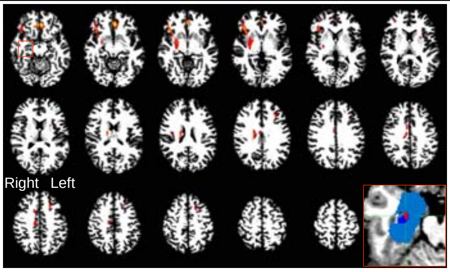


Fig. 1. Functional map (color-coded t-values) of BOLD-signal changes at each brain voxel during recall to the TARGET words (Animal words encoded in 1st Female Voice). N=14 subjects; P = 0.00055, corrected for multiple comparisons. Inset: area around hippocampus (deep to red square in montage) showing unilateral activity at P = 0.02.

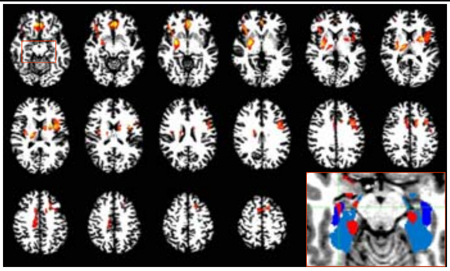


Fig. 2. Functional map (color-coded t-values) of BOLD-signal changes at each brain voxel during recall to the NON-TARGET category: Food words encoded in 1st Female Voice. N=14 subjects; P = 0.00036, corrected for multiple comparisons. Inset: area around hippocampus (deep to red square in montage) showing bilateral activity at P = 0.01.

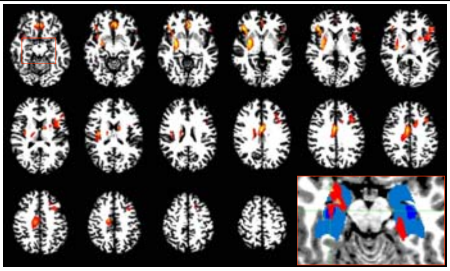


Fig. 3. Functional map (color-coded t-values) of BOLD-signal changes at each brain voxel during recall to the NON-TARGET category: Food words encoded in Male Voice. N=14 subjects; P = 0.00007, corrected for multiple comparisons. Inset: area around hippocampus (deep to red square in montage) showing bilateral activity at P = 0.005.

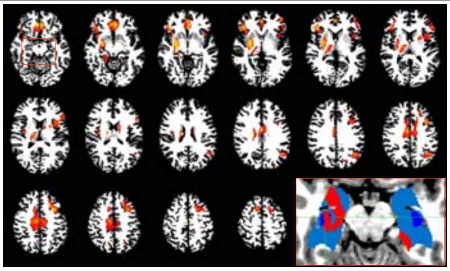


Fig. 4. Functional map (color-coded t-values) of BOLD-signal changes at each brain voxel during recall to the NON-TARGET category: NEW Food words + 2nd Female Voice. N=14 subjects; P = 0.0009, corrected for multiple comparisons. Inset: area around hippocampus (deep to red square in montage) showing bilateral activity at P = 0.005.

Conclusions

❑ Behavioral data revealed that implicitly-encoded words can be retrieved just as readily as explicitly-encoded words, and subjects can be forced to increase their memory capacity for irrelevant words simply by increasing the number of implicit stimuli (irrelevant distractors) relative to explicit targets.

❑ Recognition, a type of declarative memory, consists of two components: 1) familiarity ("Did I hear that word before?") and 2) recollection ("Do I remember the details?"). According to some studies using visual memory, recollection involves activity in the hippocampus, while familiarity involves parahippocampal regions.

❑ Recall of the auditory targets (animal names spoken in a female voice) engaged the fewest ROIs: primarily **ventral ACC** (bilat.), but also **dorsal ACC** and a group of clusters localized to RH: **AIC-IFG-MFG**. We observed no hippocampal or parahippocampal activity.

❑ In contrast, recall of non-target words (task distractors) activated the **AIC-IFG-MFG** complex **bilaterally**. This activity was more inferior in RH, more superior in LH. These words also engaged significantly more subcortical resources. These included RH **Thalamus** and **Hippocampus/Parahippocampal Gyrus**, and LH **anterior Putamen**.

❑ In the FOODS-FEMALE condition, LH **AIC** is stronger than in the RH. In the FOODS-MALE condition, LH **Caudate body** is more inferior than RH **Caudate body**, the opposite to the other three conditions.

❑ The NEW FOODS condition also engaged areas closer to primary auditory cortex (**STG**, **Ang Gyr**, **SMG**) in LH. This condition alone also showed the strongest **parahippocampal** activity in RH.

❑ Our fMRI data indicate that the model for visual memory as proposed by Kirwan *et al*. 2008 requires some revision in order to examine recognition memory in the auditory domain.

Summary Table of ROIs for Each Stimulus Category

Key: correct item | correct context | wrong item | wrong context

Explicit Encoding	Implicit Encoding		
Animals / Female	Foods / Female	Foods / Male	Foods / NEW
Right Hemisphere	**Right Hemisphere**	**Right Hemisphere**	**Right Hemisphere**
• ventral ACC	• ventral ACC	• ventral ACC	• ventral ACC
* dorsal ACC	* dorsal ACC	• dorsal ACC	• dorsal ACC
* AIC-IFG-MFG	* AIC-IFG-MFG	• AIC-IFG-MFG	• AIC-IFG-MFG
* Caudate body	• Caudate body	• Caudate body	• Caudate body
* post Putamen	* post Putamen	* post Putamen	* post Putamen
	* Thalamus (VLN+)	* Thalamus (VLN+)	* Thalamus (VLN+)
		* Hippocampus	* Hippocampus
		* posterior insula	* Parahipp G (35/36)
Left Hemisphere	**Left Hemisphere**	**Left Hemisphere**	**Left Hemisphere**
• ventral ACC	• ventral ACC	• ventral ACC	• ventral ACC
	• dorsal ACC	• dorsal ACC	• dorsal ACC
	* AIC-PCG-IFG-MFG	• AIC-IFG-MFG	* AIC-IFG-MFG-SFG
	• Caudate body	* Caudate body	* Caudate body
* MFG-SFG		* MFG-SFG	* MFG-SFG
	* anterior Putamen	* anterior Putamen	* anterior Putamen
			* STG
			* Angular Gyr
			* SMG

References

1. Kirwan CB, Wixted JT, Squire LR (2008) Activity in the medial temporal lobe predicts memory strength, whereas activity in the prefrontal cortex predicts recollection. *J. Neuroscience* **28**:10541-10548.

2. Christensen TA, Antonucci SM, Lockwood JL, Kittleson M, Plante E (2008) Cortical and subcortical contributions to the attentive processing of speech. *Neuroreport* **19**: 1101-1105.

3. MacDonald III, AW, Cohen JD, Stenger VA, Carter CS (2000) Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. *Science* **288**: 1835-1838.

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