Abstract and concrete noun processing in healthy older adults using fMRI

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Background

- Behavioral data from both normal and brain-injured subjects suggests that abstract words and concrete words are processed differently
- Dual Coding Theory (Paivio, 1991)
  - Suggests two systems for encoding words into semantic memory
    - Verbal (linguistic): Abstract words are encoded into the semantic system with only verbal information
    - Nonverbal (sensory): Concrete words are encoded into the semantic system with both verbal and multi-modal sensory information
- Evidence from recent neuroimaging studies suggests the possibility of dissociable neural correlates for abstract and concrete word processing (Binder, 2007)
- An issue yet unaddressed in the current literature is the processing of abstract and concrete nouns in normal, healthy older adults, although neural activation corresponding to different cognitive processes has been shown to change as a function of age (Cabeza, 2001)
- Patients with aphasia, who typically fall into the category of older adults, are hypothesized to use the right hemisphere for semantic processing instead of the damaged left hemisphere
- If concrete words are processed bilaterally, then patients with aphasia will exhibit preference for concrete words, which has been shown behaviorally (Nickels & Howard, 1995; Barry & Gerhand, 2003; Kiran, Abbott, & Sandberg, 2009)
- In order to test these hypotheses, we must establish a healthy older adult neural activation baseline against which to compare neural activation in patients with aphasia

Methods

Participants

- N=10; 5 male, 5 female. Age range: 50-63.
- Right-handed, monolingual English speakers
- No history of neurological disease, trauma, or disorders. Normal cognitive and linguistic functioning.

Tasks

Lexical Decision (replicated from Binder et al., 2005)

- 50 abstract words, 50 concrete words, 100 pseudowords

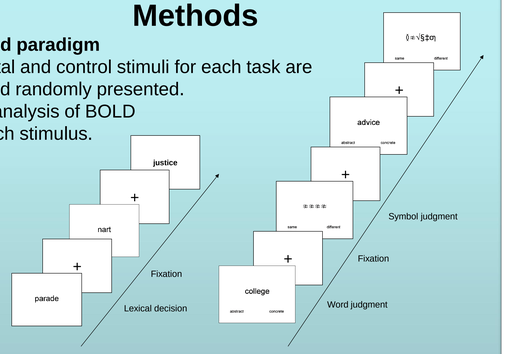
Word Judgment

- 50 abstract words, 50 concrete words, 50 same symbol strings, and 50 different symbol strings

Methods

Event-related paradigm

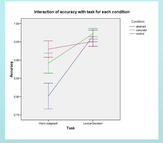
- Experimental and control stimuli for each task are combined and randomly presented.
- Allows for analysis of BOLD signal for each stimulus.

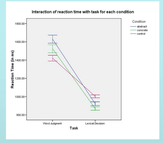


Task	Lexical Decision	Word Judgment
Example	*nart* - yes or no *parade* - yes or no	*advice* - abstract or concrete *college* - abstract or concrete ##### - same or different ?*#!% - same or different
Response type	button press	button press
Initial baseline	8 sec	8 sec
Pseudo-randomized ISI (fixation cross)	1.5/3.0/4.5 sec	1.5/3.0/4.5 sec
Total ISI duration per run	153 sec	153 sec
Stimulus duration per run	50 stimuli x 2 sec = 100 sec	50 stimuli x 3 sec = 150 sec
# runs, # items per run	4 runs, 50 items per run	3 runs, 50 items per run
Total time in minutes	17.4 minutes	15.6 minutes

Results

Behavioral





fMRI MNI coordinates

Lexical Decision

Abstract words vs Nonwords				
Structure	*x*	*y*	*z*	*Z-score*
L Posterior Cingulate Gyrus	-4	-38	38	3.53
L Middle Temporal Gyrus	-62	-50	2	3.81
R Supramarginal Gyrus	58	-40	28	3.51

Concrete words vs Nonwords				
Structure	*x*	*y*	*z*	*Z-score*
L Posterior Cingulate Gyrus	-8	-42	40	3.8
R Parietal Operculum Cortex	58	-28	20	3.85
L Superior Lateral Occipital Cortex	-48	-66	22	4.24
L Middle Frontal Gyrus	-34	28	40	3.63
R Frontal Pole	18	40	42	3.33
L Insular Cortex	-40	-10	6	3.32

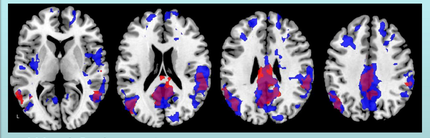
Word Judgment

Abstract nouns vs Symbol strings				
Structure	*x*	*y*	*z*	*Z-score*
L Inferior Frontal Gyrus	-54	30	-6	4.99
L Paracingulate Gyrus	-6	22	46	4.4
L Middle Temporal Gyrus	-66	-38	-8	4.1
R Frontal Orbital Cortex	36	24	-8	3.95
L Caudate Nucleus	-14	12	6	3.78

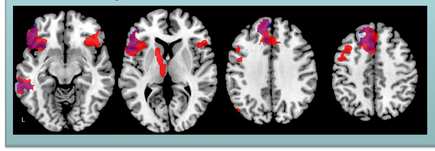
Concrete nouns vs Symbol strings				
Structure	*x*	*y*	*z*	*Z-score*
L Inferior Frontal Gyrus	-52	22	-8	4.59
L Frontal Pole	-10	50	36	4.66
L Middle Temporal Gyrus	-66	-36	-10	3.89

Results

Lexical Decision



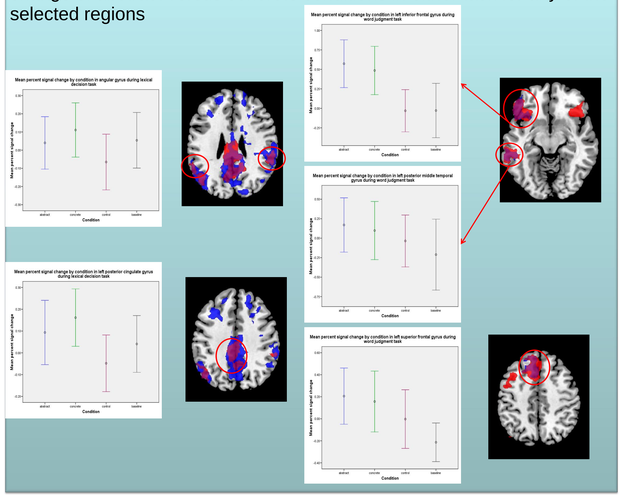
Word Judgment



Red = activation during abstract word processing
Blue = activation during concrete word processing
Purple = overlap in activation

Region of Interest Analysis

- Performed ROI analysis on areas of overlap which coincided with areas set forth by Binder, Desai, Graves, & Conant (2009) as semantic processing areas
- No significant differences were found between the mean percent signal change of abstract versus concrete conditions in either task for any of the selected regions



Discussion

- The areas of overlap obtained in the lexical decision task (angular gyrus bilaterally and left posterior cingulate gyrus) agree with suggested areas of general semantic processing.
  - These areas did not show a preference for either abstract or concrete word processing.
  - Overall, more areas of activation were found bilaterally for concrete words during the lexical decision task. This may be reflecting:
    1. a bilateral network for processing concrete words
    2. similarities in processing between abstract words and pseudowords (see behavioral data)
- The areas of overlap obtained in the word judgment task (left inferior frontal gyrus, left posterior middle temporal gyrus, and left superior frontal gyrus) also agree with suggested areas of general semantic processing.
  - These areas also did not show a preference for either abstract or concrete word processing.
  - Overall, more areas of activation were found for abstract words bilaterally during the word judgment task, specifically in the IFG. This may be due to the effects of healthy aging.
    - Bilateral activation of PFC in healthy older adults versus left-lateralized activation in healthy younger adults during semantic tasks may be due to a compensatory mechanism to counteract age-related cognitive decline (Bergerbest et al., 2009).

Conclusion

In general, this study agrees with previous neuroimaging studies exploring neural correlates of semantic processing. However, the left-lateralized processing of abstract words and bilateral processing of concrete words was only supported for the lexical decision task. The word judgment task appeared to have the opposite pattern. This may be due to differences in processing demands of the two tasks and/or to the effects of normal aging. Future research should focus on a larger sample, with a wider healthy older adult age range.

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