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Naming in semantic dementia—what matters?

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Abstract—One of the major symptoms of semantic dementia (or progressive fluent aphasia) is profound word-finding difficulties. We present here a cross-sectional study of the factors affecting picture naming in semantic dementia based on data obtained from eight patients, together with a longitudinal analysis of naming in another patient.

Various properties and attributes of the objects were entered into a series of regression analyses in order to predict which items the patients could or could not name. The analyses showed that object familiarity, word frequency and age-of-acquisition predicted naming success for the group and, in most cases, for each individual patient, irrespective of lesion site or overall naming success.

We propose that the pattern of naming in semantic dementia is best described in terms of reduced semantic activation within a cascading/interactive speech production system. We suggest that object familiarity, and possibly word frequency, reflect the inherent robustness of individual semantic representations to the decay process in terms of both quantity and quality of experience. Age-of-acquisition and word frequency (at a phonological–lexical level) predicts naming success, because frequent, early-acquired words are relatively easy to activate even with reduced semantic "input". © 1998 Elsevier Science Ltd. All rights reserved.

Key Words: semantic dementia; progressive fluent aphasia; semantic memory; anomia; speech production.

Introduction

Semantic dementia, or progressive fluent aphasia [26, 41] is a disorder associated with progressive atrophy of the anterior temporal lobes, particularly of the inferior temporal gyrus. The atrophy typically involves the left side [24, 26] although the disease eventually leads to bilateral damage [24].

The progressive loss of temporal structures is associated with an inexorable loss of knowledge about the meanings of words, objects and concepts. The semantic deficit is present when tested in all sensory modalities [26, 41] and is accompanied by a profound anomia. The vast majority of patients manifest features of surface dyslexia (although see [6]). Despite sometimes severe semantic impairment, the patients demonstrate a relative preservation of performance on tests of auditory-verbal short-term memory, non-verbal reasoning, perceptual and spatial skills, have good single-word phonology and syntax, and excellent day-to-day (episodic) memory [26, 41] although recent research has shown relatively poor recall of events that occurred in the distant past [19].

To date, there have been few analyses of the factors which affect the cognitive performance of patients with semantic dementia. In her seminal paper, Warrington [42] demonstrated that the comprehension of her three patients was affected by word frequency. In addition, one patient showed a reverse concreteness effect (better definition of abstract than concrete words). These two effects, frequency and reverse concreteness, have been reported since in two patients with semantic dementia [4, 6] and of frequency alone in two others [12, 25]. Breedin *et al.* [4] found that their patient exhibited a category effect in favour of tools over animals in a synonym judgement task.

The factors that affect picture naming performance in semantic dementia have been investigated in three papers which report significant effects of frequency for a total of four patients [25, 34]. Although Parkin's patient [34] showed relatively better naming of man-made objects than natural kinds, this effect was absent if the confounding factor of familiarity was partialled out.

Frequency effects have been reported in other non-progressive aphasics [9, 29], although the validity of this finding has been questioned [10, 22, 32] because the orig-

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inal reports did not consider the influence of other potentially confounding factors. For example, frequent words tend to be short, early acquired, imageable and conceptually familiar. When naming has been investigated more fully, few aphasic patients have been found to demonstrate a significant, independent effect of frequency on their accuracy [10, 22, 32].

Two studies have compared the factors that affect naming performance for each individual and for the group as a whole [10, 32]. The studies found a high degree of variation between individual aphasic subjects, and little consistency in the comparison between the group and individual subjects, even when the patients were split into fluent and non-fluent types. This lead Nickels and Howard to conclude that "attempting to characterise aphasic naming generally by examining groups of aphasics is meaningless as there is no 'average aphasic'" [32].

Category-specific disorders have been reported for non-progressive aphasic patients [e.g. 15, 44], although the validity of this finding has again been challenged [14]. Funnell and Sheridan [14] re-analysed the naming performance of their patient [44] and found that the animate kinds were less familiar than the man-made objects, and when this factor was partialled out no category effect remained. It would seem fair to say, however, that category-specific deficits can be observed even when confounding factors, such as familiarity, have been taken into account [e.g. 15]. Funnell, herself, on re-testing patient JBR with items drawn from matched sets, found that naming of animate kinds was worse than inanimate objects [13].

There are two papers in the literature which have attempted to investigate which factors affect naming in individual cases of semantic dementia. Barbarotto, Capitani, Spinnler and Trivelli [1] have recently reported data collected from patient MF. With a series of logistic regression analyses, Barbarotto *et al.* demonstrated that MF's naming and comprehension was significantly affected by frequency, familiarity and category (better performance for non-living than living categories). It should be noted that the dissociation between living and non-living was a classical one — MF's performance for artefacts was within the normal range. Unfortunately Barbarotto *et al.* did not include age-of-acquisition within their analyses.

Hirsh and Funnell reported data for patient EP [23]. There were significant simple correlations (measured across 76 items) between EP's naming and (log) word frequency, familiarity and rated age-of-acquisition (AoA). When these factors were included in a simultaneous linear regression only familiarity was found to be a significant independent predictor of naming accuracy, while word frequency approached significance ($P = 0.06$). Hirsh and Funnell [23] also reported a similar analysis for a patient with presumed Alzheimer's disease ("Mary") whose comprehension was initially spared while her naming gradually deteriorated. They found that the same three variables correlated with Mary's naming but only AoA reached significance in the regression analysis (which included 82 items). This apparent dissociation was interpreted as favouring a modular effect of each variable, with a familiarity effect occurring when an impairment occurs at the semantic level and an AoA effect when the damage is at a lexical-phonological level.

There are a number of reasons why this conclusion may be premature. Mary might have had a slight semantic impairment early in her deterioration (her comprehension was only assessed with one word-picture matching test) which could have contributed to her naming difficulties. If familiarity and AoA effects are located in the semantic system and lexical-phonological level, respectively, it is possible that, for example, AoA might influence the naming performance of a patient with a selective semantic impairment. If speech production is viewed as an interactive or cascading process [8, 37] then early acquired words may be easier to activate than late acquired words given an impoverished semantic input. Similarly, a post-semantic impairment may be more readily overcome by the extra "strength" or "boost" of semantic input given by highly familiar concepts. It is also possible that Hirsh and Funnell's analysis revealed only one significant factor for each patient because relatively few items were included.

We report below the results of an investigation into the factors affecting naming in nine patients with semantic dementia across the same set of 132 pictures. The analyses were designed to address the following questions:

(1) What factors affect naming in semantic dementia?
(2) Is performance consistent between individual patients?
(3) Do the factors that affect performance depend on the severity of anomia or the laterality of atrophy (left vs right temporal lobe)?
(4) Are the results found in a cross-sectional analysis repeated in a longitudinal assessment of one patient (JL)?

Method

Subjects

Nine patients with semantic dementia were included in this study. Some have been described in previous papers [16, 18, 20, 25–27, 35]. Structural imaging (3D volumetric MRI acquisition) showed focal temporal lobe atrophy in all nine patients. The degree and relative laterality of the temporal lobe atrophy was assessed with T1-weighted coronal images by an experienced behavioural neurologist (JRH), and the results are coded in Table 1. This table also shows the performance of the nine patients (and a group of 24 age-matched control subjects, see [25] on a battery of tests of neuropsychological function. On tests of visuo-perceptual and non-verbal problem-solving abilities, the patients that were tested showed relatively preserved performance. DG showed a mild impairment when asked to copy the Rey Complex Figure [33] and GC was slightly outside the normal range on the Benton Face Recognition Test. On the two language tests shown, the patients, apart from GC, JH, MS

Table 1. A summary of the nine patients' performance (and 24 age-matched control subjects; see [25]) on a battery of neuropsychological tests

Tests	GCB	GC	BM	PS	FM	DG	JH	MS	JL	Controls (*n* = 24)
Atrophy (from MRI scan)	L > R	Left	R > L	L > R	Left	R > L	L > R	L > R	R > L	
Visuo-perceptual and non-verbal problem solving abilities										
Copy of the Rey Figure (36)	36	36	36	32	31	25.5	31	36	34	34.0 (2.9)
Benton Face Recognition Test (54)	NT	38	45	48	47	NT	NT	NT	50	41–54*
Raven's Coloured Matrices (36)	NT	32	31	36	29	NT	29	33	29	25 (50%ile)*
Language										
Test for the Reception of Grammar (80)	80	72	75	74	76	62	67	71	76	78.8 (1.8)
Letter fluency (F, A and S)	31	14	18	12	3	26	12	NT	10	44.6 (10.2)
Episodic/Working Memory										
Delayed copy of the Rey Figure (36)	22	18	16	3.5	10	3.5	12	10	16	15.2 (7.4)
Recognition Memory Test										
Faces (50)	37	30	24	35	43	27	NT	36	22	44 (3.8)
Words (50)	38	32	38	NT	39	28	NT	30	32	47 (2.8)
Digit span—forwards	6	7	8	5	6	5	7	NT	7	6.8 (1.0)
Digit span—backwards	6	5	7	4	5	3	4	NT	5	4.7 (1.2)
Semantic memory										
Naming (48)	33	NT	11	5	9	10	6	0	17	43.6 (2.3)
Word-picture matching (48)	43	23	28	23	44	23	26	15	31	47.4 (1.1)
Pyramids and Palm Trees Test (52)	43	47	30	42	42	21	33	NT	36	51.2 (1.4)
Category fluency (8 categories)	65	12	37	11	15	39	11	3	36	113.7 (19.4)

The data were taken from the same time period as patients' picture naming results. For the control subjects, mean scores are given with standard deviations in parentheses. A * represents original test norms for age-matched control subjects. References for the test as follows: Rey Figure [33]; Benton Face Recognition Test [2]; Raven's Coloured Matrices [38]; Test for the Reception of Grammar (TROG, [3]); Recognition Memory Test [43]; Semantic Battery [25, 26].

and DG, were not impaired on the Test for the Reception of Grammar [3], which measures syntactic comprehension. Letter fluency was impaired in seven out of eight patients tested: GCB produced 31 words which was not significantly different from the control subjects (mean = 44.6 ± 10.2). Working memory, as measured using forward and backward digit span, was intact in all nine patients. Tests of episodic memory revealed some degree of impairment in almost all patients.* On the two versions of the Recognition Memory Test [43] all the patients were impaired, although FM and GCB showed normal recognition of faces (43 and 37 (control mean = 44 ± 3.8) respectively), but not words (39 and 38 (control mean = 47 ± 2.8) respectively). When asked to reproduce the Rey Complex Figure after a delay of 45 min, almost all patients, apart from PS and DG, were able to produce a relatively good drawing. It should be noted, however, that it was difficult to determine whether a patient was impaired on this test because of highly variable performance from the controls subjects (mean = 15.2 ± 7.4). On tests of semantic memory, all nine patients were anomic, impaired on spoken word-picture matching and the Pyramid and Palm Trees Test [28] and had great difficulty producing exemplars on category fluency (4 living and 4 non-living categories). GCB showed the best performance on this test producing 65 examples over the 8 categories, although this performance was still well below the controls (mean = 113.7 ± 19.4).

Two patients are of added interest. Patient JL was assessed longitudinally over a 2-year period. His performance on a number of tests, including his picture naming of the Snodgrass and Vanderwart drawings, was reported by Hodges *et al.* [25]. JL was given the Snodgrass and Vanderwart picture corpus to name on four successive occasions. In this paper, we investigate the factors that affected his naming accuracy for each administration, and determine whether the influence of factors changed over time. Patient FM presented in April 1991 with a history of profound word-finding difficulties. At this time, she had a mild semantic memory impairment and it was thought that she was in the early stages of semantic dementia [26]. Over time, however, it became clear that while FM's performance on tests of word production was declining, she was not showing the characteristic deterioration on tests of semantic memory seen in semantic dementia (see [16]). More recently, approximately five years after FM first presented, she has started to show impairments to semantic memory and thus fits the characteristics of the semantic dementia syndrome. The data included in this analysis were collected during the period in which FM's comprehension was relatively stable (albeit mildly impaired) but her naming was gradually declining (September 1991).

The factors affecting picture naming performance were analysed for each patient (using simultaneous logistic regression) and the group as a whole (the score for each item across the nine patients† analysed by simultaneous linear regression).

* The integrity of new learning in semantic dementia is currently a controversial topic. While some studies have shown normal pictorially-based recognition memory [17], patients are typically impaired on verbal tests of new learning, such as Logical Memory [5; see Table 1: 45] and the words component of the Recognition Memory Test [43]. We have suggested [see 17], that relatively good performance on non-verbal tests of episodic memory may reflect the preservation of higher-order perceptual inputs to the hippocampus, which support non-verbal but not verbal learning.

† JL's naming data from September (1991) was included within the group analysis.

Items and variables

Each patient was asked to name the items from the Snodgrass and Vanderwart picture corpus (1980). The patients were under no time pressure when performing the task. From this database, we selected the 132 items with available values for all eight variables described below:

(1) *Age-of-acquisition* (*AoA*): Morrison, Chappell and Ellis [31] presented objective age-of-acquisition data derived from 300 children aged 2:6 to 10:11 naming 311 drawings, including the drawings used in the present study. There were 20 children in each of the 6-month age bands, 2:6–3:0 to 7:6–7:11, and a further 20 children in each of the 12-month age bands 8:0–8:11, 9:0–9:11 and 10:0–10:11. The age of acquisition of each item was taken to be the age of the youngest group in which 75% or more of the children could name that picture either unassisted or with the aid of an initial phoneme cue, or an extrapolated value was derived for a small number of items which the youngest group could already name (see [31] for details).
(2) *Category*: The items were split into man-made and natural kinds (man-made objects were given a value of 1, natural kinds 0).
(3) *Imageability*: This scale provides a measure (taken from the Oxford Psycholinguistic database [7] of the ease with which participants can summon up a mental image of an object when given its written name. The scale runs from 1 (with great difficulty) to 7 (very easily).
(4) *Name agreement*: The percentage of subjects which produce the target label for each picture. The value was drawn from Morrison *et al.* [31].
(5) *Object familiarity*: Morrison *et al.* [31] asked 20 subjects to rate "the degree to which you come into contact with or think about the concept" on a scale from 1 (unfamiliar) to 5 (very familiar).
(6) *Phoneme length*: The number of phonemes in the picture's name.
(7) *Spoken frequency*: The Celex Lexical Database [5] provides an up-to-date count of spoken word frequency based on samples of British English. The count per million was logarithmically transformed.
(8) *Visual complexity*: This is a rated measure (drawn from reference [31]) of the visual complexity of the target picture. Twenty subjects were asked to rate each item on a 1 to 7 scale where 7 denotes the most complex picture.

The mean, standard deviation and range for each factor is shown in Table 2. The intercorrelations between the predictor variables are shown in Table 3.

Table 2. Mean, standard deviation and range of each predictor variable

Variable	Mean	SD	Min.	Max.
Age-of-acquisition	44.5	23.3	22.1	126.5
Category[a]	0.59	0.49	0	1
Imageability	6.00	0.27	4.94	6.45
Name agreement (%)	95.1	7.3	59	100
Object familiarity	3.28	0.99	1.64	4.86
Phoneme length	3.95	1.46	1	10
Spoken frequency (log)	0.88	0.62	0	2.72
Visual complexity	2.63	0.78	1	4.60

[a] Natural vs artefacts (coded 0 and 1, respectively).

Results

Cross-sectional analysis

The simple correlations between naming accuracy and each variable are shown in Table 4. For the group as a whole, the correlations between accuracy and AoA, object familiarity, phoneme length (in favour of shorter words), spoken frequency and visual complexity were all significant. AoA, object familiarity and spoken frequency correlated significantly with each individual patient's naming data. The effect of length was significant for all but three patients (BM, FM and MS). Visual complexity and category were significant for one patient (GC) and name agreement for two others (PS and FM). Imageability was not correlated with any of the patients' performances. Simple correlations between naming accuracy and individual factors, however, should be treated with caution given the degree of intercorrelations between the predictor variables (see Table 3). Regression analyses were used to test for the independent effect of each variable on group and individual naming accuracy.

The results of the various regression analyses and the overall naming accuracy for each patient are shown in Table 5. All regression equations produced were significant (linear regression for the group analysis: $F = 23.9$, $P < 0.001$: logistic regressions for the individual analyses, χ^2 between 41.1 and 68.1, $P < 0.0001$) showing that the variables taken together were capable of predicting success or failure for the individual patients and for the group as a whole. A P-value is reported in Table 5 if the independent contribution of the variable to the regression equation was significant or approached significance.

Naming accuracy for the group of semantic dementia patients was significantly affected by AoA, object familiarity and spoken frequency ($t = -2.04$, $P = 0.04$; $t = 4.49$, $P < 0.001$; $t = 3.43$, $P = 0.001$, respectively). No other variable approached significance. There was a striking degree of concordance between the individual and group analyses, and the results for each patient did not seem to vary with the degree of anomia or laterality of atrophy. All eight patients demonstrated a significant (or near-significant) effect of spoken frequency (Wald between 2.92 and 8.34, P between 0.08 and 0.004); 7/8 exhibited a significant effect of object familiarity (Wald between 3.86 and 16.6, P between 0.05 and 0.001); and, 6/8 showed a significant or near-significant effect of AoA (Wald between 3.58 and 8.89, P between 0.06 and 0.003). There were few individual subjects who exhibited significant effects of any other variable. The exceptions were as follows. One patient's naming (GC) was significantly effected by category (better naming of artefacts than natural kinds: Wald = 4.71, $P = 0.03$) while the same effect approached significance in one other patient (DG: Wald = 2.96, $P = 0.09$). Patient FM demonstrated a significant effect of visual complexity (Wald = 4.46, $P = 0.03$). Length exerted a significant independent effect

Table 3. Intercorrelations between the predictor variables

No.	Variable	2	3	4	5	6	7	8
1	Age-of-acquisition	+0.18*	−0.18*	−0.21*	−0.43**	+0.23**	−0.40**	+0.09
2	Category[a]		−0.36**	+0.12	+0.15	+0.02	+0.13	−0.11
3	Imageability			−0.02	−0.08	+0.11	+0.03	+0.11
4	Name agreement (%)				+0.25**	+0.04	+0.12	−0.10
5	Object familiarity					−0.29**	+0.51**	−0.42**
6	Phoneme length						−0.40**	+0.10
7	Spoken frequency (log)							−0.17
8	Visual complexity							

[a] Natural vs artefacts (coded 0 and 1, respectively).
* $P < 0.05$.
** $P < 0.01$.

Table 4. Simple correlations between each patient's naming accuracy and the predictor variables

Variable	GCB	GC	BM	PS	FM	DG	JH	MS	Group
Age of acquisition	−0.48**	−0.19*	−0.31**	−0.40**	−0.33**	−0.39**	−0.29**	−0.30**	−0.50**
Category[a]	−0.04	+0.22*	+0.13	−0.03	+0.09	+0.14	−0.02	+0.07	+0.10
Imageability	+0.01	−0.09	−0.07	+0.08	−0.07	+0.01	+0.14	+0.08	+0.01
Name agreement (%)	+0.06	−0.01	+0.14	+0.20*	+0.19*	+0.13	+0.17	+0.11	+0.17
Object familiarity	+0.44**	+0.35**	+0.51**	+0.60**	+0.56**	+0.44**	+0.45**	+0.44**	+0.71**
Phoneme length	−0.29**	−0.30**	−0.05	−0.26**	−0.16	−0.14**	−0.20*	−0.10	−0.31**
Spoken frequency (log)	+0.43**	+0.44**	+0.36**	+0.44**	+0.42**	+0.42**	+0.46**	+0.44**	+0.62**
Visual complexity	−0.17	−0.18*	−0.14	−0.17	−0.06	−0.09	−0.06	−0.08	−0.23**

[a] Natural vs artefacts (coded 0 and 1, respectively).
* $P < 0.05$.
** $P < 0.01$.

Table 5. Results of the regression analysis for each patient and the whole patient group

Variable	GCB	GC	BM	PS	FM	DG	JH	MS	Group
Age-of-acquisition	0.01	n.s.	0.06	0.05	0.06	0.003	n.s.	0.05	0.04
Category[a]	n.s.	0.03[c]	n.s.	n.s.	n.s.	0.09[c]	n.s.	n.s.	n.s.
Imageability	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Name agreement (%)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Object familiarity	0.05	n.s.	<0.001	<0.001	<0.001	0.05	0.003	0.004	<0.001
Phoneme length	n.s.	n.s.	0.02[b]	n.s.	n.s.	n.s.	n.s.	0.05[b]	n.s.
Spoken frequency (log)	0.03	0.004	0.06	0.08	0.02	0.07	0.005	0.006	<0.001
Visual complexity	n.s.	n.s.	n.s.	n.s.	0.03	n.s.	n.s.	n.s.	n.s.
Percentage correct	76	59	41	37	33	28	27	18	41

[a] Natural vs artefacts (coded 0 and 1, respectively).
[b] Positive effect: i.e., better naming of longer words.
[c] Positive effect: i.e., better naming of artefacts than natural kinds.
n.s.—$P > 0.10$

Table 6. Simple correlations between JL's naming accuracy and the predictor variables

Variable	JL (Sept '91)	JL (Mar '92)	JL (Sept '92)	JL (Mar '93)	Combined Analysis
Age-of-acquisition	−0.42**	−0.39**	−0.36**	−0.24**	−0.45**
Category[a]	+0.04	+0.10	+0.11	−0.01	+0.08
Imageability	+0.15	+0.04	+0.04	+0.10	−0.10
Name agreement (%)	+0.12	+0.13	+0.02	+0.11	+0.12
Object familiarity	+0.56**	+0.57**	+0.44**	+0.34**	+0.61**
Phoneme length	−0.31**	−0.32**	−0.27**	−0.21*	−0.35**
Spoken frequency (log)	+0.47**	+0.55**	+0.53**	+0.33**	+0.60**
Visual complexity	−0.27**	−0.20*	−0.11	−0.11	−0.22*

[a] Natural vs artefacts (coded 0 and 1, respectively).
* $P < 0.05$.
** $P < 0.01$.

for BM (Wald = 5.24, $P = 0.02$) and MS (Wald = 3.73, $P = 0.05$), where each patient was more likely to name pictures with longer names.*

The consistency of the effects of object familiarity, spoken frequency and AoA on each of the nine patients' naming accuracy was assessed using one final logistic regression analysis. This included an additional predictor variable, *patient*, plus interactive terms between patient and object familiarity, spoken frequency and AoA. In this combined analysis, AoA (Wald = 9.29, $P = 0.002$), object familiarity (Wald = 4.50, $P = 0.03$) and spoken frequency (Wald = 6.72, $P = 0.001$) were the only factors to reach significance. There was also one significant interaction between AoA and patient GC (Wald = 6.62, $P = 0.01$). Given that there are 24 potential interactions, it is possible that this one significant interaction arose by chance (a type 1 error). Thus we cannot reject the null hypothesis that there was a similar effect of the three identified variables across each patient—i.e., all nine patients' naming was affected by AoA, object familiarity and spoken frequency.

Longitudinal analysis (patient JL)

JL's naming performance had been assessed four times over a 2-year period. Simple correlations between the eight variables and JL's accuracy at each point during the longitudinal study and for a combined analysis (JL's scores summed across each item) are shown in Table 6. At each administration, his accuracy was significantly correlated with AoA, object familiarity, phoneme length (in favour of short words) and spoken frequency. For the first two administrations, JL's performance correlated with visual complexity (better naming of simple than complex items). All five factors significantly correlated with JL's combined score.

The independent effect of each variable was assessed using a series of logistic regression analyses, and a linear regression for the combined score. The results are shown in Table 7. The regression equations were significant for each administration (χ^2 between 26.3 and 74.7, $P < 0.001$) and for the combined score ($F = 16.7$, $P < 0.001$). Despite a large drop in naming accuracy over time (from 52% to 22%), the analyses of JL's naming were very consistent. AoA and object familiarity predicted naming accuracy for the first three administrations (AoA: Wald between 4.04 and 6.89, P between 0.04 and 0.009; object familiarity: Wald between 4.97 and 12.04, P between 0.03 and 0.001). Spoken frequency also predicted accuracy, although it was only statistically significant in March 1992 (Wald = 8.91, $P = 0.003$) and September 1992 (Wald = 11.20, $P = 0.001$). Imageability was found to affect performance in the first administration only (September 1991: Wald = 5.49, $P = 0.02$). By March 1993, no variables predicted naming success although this was probable due to the very small number of items correctly named by JL at this stage in his progressive illness (11%). A linear regression on JL's combined score for each item across the four sessions revealed significant effects of AoA ($t = -1.91$, $P = 0.05$), object familiarity ($t = 4.40$, $P < 0.001$) and spoken frequency ($t = 3.65$, $P < 0.001$). No other variable reached significance.

Discussion

We have presented an analysis of the factors that affect picture naming in nine patients with semantic dementia. All the patients, independent of their severity of anomia or laterality of atrophy, exhibited significant effects of object familiarity (log), spoken frequency and objective

* Most patients exhibited a significant correlation between accuracy and length in favour of short words (see Table 4). It is possible that this was due to the effect of other confounding factors: frequent, familiar, early-acquired words tend to be short. For MS and BM, the simple correlation was not significant, presumably because the reverse length effect was "masked" by the influence of the other intercorrelated variables whose predominant effect works in the opposite direction. This result highlights the danger of drawing firm conclusions about both significant and non-significant simple correlations.

Table 7. Results of the regression analysis for JL at each stage during the longitudinal study and for his combined score

Variable	JL (Sept '91)	JL (Mar '92)	JL (Sept '92)	JL (Mar '93)	Combined Analysis
Age-of-acquisition	0.04	0.03	0.009	n.s.	0.05
Category[a]	n.s.	n.s	n.s.	n.s.	n.s.
Imageability	0.02[b]	n.s.	n.s.	n.s.	0.08[b]
Name agreement (%)	n.s.	n.s.	0.06	n.s.	n.s.
Object familiarity	0.005	0.001	0.03	n.s.	<0.001
Phoneme length	n.s.	n.s.	n.s.	n.s.	n.s.
Spoken frequency (log)	0.09	0.003	0.001	n.s.	<0.001
Visual complexity	n.s.	n.s.	n.s.	n.s.	n.s.
Percentage correct	52	39	22	11	35

[a] Natural vs artefacts (coded 0 and 1, respectively).
[b] Positive effect (better naming of imageable items).
n.s.—$P > 0.10$.

age-of-acquisition (AoA). This was found both in a cross-sectional analysis of eight patients and in four stages of a longitudinal study of another patient.

The high degree of consistency between patients and the close relationship between group and individual analyses stands in contrast to the results of identical investigations of non-progressive aphasics [10, 32]. As noted in the Introduction, these studies found a great deal of variation between patients and little correspondence between group and individual analyses. This encouraged the conclusion, drawn by Nickels and Howard [32], that group analyses are very limited as there is no "average aphasic". From our study, it would appear that there is very much an "average" semantic dementia profile despite different degrees and patterns of temporal lobe damage.

Although these patients have a central semantic impairment there was little evidence that their resultant anomia was any greater for animate than inanimate categories. Only one of the nine patients' naming (patient GC; see Table 5) was significantly better for artefacts than natural kinds when the other seven factors were taken into account. It would seem from our study that category-specific naming deficits are generally absent from or, if present, are hard to measure in semantic dementia. Comprehension-based tests of semantic knowledge may, however, reveal significantly larger category-specific effects in patients with semantic dementia.

The regression analyses reported here partially replicate those found by Hirsh and Funnell [23] for one patient with semantic dementia (EP). As noted in the Introduction, the authors found significant raw correlations between naming and the three key factors identified in this study (AoA, object familiarity and spoken frequency) but when these were entered into a simultaneous regression, only familiarity was found to be significant. Hirsh and Funnell interpreted the null effect of AoA in EP as support for their hypothesis that this variable only affects performance when the lexical-phonological level is damaged or is precipitously hard to activate. Our current study is contradictory to this interpretation: if the AoA effect is located at the lexico-phonological level, why does AoA influence naming accuracy in our semantic dementia patients? One possible explanation is that these patients have an additional post-semantic impairment (e.g., a loss of communication between semantics and phonology) which exacerbates their anomia. If this hypothesis is correct then we should have expected FM (the patient who had only a mild semantic impairment, yet was profoundly anomic, see reference [16]) to exhibit a strong effect of AoA and not familiarity (like Hirsh and Funnell's patient, "Mary"). It is clear from Table 5, however, that FM was like the other semantic dementia patients, affected predominantly by object familiarity, as well as AoA and spoken frequency. One alternative reason for the lack of AoA and frequency effects in Hirsh and Funnell's patient EP could be that the analysis had sufficient statistical power ($n = 72$ items) to resolve only the strongest factor (familiarity). The regression analyses reported here contained nearly twice as many items ($n = 132$) and consequently had greater power. It is possible that an AoA effect might have been resolved for all the patients in our group if we had been able to include a greater number of items in the analysis.

We believe that our results are best interpreted within an interactive or cascading approach to speech production [8, 37], rather than the strictly modular system adopted by Hirsh and Funnell [23]. One important difference is that an interactive or cascading model predicts the effect of AoA in patients with semantic impairment, which a modular system does not. The rated familiarity of each object probably reflects the strength of the stored knowledge about that item (see below). Age-of-acquisition (and, perhaps, spoken word frequency) reflects the ease with which a lexical-phonological representation can be activated. Although these variables may be located within separate sub-systems, their effects may be present even if damage occurs at only one of the levels. In semantic dementia, for example, the primary impairment is to the semantic system itself. Familiarity will predict success because the most familiar items have the greatest resistance to damage. In turn, frequent, early-acquired words are more likely to be activated by the remaining semantic input. Thus, these patients typically exhibit effects of all three variables on their naming performance.*

The results of this study reinforce the importance of familiarity/frequency in semantic dementia which has been highlighted in previous reports, both for naming [20, 25, 34] and comprehension [4, 6, 12, 20, 25, 42]. The powerful and consistent familiarity effect found in semantic dementia may be underpinned by two potential factors: the effects of continued experience and the premorbid properties of the semantic system.

It has been argued that continued day-to-day experience of man-made objects and natural kinds might help to maintain the integrity of patients' conceptual knowledge for the specific exemplars involved [39, 40]. If this hypothesis were correct then experience-driven maintenance would be most effective for the familiar concepts. Graham, Lambon Ralph and Hodges [21], however, found little evidence to support this hypothesis. Two patients with semantic dementia were tested on their semantic knowledge of golf and bowls (sports they played regularly, 4–5 times a week). Although the two patients were able to recall recent episodes relating to their sport, their semantic knowledge of golf and bowls was as poor as that of other sports (which were not currently experienced). Graham *et al.*'s results suggest that autobiographical experience (i.e., familiarity) does not help to maintain pre-existent conceptual knowledge in semantic dementia.

It seems more likely that the familiarity effect observed in our nine patients reflects the architecture and organisation of the semantic system. The most familiar items will have the "strongest" semantic representations, which will have the highest probability of preservation following brain injury. The relative strength of a concept may be captured by two closely related factors—"concept frequency", the number of times an object is encountered, and "concept quality", the amount of knowledge about an item. Concepts that are encountered the most often may be more resistant to the gradual degradation of semantic memory because frequent experience of an item will lead to a relatively stable representation. An analogous process can be seen, for example, in connectionist models of reading [36]. After a word has been presented frequently to the model during the training phase, it becomes relatively robust to the effects of simulated damage (see simulation 4, [36]).

Concept "quality" refers to the richness of the underlying semantic representation. This quality could be reflected in detailed sensory information, such as shape, size, texture, sounds, smell, together with knowledge about function and "encyclopaedic" facts, such as where an item is located, etc. Concept quality will be closely linked to concept frequency in as much as our ability to build up a multi-sensory, multi-faceted representation will be dependent upon the number of opportunities we have to encounter the object or its name.

Familiarity, as a combination of concept frequency and quality, can be captured within a model of semantic memory that contains a distributed network of features or attributes [11, 30]. In these models, individual concepts are represented as a collection of attributes which when taken as a whole, uniquely identify an exemplar and differentiate it from all other concepts. In this framework, concept quality could be reflected in the number of features that constitute the item. The most familiar items will have greater "quality" because they are represented by a larger number of semantic features. Concept frequency will not only influence the number of attributes used to form a representation (we have already noted the likelihood that concept quality is highly-reliant on the number of times an object or animal is encountered) but may be encoded directly within the model as higher connection weights or strengths between the features. The number of attributes, and the connection strength, will determine the behaviour of the model as it is subjected to simulated impairment. Damage will have much less impact on a concept made up from many individual features than if it is reliant on a small number of underlying attributes. In addition, intact features will be more likely to activate impoverished or "noisy" aspects of a target concept if the connection strength is high. This will tend to occur because the correctly activated attributes will propagate activation to the other features that make up the full concept and may also assist by inhibiting erroneously activated features. By a combination of attribute number and connection strength, a distributed model of semantic memory would tend to exhibit the strong and reliable effects of familiarity demonstrated by patients with semantic dementia.

* Although we have argued for a non-modular approach to the effects of variables placed in different positions within the speech production system, it seems unlikely that the strength of each effect will be independent of the locus of impairment. Plaut and Shallice [37] found that their model of deep dyslexia produced visual and semantic errors irrespective of the site of damage, but the relative proportions of each did change: semantic errors were most prominent when the lesion was placed near the semantic system, while the number of visual errors increased when the impairment occurred at the orthographic end of the model. It is possible that the influence of each variable will also vary with the locus of impairment: familiarity will be most often associated with semantic impairment and AoA with a more lexical-phonological locus.

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