Introduction

The difference in processing abstract and concrete words with a specific advantage for concrete words is called a 'concreteness effect' and has been shown to exist in normal and language-disordered populations. Faster reaction times and more accurate responses for concrete versus abstract words during a variety of lexical tasks have been observed for normal subjects as well as in patients with aphasia (Paivio, 1991; Nickels & Howard, 1995; Barry & Gerhand, 2003; Kiran, Abbott, & Sandberg, in press).

One theory that has been proposed to explain the concreteness effect and is testable with fMRI is the dual coding theory (DCT; see Paivio, 1991, for a review). The DCT posits that there are two systems for encoding words into semantic memory: verbal/linguistic and nonverbal/sensory. Abstract words are encoded into the semantic system with only verbal information, whereas concrete words are encoded into the semantic system with both verbal and multi-modal sensory information. When concrete words are retrieved from the semantic system, both verbal and sensory systems will be activated, making the appropriate selection more salient. When abstract words are retrieved, only the verbal system will be activated, resulting in a relative selection disadvantage. This theory may support the existence of differing neural substrates for the processing of abstract vs. concrete words.

There is evidence from recent neuroimaging studies that suggests the possibility of dissociable neural correlates for abstract and concrete word processing (see Binder, 2007, for a review). Binder and colleagues (Binder, Westbury, McKiernan, Possing, & Medler, 2005a; Binder, Medler, Desai, Conant, & Liebenthal, 2005b; Sabsevitz, Medler, Seidenberg, & Binder, 2005) found bilateral activation for concrete nouns and left-lateralized activation for abstract nouns, lending support to the DCT. These studies are noteworthy because similar methods, participants (healthy young adults), and stimuli were used; only the task differed in each experiment.

An issue yet unaddressed in the current literature is the processing of abstract and concrete nouns in normal, healthy older adults. Neuroimaging studies have shown that the neural activation corresponding to different cognitive processes changes as a function of age (see Cabeza, 2001). Much of the behavioral data regarding the concreteness effect comes from patients with aphasia, who typically fall into the category of older adults. Patients with aphasia 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 in a treatment study using abstract and concrete concepts (Kiran et al, in press). 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. The present study provides such a baseline by extending the results of Binder et al. (2005a) to an older population.

Methods

Participants

Eight (five male, three female) monolingual, right-handed, English speaking adults aged 50-63 participated in the experiment. Handedness was confirmed with the Edinburgh Inventory (Oldfield, 1971). Participants were screened using a medical history and demographic questionnaire to rule out individuals with a history of neurological disease, head trauma, psychiatric disorders, or developmental speech, language, or learning disabilities. All participants completed at least a high school education and were screened with the MMSE (Mini Mental State Exam; Folstein et al., 1975) and BNT (Boston Naming Test; Kaplan et al., 1983) to rule out cognitive and semantic deficits.

Tasks and Stimuli

Two tasks were developed for the present experiment. The lexical-decision task was replicated from Binder et al. (2005a) so as to decrease the confounding effects of differing methods, thus allowing for a direct comparison of results of the present study with the extant literature. For this task, 50 abstract (*ability*) and 50 concrete (*parade*) words and 100 word-like nonwords (*nart*) were presented to each participant on a computer screen in the fMRI scanner. Participants were asked to determine whether each stimulus was a word or not.

The abstract/concrete word-judgment task was developed as a task that required deeper semantic processing than lexical decision in order to compare the pattern of concrete versus abstract activation during cursory semantic processing with that of more in-depth semantic processing. For this task, 50 abstract (*advice*) and 50 concrete (*college*) nouns as well as 50 same (#####) and 50 different (#$@!*) symbol strings were presented to each participant. Participants were asked to decide whether the noun was abstract or concrete (experimental condition) and whether the symbol string was made up of symbols that are the same or different (control condition).

The nouns used for the word-judgment task as well as the ratings for concreteness, imageability, frequency, and familiarity were obtained from the Medical Research Council psycholinguistic database (www.psy.uwa.edu.au/mrcdatabase/uwa_mrc.htm). Abstract and concrete nouns were matched on familiarity, frequency, syllables and letter-length. Abstract nouns had significantly lower concreteness and imageability ratings than concrete nouns. Only nouns that cannot be used as another part of speech were included in order to control for possible confounding effects due to word class or ambiguity. The length of each symbol string was matched to the letter length of each concrete and abstract noun.

Experimental design

Both the lexical-decision task and the word-judgment task were carried out in an event-related design (see Table 1 in appendix) using a GE 3.0 Tesla MRI scanner. The visual stimuli were presented on a screen fitted to a head coil in the scanner. Standardized optical lenses were used when necessary to correct visual acuity.

Results

Activation for abstract and concrete words was determined by subtracting the activation of nonwords for the lexical-decision task and symbol strings for the word-judgment task. On the lexical-decision task, reaction time was significantly longer for nonwords than concrete words, but only slightly longer than abstract words (see Table 3 in appendix). This similarity between nonwords and abstract words may be overshadowing the true difference in activation of concrete and abstract words. Correspondingly, concrete words produced greater overall activation than abstract words. Additionally, in comparison to nonwords, concrete words produced more bilateral activation, whereas abstract words produced more right-hemispheric activation (see Table 2 and Figure 1 in appendix). Reaction time effects from the word-judgment task showed that reaction time was significantly shorter for symbol strings than abstract words, but only slightly shorter than concrete words. Likewise, abstract words produced greater overall activation than concrete words. Additionally, in comparison to symbol strings, abstract words produced more bilateral activation, whereas concrete words produced more left-hemispheric activation (see Table 2 and Figure 2 in appendix).

Discussion

The results of the lexical-decision task do not directly coincide with the results of Binder et al. (2005a). This may be due to the difference in the average age of the participants. Healthy older adults have exhibited differing patterns of activation than their younger counterparts; specifically, increased overall activity as well as increased bilateral activity (Cabeza, 2001). The results of the word-judgment task seem to reveal a more precise pattern of semantic processing than the lexical-decision task. This may be due to the nature of the control condition for each task and/or the degree of difficulty of each task. It is important to note that with the limited number of participants in this study, these findings are quite tentative.

Selected References

Barry, C., & Gerhand, S. (2003). Both concreteness and age-of-acquisition affect reading accuracy but only concreteness affects comprehension in a deep dyslexic patient. *Brain and Language, 84*, 84-104. Retrieved from Elsevier database.

Binder, J. R. (2007, March 22). Effects of word imageability on semantic access: Neuroimaging studies. In M. A. Kraut & J. Hart, *Neural basis of semantic memory* (pp. 149-181). Cambridge: Cambridge University Press. Retrieved from http://www.utxa.eblib.com.ezproxy.lib.utexas.edu/EBLWeb/patron/

Binder, J. R., Medler, D. A., Desai, R., Conant, L. L., & Liebenthal, E. (2005b). Some neurophysiological constraints on models of word naming. *Neuroimage, 27*, 677-693. Retrieved from PubMed database.

Binder, J. R., Westbury, C. F., McKiernan, K. A., Possing, E. T., & Medler, D. A. (2005a). Distinct brain systems for processing concrete and abstract concepts. *Journal of Cognitive Neuroscience, 17*(6), 905-917. Retrieved from PubMed database.

Cabeza, R. (2001). Cognitive neuroscience of aging: Contributions of functional neuroimaging. *Scandinavian Journal of Psychology, 42*, 277-286. Retrieved from PubMed database.

Folstein MF, Folstein SE, McHugh PR (1975). "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *Journal of psychiatric research, 12* (3), 189-98.

Kaplan, E., Goodglass, H., & Weintraub, S. (1983). *Boston naming test.* Philadelphia: Lea & Febiger.

Kiran, S., Abbott, K., & Sandberg, C. W. (2007). Effects of abstractness for treatment of generative naming deficits in aphasia. In press.

Nickels, L., & Howard, D. (1995). Aphasic naming: What matters? *Neuropsychologia, 33*(10), 1281-1303. Retrieved from Elsevier database.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 1*, 97-113. Retrieved from PubMed database.

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology, 45*(3), 255-287. Retrieved from ScienceDirect database.

Sabsevitz, D. S., Medler, D. A., Seidenberg, M., & Binder, J. R. (2005). Modulation of the semantic system by word imageability. *Neuroimage, 27*, 188-200. Retrieved from Elsevier database.

Appendix

Table 1. Details of stimuli and tasks to be employed in the experimental fMRI task.

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

Table 2. Cluster peak activation MNI coordinates.

Lexical Decision

Abstract words vs Nonwords					**Concrete words vs Nonwords**				
Structure	*x*	*y*	*z*	*Z-score*	*Structure*	*x*	*y*	*z*	*Z-score*
L Cingulate Gyrus	-6	-42	32	4.88	R Parietal Operculum Cortex	54	-30	22	6.18
L Middle Temporal Gyrus	-60	-50	2	5.99	L Lateral Occipital Cortex	-48	-68	22	7.09
R Supramarginal Gyrus	60	-40	28	5.86	L Insular Cortex	-38	-8	6	5.29
R Middle Frontal Gyrus	38	32	38	4.87					
R Temporal Pole	54	8	-4	5.19					

Word Judgment

Abstract nouns vs Symbol strings					**Concrete nouns vs Symbol strings**				
Structure	*x*	*y*	*z*	*Z-score*	*Structure*	*x*	*y*	*z*	*Z-score*
L Paracingulate Gyrus	-6	18	48	13.5	L Inferior Frontal Gyrus	-50	30	-4	12.2
L Middle Temporal Gyrus	-56	-36	-8	10.8	L Middle Temporal Gyrus	-66	-42	-12	8.56
R Frontal Orbital Cortex	42	26	-12	8.28	L Lateral Occipital Cortex	-48	-74	36	8.56
R Middle Temporal Gyrus	50	-30	-6	5.42	R Frontal Orbital Cortex	38	26	-10	5.83
R Postcentral Gyrus	42	-22	60	4.35					

Table 3. Mean reaction times (RT) and accuracy (ACC).

	Lexical Decision			**Word Judgment**		
	Abstract	**Concrete**	**Control**	**Abstract**	**Concrete**	**Control**
RT	923.13	855.60*	1011.14*	1646.69*	1549.01	1438.24*
(std dev)	(72.00)	(66.91)	(128.18)	(165.50)	(94.33)	(155.31)
ACC	96.07%	96.77%	94.25%	80.76%*	88.52%	93.46%*
(std dev)	(3.71%)	(3.19%)	(3.58%)	(10.46%)	(12.35%)	(4.02%)

Figure 1. fMRI results for the lexical decision task.
Red: Abstract words versus nonwords
Blue: Concrete words versus nonwords
Pink: Areas of overlap

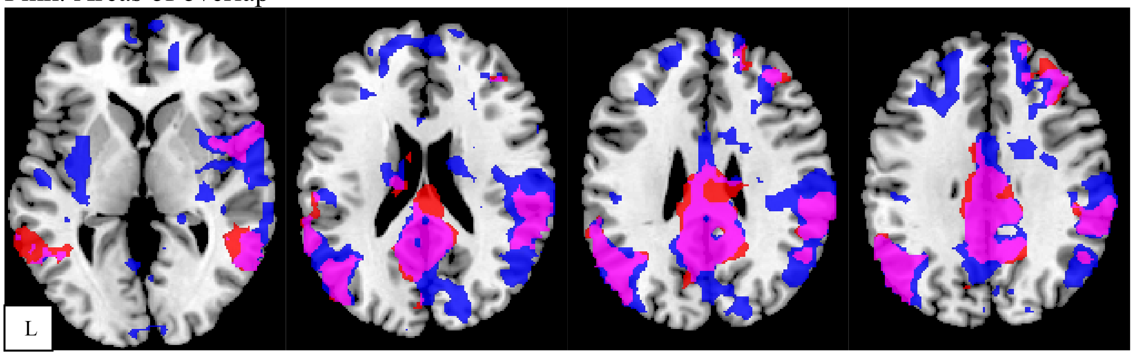

Figure 2. fMRI results for the word judgment task.
Red: Abstract nouns versus symbol strings
Blue: Concrete nouns versus symbol strings
Pink: Areas of overlap