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Verbal learning in semantic dementia: Is repetition priming a useful strategy?

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Background: Semantic dementia (SD) is a neurodegenerative disease that impacts long-term conceptual and lexical knowledge (Hodges & Patterson, 1996). Severe naming difficulties are prevalent in SD, yet little is known about the potential for word learning in this population.
Aims: We assessed patterns of repetition and implicit learning in patients with moderate to advanced SD via repeated exposure to word lists varied by frequency and imageability. We propose a tentative framework for the language loss incurred in SD and open a dialogue for treatment approaches targeted towards progressive semantic anomia.
Methods and Procedures: In two experiments, we examined immediate serial recall and short-term learning in five patients with SD. We predicted reduced semantic effects (imageability), preservation of lexical effects (frequency), and diminished primacy effects in serial recall, consistent with other semantically impaired populations (Martin & Saffran, 1997). We also predicted that severity of semantic impairment would modulate the facilitative effects of repeated exposure (i.e., repetition priming) on word list recall.
Outcomes and Results: In immediate serial recall, all participants showed reduced imageability effects, but only one patient showed a significant word frequency advantage. Two patterns of serial position effects emerged: (1) poor recall of initial list items and (2) better recall of initial and final items. All participants showed minimal gains across repeated trials; however, patients who poorly recalled initial items showed the least benefit from repeated exposure.
Conclusions: We discuss the usefulness of repetition-based interventions for SD and advocate maintenance of known vocabulary over reacquisition of forgotten words. We provide a theoretical framework for progressive language loss associated with SD; this model reflects an ordered reduction of lexical-semantic support coinciding with dementia severity.

Semantic dementia (or SD) denotes the temporal lobe variant of frontotemporal dementia; a disease characterised by a progressive loss of long-term semantic memory and associated word meanings (Snowden, Neary, & Mann, 2002). Anomia has been identified as among the most prevalent and socially isolating aspects of SD, yet little is known regarding the potential for vocabulary acquisition in this popula-

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tion (Graham, Patterson, Pratt & Hodges, 2001). Our aims here were twofold: (1) to provide a tentative theoretical framework for the progressive language loss incurred in SD, and (2) to evaluate the effects of repeated exposure (i.e., repetition priming) on word retention.

In the early stages of SD, cortical damage impacts the inferior temporal neocortex, often sparing subcortical and frontal lobe structures (Grossman, 2002; Mummery, Patterson, Hodges, & Price, 1998; Snowden et al., 2002). Until the latest stages of the disease, patients with SD show intact abilities across non-semantic domains, including: phonology, syntax, perceptual discrimination, executive function, and day-to-day autobiographical memory (Hodges, Patterson, Oxbury, & Funnell, 1992; Hodges & Patterson, 1996). Patients with SD typically produce fluent but empty speech, and in this way SD is similar to primary progressive aphasia (Grossman & Ash, 2004; Mesulam, 1982). SD is differentiated from aphasia, however, in that it represents a disorder of both conceptual *and* word form knowledge rather than an isolated linguistic loss (Hodges & Patterson, 1996; Lambon Ralph, McClelland, Patterson, Galton & Hodges, 2001).

Techniques such as spaced retrieval training and errorless learning have recently shown promise for naming difficulties associated with other forms of dementia; however, these interventions remain unexplored in SD (Grandmaison & Simard, 2003; Hopper, 2004). The success of such interventions depends on a patient's ability to establish lasting connections between words and concepts (e.g., this is a *cat* . . . say the word *cat*). One hypothesis about learning in SD is that patients can make such connections when tasks do not demand prior conceptual knowledge. This idea has received some support from recent studies of learning in SD where, after training, patients have accurately discriminated new words, objects, pictures, and faces (Graham, Becker, & Hodges, 1997; see Simons & Graham, 2000, for a review). It has been suggested, however, that these learning effects are transient because they are supported by rote recognition rather than a more stable reserve of long-term conceptual knowledge (Graham et al., 2001; Simons & Graham, 2000).

Recognition memory is useful for object discrimination, but it may have only limited facilitative effects on word retention. This trend was evident in a longitudinal case study of verbal learning reported by Graham and colleagues (2001). Patient DM was a retired surgeon who experienced several years of progressive word-finding difficulties prior to being diagnosed with SD. In the interim, DM made ceaseless efforts to retain personally relevant words, studying the *Oxford English Picture Dictionary* for up to 6 hours a day and also maintaining a picture journal of famous faces matched to names. After he discontinued this strategy, DM showed gains on measures of fluency naming. However, in the ensuing months without intensive training, DM's naming ability declined to near baseline levels.

Treatment paradigms for word retrieval in aphasia rely on similar techniques to those employed by patient DM (e.g., word–picture matching). These approaches appear to have only transient facilitative effects on word retrieval when access to lexical-semantic representations is impaired (Martin, Fink, & Laine, 2004). Such treatment strategies may be similarly limited in SD, depending on the extent to which loss of semantic representations has impacted lexical and phonological representations. One avenue for assessing the integrity of conceptual-semantic knowledge is through immediate recall. Repetition without comprehension produces qualitatively different patterns of forgetting than does recall of meaningful stimuli (Hulme, Newton, Cowan, Stuart, & Brown, 1999; Knott, Patterson, & Hodges, 1997).

We argue here that conceptual impairment in SD forces dependency on lexical and phonological detail for word processing. Furthermore, patterns of recall, repetition priming, and ultimately word learning are likely to reflect this reduction in semantic support. Under these circumstances, repetition should be influenced by factors unique to lexical processing, such as word frequency (Jescheniak & Levelt, 1994) and phonological processing, such as phonological similarity (Conrad & Hull, 1964). Repetition should be less affected by factors that reflect semantic processing, e.g., imageability (Breedin, Saffran, & Coslett, 1994; Martin & Saffran, 1997).

Models of word processing that invoke interactivity between semantic, lexical, and phonological levels of processing (Foygel & Dell, 2000) provide a useful framework for predicting repetition patterns in SD. Repetition, according to such models, engages phonological, lexical, and semantic representations of speech input in accordance with the characteristics of the stimuli to be repeated. In the case of acquired language impairment, repetition will proceed by activating whatever representations are appropriate to the stimuli and still accessible to the damaged system. Thus, if language impairment involves access to or degradation of semantic representations, repetition of words will no longer be supported by these representations. This lack of support would be manifested in reduction of semantic variables that typically influence repetition accuracy.

Chronic aphasia disrupts access to one or more levels of representation (i.e., semantic, lexical, phonological). Progressive language impairments, on the other hand, lead to a more dynamic erosion of support, beginning with conceptual-semantic representations in SD. As the disease progresses, cortical atrophy spreads from the inferior temporal lobe to medial and superior structures (Snowden et al., 2002). The language impairment associated with this anatomical deterioration progresses from word-finding difficulties, through degraded lexical knowledge, and ultimately to loss of the multimodal concept underlying a word (Grossman & Ash, 2004).

We argue that as conceptual comprehension declines, patients with SD will increasingly rely on systems that continue to support verbal memory (e.g., phonology). If progressive semantic impairment does, indeed, result in an increased dependence on lexical and phonological processes, effects of phonological *dominance* should emerge in word list repetition. These strategies would serve to provide the richest phonological and lexical representations possible in the absence of strong semantic support. Such processing will impact the following variables in specific ways:

- *Imageability.* Adults typically recall high-imageability words more accurately than low-imageability or abstract words (Kroll & Merves, 1986). If this advantage is contingent on accessing a wider range of perceptual features for high-image words (Paivio, Walsh, & Bons, 1994), we expect a reduction of the effect when conceptual knowledge is degraded or inaccessible (Breedin et al., 1994, Reilly, Martin, & Grossman, 2004).
- *Frequency.* In serial recall tasks, typical adults recall more high- than low-frequency words (Watkins & Watkins, 1977), an advantage linked to a lexical level of processing (Jescheniak & Levelt, 1994). Isolated semantic impairment should spare lexical processing if these systems are functionally distinct. We therefore predict that SD patients will show a repetition advantage for high-frequency words until late stages of SD when lexical representations are also affected.
- *Serial position effects.* Accurate recall of initial word list items (i.e., primacy effect) relies heavily on lexical-semantic processing (Martin, Ayala, & Saffran, 2002). As a consequence, primacy effects are especially sensitive to lexical variables such as word

frequency (Watkins & Watkins, 1977) and semantic factors such as word imageability and category membership (Schulman, 1971). In contrast, recall of the most recent items presented (i.e., recency effect) is more sensitive to phonology than lexical-semantic variables (Saffran & Marin, 1975). Neuropsychological investigations of serial recall have revealed findings consistent with these relationships. Whereas patients with phonological deficits typically show some degree of loss of recency in list repetition while maintaining more accurate recall of initial list items (Saffran & Marin, 1975), patients with lexical-semantic impairments (e.g., transcortical sensory aphasia) often show the reverse pattern, with reduced primacy and accurate recall of final words (Martin & Saffran, 1990). We predict that SD patients will show an overall reduction in word span as a consequence of degraded knowledge, but those who show residual lexical and semantic support should continue to recall initial word list items. Patients with more severe top-down impairment (extending through a lexical level) should show more marked reductions in primacy and gradually revert from a lexical-phonological repetition pathway to one of pure phonology. This transition will be evident when patients recall only final words in a sequence (i.e., recency effect).

PARTICIPANTS

Five adults with moderate to advanced semantic dementia participated in this study; all were initially diagnosed by the third author upon presentation to the cognitive neurology clinic at the University of Pennsylvania. As part of a consensus conference reviewing clinical diagnosis, two independent investigators obtained a structured medical history and completed mental state and neurologic assessments for each patient. A differential diagnosis of semantic dementia was based on behavioural criteria that included: decline in naming ability, impaired single word comprehension, fluent speech, preserved episodic memory and personality, and the presence of reading difficulties (i.e., surface dyslexia and dysgraphia) (Grossman & Ash, 2004; Neary et al., 1998). Patients agreed to participate in a longitudinal study and were then followed regularly on a range of measures (see Table 1).

GM is a 67-year-old retired businessman who demonstrates strong insight into his naming difficulties. GM often remarks, ''I used to know that, but now . . .'' A SPECT scan (8/01) revealed reduced activity throughout GM's left temporal lobe involving the temporal pole and temporal neocortex more than the medial temporal lobe structures.

JC is a 73-year-old retired accountant whose speech is fluent but circumlocutory. He pursued speech therapy but soon abandoned it and now works on drill exercises at home using a child's picture dictionary. Despite these efforts, JC remains severely anomic. A structural MRI (2/02) revealed an area of low signal intensity in JC's right anterior temporal lobe.

MH is a 54-year-old retired female financial manager. She currently depends on her husband for assistance with activities of daily living and has recently experienced a rapid decline in comprehension. PET (3/02) revealed reduced activity in the left frontotemporal distribution and left parietal lobe.

BE is a 58-year-old retired chemical engineer. Upon retirement, BE completed several culinary courses and today remains an avid cook and gardener. BE spends his days refinishing the woodwork of his home and is the most independent of the SD participants. SPECT (8/02) revealed moderately decreased profusion of BE's left temporal, parietal, bilateral frontal lobes, and left basal ganglion.

TABLE 1
Basic neuropsychological and demographic data

	Patient					*Controls*†	
Patient	*BE*	*GM*	*JC*	*CB*	*MH*	*Mean*	*SD*
Battery completion date	9/03	10/03	4/03	4/03	9/03	*	*
[a]MMSE (of 30)	25	18	14	28	11	29.11	0.92
Digit Span Forward/Backward	3/3	3/0	4/2	7/3	4/3	*	*
[b]Boston Naming Test (BNT) (of 60)	4	10	12	13	1	55.82	2.63
Low-frequency items (of 20)	0	5	4	5	1	*	*
Medium-frequency items (of 20)	0	4	5	5	0	*	*
High-frequency items (of 20)	4	1	3	3	0	*	*
[c]Pyramids & Palm Trees: Words	49	50	*	42	*	51.2	1.4
Pictures	50	50	43	42	*	*	*
† Word List Memory (3 trials × 10 items)	6	14	3	14	0	see below	
(Trial 3 – Trial 1)	2	3	0	0	0	2.68	1.73
† Total FAS / 60 s	8	11	*	11	*	13.96	3.87
† Fluency Naming (Animals)/120 s	7	8	6	14	0	21.36	4.68

* = Not available or not applicable. [a] Mini Mental State Examination (Folstein et al., 1975). [b] Boston Naming Test norm above for adults 50–59 years of age, norm for 60–69 years = 53.3, norm for 70–79 years = 48.9, (Kaplan, Goodglass, & Weintraub, 1976). [c] Pyramids & Palm Trees test (Howard & Patterson, 1992), † Control data (*N* = 24). Word list learning was measured by three repeated presentations of lists of 10 high-frequency nouns (T_3–T_1).

CB is a 76-year-old retired public-school music teacher whose symptom onset began early in 2000 with difficulties in naming and understanding conversational speech. SPECT (2/02) revealed moderate to severely decreased radiotracer accumulation within the left temporal lobe in its entirety, with extension into the left parietal lobe (see Figure 1). Of note, CB's Mini Mental State Examination score was high (28/30), within range of uncertain cognitive impairment (Folstein, Folstein, & McHugh, 1975). CB's temporal orientation and ability to execute simple multi-step commands is functional, as is typical in semantic dementia (Hodges et al., 1992). However, CB often commits judgement errors in his daily life (e.g., using detergent instead of salt). It has been suggested that the MMSE is insensitive to this combination of symptoms but may be more useful for providing a measure of global cognition (Bowie, Branton, & Holmes, 1999).

We reported normative data from two comparison groups. Table 1 reflects performance of a group of 24 adults recruited through the University of Pennsylvania, matched by age and education level to the patient sample. Controls in Experiment 2 (repetition priming) were recruited from a volunteer pool affiliated with Albert Einstein Hospital, Philadelphia, Pennsylvania. Control participants were non-brain-injured adults who received nominal monetary compensation for their participation, mean age = 63.00 years, *SD* =16.40.

EXPERIMENT 1

Method

We examined repetition of two- and three-word noun lists varied by frequency and imageability. We operationalised high-frequency words as those occurring greater than 25 times per million words and low-frequency words as occurring less than 25 times per million (Kučera & Francis, 1982). High-imageability words have ratings higher than 4.97

Figure 1. SPECT scan illustrating bilateral temporal lobe atrophy of patient CB.

(1–7 scale), and low-imageability words were rated less than 4.97 on the same scale (Paivio, Yuille, & Madigan, 1968). Stimuli were blocked in the following list conditions: (a) high-image, high-frequency; (b) high-image, low-frequency; (c) low-image, high-frequency; and (d) low-image, low-frequency.

Stimuli included 40 randomised word strings, 10 of each frequency and imageability condition, presented aurally at an approximate rate of one word per second. We began testing participants at a two-word length and presented increasing list lengths until less than 50% of the items at a particular list length were repeated correctly in any order. Items were not repeated within the set of lists, and word strings were matched for overall length within one syllable.

Testing was completed via live-voice by a single examiner (Reilly) in a quiet setting in the patients' homes. Responses were recorded and later were phonetically transcribed. Scoring was completed online during the task and verified at a later date using the original audiotape. Responses were scored as either correct or incorrect. Raw totals were then converted to proportions to account for trials we eliminated due to experimenter error or unclear stimuli presentation. In some cases, patients produced phonemic approximations of the target word (e.g., goose → goosh). For these ambiguous cases, an independent rater (a graduate research assistant) judged whether the participant's production matched the target word.

Results

Table 2 summarises repetition accuracies and Pearson chi-square tests of independence by imageability and frequency. All participants showed reduced imageability effects and diminished word spans (three words). However, only one patient (CB) showed the predicted lexicality effect of superior recall of high- over low- frequency words. A second

TABLE 2
Repetition accuracies by serial position and significance tests

		2-Word Span				*3-Word Span*						*Statistic*	
		Serial Position 1		2		*Serial Position* 1		2		3			
		L	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	$\chi^2(1)$	*Sig.*
Image	BE	0	.15	.85	.90	0	.05	0	.05	.85	.70	0	1.00
	CB	.75	.85	.60	.70	.40	.50	.10	.45	.25	.30	1.35	.25
	JC	1.0	.95	.90	1.0	.85	.90	.60	.40	.65	.65	1.86	.17
	GM	.73	.90	.21	.50	.50	.55	0	.25	.35	.50	2.90	.09
	MH	.70	.85	.90	.95	.15	.20	.10	.10	.55	.45	0.04	.84
Freq.	BE	.10	.05	.90	.85	.05	.00	.00	.05	.65	.85	0.68	.41
	CB	.65	.95	.55	.75	.45	.45	.20	.35	.20	.35	3.51	.05
	JC	.95	1.0	1.0	.90	.85	.90	.60	.65	.35	.70	3.07	.07
	GM	.73	.90	.31	.40	.50	.55	.10	.15	.30	.55	1.78	.18
	MH	.60	.95	.90	.95	.20	.15	.10	.10	.45	.55	0.04	.84

Scores are proportion correct by each position. L & H are low and high image and frequency. The χ^2 statistic reflects whether recall was significantly different between low and high image and frequency at the participant's maximum word span length (i.e., three words).

patient (JC) showed nearly a statistically significant advantage for repeating high-frequency words (p = . 07).

Two patterns of serial position effects emerged. Participants MH and BE showed negligible recall of initial items with more accurate repetition of list-final items. The remaining participants were better able to recall initial word list items, i.e., primacy.

Diminished primacy effects observed in the performance of BE and MH suggest primarily phonological contributions to word repetition. Of note, BE and MH also show the most severe anomia on other measures (see Table 1). In contrast, the remaining participants demonstrated intact primacy effects, suggesting a continued benefit from lexical-semantic support.

EXPERIMENT 2: REPETITION PRIMING

Language comprehension entails mapping arbitrary phonological forms to conceptual representations. However, in SD, intact word forms are mapped onto a deteriorating conceptual system (Knott et al., 1997). We predicted that typical learning and priming effects would not be observed in this population. If each repetition trial is based primarily on activation of phonological representations of words, learning of that word sequence will be negatively impacted.

In this experiment, we examined effects of repetition priming on short-term learning of word lists varied by semantic and phonological relatedness. We predicted that without the benefit of conceptual comprehension, SD patients would learn semantically related and unrelated word lists with similar accuracy. Furthermore, if SD patients rely on phonology to support verbal short-term memory, then phonological relatedness may affect repetition in two very different ways. The first possibility would be that phonological similarity among list items would interfere with recall as it does for typical adults (Conrad & Hull, 1964). The second possibility is that in the absence of semantic support, words with similar onsets might form ad hoc phonological categories, with facilitative effects on recall.

Method

Participants heard 10 sequential presentations of three separate word lists via live voice. Each of the three lists was composed of 10 low-frequency nouns (i.e., <50 observations per million words of print; Kučera & Francis, 1982). Stimuli were varied by semantic and phonological relatedness with conditions including semantically related items (i.e., professions); phonologically related items (i.e., words with / d / onsets); and unrelated items. Participants were verbally cued to recall as many words as possible in any order immediately following each list presentation. After presenting the first word list, the same list was presented nine more times in consecutive order. Participants' responses to each were tape recorded. This task was completed in a single 1-hour session. We operationalised short-term learning as showing a significant positive linear trend in recall across repeated trials.

Results

Table 3 summarises participant performance. Age-matched controls (*N*=10) showed rapid word list learning on consecutive trials (i.e., repetition priming). SD participants, however, showed negligible improvement on repeated presentations. On many trials, the SD participants experienced significant distress with this learning paradigm. We abandoned

TABLE 3
Memory for repeated lists of 10 items

	Repeated list number									
List condition	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Semantically related										
BE	.10	.20	.10	.10	.20	.20	.10	.20	.20	.20
CB	.10	.10	.20	.20	.40	.20	.10	.30	.30	.20
JC	0	.20	0	.20	.10	.20	.10	.20	.20	.20
GM	0	.10	0	.10	0	.10	.30	.20	.20	.30
*Control	.49	.71	.77	.79	.83	.91	.90	.91	.94	.91
Phonologically related										
BE	.10	.10	.20	.20	.20	.20	.20	.20	.20	.20
CB	.30	.30	.30	.40	.30	.40	.30	.40	.40	.40
JC	.20	.20	.40	.30	.40	.60	.20	.30	.40	.30
GM	0	.10	.10	.10	.10	.20	.10	.10	.10	.10
Control	.48	.68	.69	.75	.79	.83	.81	.83	.81	.86
Unrelated										
BE	.10	.10	.10	.10	.20	.10	.10	.20	.10	.10
CB	.10	.10	.30	.30	.20	.30	.40	.30	.20	.50
JC	0	.20	.10	.20	.10	.20	.10	.20	.20	.20
GM	.10	.10	.10	.10	.20	.30	.20	.30	.30	.20
Control	.46	.61	.74	.80	.88	.88	.89	.86	.89	.83

Control subjects (*N* = 10) average age = 63.00 years, *SD* = 16.40. Participant MH experienced distress with this task, and we abandoned testing after the third list presentation. Scores represent proportion correct (of 10) on each repeated trial.

testing for MH after the third consecutive trial of no correct responses. Interestingly, the only patient who showed even modest improvement in word list recall was JC, improving in the one list that we predicted he would benefit from least, i.e., phonologically related items.

GENERAL DISCUSSION

We examined recall and short-term word learning via repetition priming in a group of adults with semantic dementia. In the first experiment, none of the participants showed a significant recall advantage for high-imageability words, and only one showed the predicted repetition benefit for high-frequency words. Two patterns of serial position effects emerged in immediate recall. The two patients with the most severe anomia often repeated only the most recent item presented. The remaining three patients showed more typical effects of primacy and recency. Furthermore, none showed significant improvement upon repeated list presentation. We offer the following account of these patterns:

Top down lexical-semantic support for repetition and verbal short-term memory diminishes with the course of semantic dementia. This degradation appears to occur in the following temporal order: semantic → lexical → phonological. As such, individuals with SD would be expected to rely increasingly on bottom-up phonological word processing as semantic and lexical networks deteriorate. Preserved primacy effects in repetition provide evidence of lexical and semantic contributions to word processing. Therefore, it is possible that forgetting of initial word list items is a late stage clinical marker for advanced semantic impairment.

Our results further indicate that repetition priming alone is unlikely to be an effective strategy for reacquisition of forgotten vocabulary in SD. However, we have shown that some SD patients continue to benefit from lexical and phonological support in word list recall. It remains unclear how these preserved abilities may be tapped to ameliorate naming problems whose root cause is degraded conceptual comprehension. One possible approach is to create a small set of highly frequent words with attention to an individual's phonological strengths. Repetition may allow words to become highly frequent and thus more readily available to a degraded semantic system. However, this approach is intuitively limited as an intervention technique unless there is at least some degree of training on the word's underlying conceptual representation.

A second possible intervention for this form of semantic anomia is to avoid the goal of reacquisition of forgotten vocabulary in favour of maintenance of known words. This process might involve training a finite set of personally relevant words through repetition and multi-modal semantic training. Patients might be asked to spend a designated part of their day actively manipulating, naming, and describing the attributes of a small set of people and objects (e.g., odours, visual attributes, functions). Unlike training by a paired-associate approach, as is common in speech-language therapy (e.g., word–picture matching), the advantage of *maintenance* is that patients may experience benefits similar to errorless learning. In addition, such an approach would allow patients and their families to tailor their own set of personally relevant vocabulary rather than an open set of forgotten words.

The greatest potential for maintenance of known vocabulary may be during the onset of SD when individuals appear to benefit most from lexical-semantic support. As such, early differential diagnosis and language assessment for frontotemporal dementia may be crucial for maintaining functional language as conceptual comprehension declines.

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