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Lexical retrieval and semantic knowledge in patients with left inferior temporal lobe lesions

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Abstract

Background—It has been proposed that anomia following left inferior temporal lobe lesions may have two different underlying mechanisms with distinct neural substrates. Specifically, naming impairment following damage to more posterior regions (BA 37) has been considered to result from a disconnection between preserved semantic knowledge and phonological word forms (pure anomia), whereas anomia following damage to anterior temporal regions (BAs 38, 20/21) has been attributed to the degradation of semantic representations (semantic anomia). However, the integrity of semantic knowledge in patients with pure anomia has not been demonstrated convincingly, nor were lesions in these cases necessarily confined to BA 37. Furthermore, evidence of semantic anomia often comes from individuals with bilateral temporal lobe damage, so it is unclear whether unilateral temporal lobe lesions are sufficient to produce significant semantic impairment.

Aims—The main goals of this study were to determine whether anomia following unilateral left inferior temporal lobe damage reflected a loss of semantic knowledge or a post-semantic deficit in lexical retrieval and to identify the neuroanatomical correlates of the naming impairment.

Methods & Procedures—Eight individuals who underwent left anterior temporal lobectomy (L ATL) and eight individuals who sustained left posterior cerebral artery strokes (L PCA) completed a battery of language measures that assessed lexical retrieval and semantic processing, and 16 age- and education-matched controls also completed this battery. High-resolution structural brain scans were collected to conduct lesion analyses.

Outcomes & Results—Performance of L ATL and L PCA patients was strikingly similar, with both groups demonstrating naming performance ranging from moderately impaired to unimpaired. Anomia in both groups occurred in the context of mild deficits to semantic knowledge, which

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manifested primarily as greater difficulty in naming living things than nonliving things and greater difficulty in processing visual/perceptual as opposed to functional/associative semantic attributes. Lesion analyses indicated that both patient groups sustained damage to anterior inferior temporal lobe regions implicated in semantic processing.

Conclusions—These results contribute to a better understanding of the cognitive mechanism of naming impairment in patients with temporal lobe damage and support the notion that pure anomia and semantic anomia represent two endpoints along a continuum of semantic impairment. Unilateral left temporal lobe lesions in our patients resulted in relatively mild semantic deficits that were apparent primarily in lexical production tasks, whereas severe semantic impairment likely requires bilateral temporal lobe damage.

There is growing evidence that extrasylvian regions of the left temporal lobe play an important role in semantically guided lexical retrieval. For instance, functional neuroimaging studies of neurologically intact participants have demonstrated activation in left posterior inferior temporal cortex (Brodmann Area 37) during picture-naming and verbal fluency tasks (Freidman et al., 1998; Moore & Price, 1999; Mummery, Patterson, Hodges, & Wise, 1996; Murtha, Chertkow, Beauregard, & Evans, 1999; Price, Moore, Humphreys, Frackowiak, & Friston, 1996). Activation in this region is most often attributed to processes important for accessing phonological word forms from semantic input (Binder et al., 1997; Damasio, Grabowski, Tranel, Hichwa, & Damasio 1996). In contrast, activation in left anterior temporal cortex (BAs 38, 20/21, 35/36) has been implicated in amodal semantic processing (Binder & Price, 2001; Bright, Moss, & Tyler, 2004; D'Esposito et al., 1997; Moore & Price, 1999; Vandenberghe, Price, Wise, Josephs, & Frackowiak, 1996).

Neuropsychological studies with lesion analysis support the notion that the left inferior temporal lobe is critical for semantically guided lexical retrieval, and further suggest that there is some variability in the nature of the naming impairment as a function of lesion location (Benson, 1979; Damasio et al., 1996; De Renzi, Zambolin, & Crisi, 1987). This variability appears to parallel the regional differences documented in neuroimaging studies. Specifically, case studies documenting lesions to left posterior inferior temporal cortex (BA 37) provide evidence of anomia with preserved semantic knowledge (Damasio et al., 1996; Foundas, Daniels, & Vasterling, 1998; Raymer et al., 1997). Typically, naming errors produced by these individuals are semantically appropriate circumlocutions, demonstrating relatively intact conceptual knowledge as well as preserved phonological abilities. This type of naming impairment, known as “pure anomia”, has been described as reflecting a disconnection between intact semantic knowledge and phonological word forms (Benson, 1979, 1988; Damasio et al., 1996; Foundas et al., 1998; Raymer et al., 1997), an assertion that is supported by evidence that word retrieval can be facilitated by phonemic cueing. Naming impairments have also been documented following damage to more anterior (BAs 38, 20/21) and medial (BAs 28/34, 35/36) temporal lobe regions resulting from a variety of lesion aetiologies, including left anterior temporal lobectomy (Bell et al., 2001; Glosser & D'Onofrio, 2001), herpes encephalitis (Moss, Rodd, Stamatakis, Bright, & Tyler, 2005; Pietrini, Nertempi, Vaglia, Revello, & Pinna, 1988; Schmolck, Kensinger, Corkin, & Squire, 2002; Tyler et al., 2004; Warrington & Shallice, 1984), and semantic dementia (Davies, Graham, Xuereb, Williams, & Hodges, 2004; Hodges & Patterson, 1996; Hodges, Patterson, Oxbury, & Funnell, 1992a; Lambon Ralph, McClelland, Patterson, Galton, & Hodges, 2001; Mummery et al., 1999; Mummery et al., 2000). In contrast to pure anomia, the pathogenesis of the word retrieval deficit in patients with more anterior left temporal lesions appears to involve degradation of semantic knowledge, manifesting in a high proportion of semantic naming errors (e.g., beaver: *chipmunk*) and ambiguous or inappropriate circumlocutions. Typically, this “semantic anomia” occurs in conjunction with deficits of single word comprehension.

It should be noted, however, that the most striking examples of semantic anomia come from clinical populations that typically present with more diffuse brain injury (e.g., herpes encephalitis, semantic dementia), and that most of these patients had evidence of bilateral temporal lobe involvement. Therefore, it is not entirely clear whether focal damage confined to left inferior temporal cortex is sufficient to produce semantic anomia. In fact, in a previous study of patients with unilateral temporal lobe damage due to posterior cerebral artery stroke, we found that despite their obvious naming impairment participants were able to provide accurate semantic information during structured word retrieval tasks and during conversation (Antonucci, Beeson, & Rapcsak, 2004). Patients also demonstrated intact auditory comprehension and relatively well-preserved nonverbal semantic knowledge. Based on this evidence, it was proposed that the cognitive mechanism of anomia in these patients involved disrupted access to phonological word forms rather than loss of semantic knowledge. However, it was acknowledged that assessment of lexical-semantic processing was not sufficiently rigorous to detect more subtle semantic deficits. Furthermore, although most of our patients demonstrated damage to BA 37, the lesions often extended into more anterior temporal lobe regions implicated in semantic processing. Similar concerns about the presumed integrity of semantic representations and about the selectivity of damage to BA 37 may apply to other cases of pure anomia that have been described in the literature.

The present study was designed to investigate further the relationship between lexical retrieval and semantic knowledge in patients with focal damage to left inferior temporal cortex by combining comprehensive lesion analyses with detailed assessment of lexical-semantic processing. In order to explore the effects of damage throughout the anterior–posterior extent of the left temporal lobe, we included patients with anterior temporal lobectomy as well as those with posterior cerebral artery stroke. Behavioural assessments were designed to determine whether anomia in these patients was the result of degraded semantic knowledge (semantic anomia) or whether it was attributable to a post-semantic deficit resulting in a disconnection between relatively well-preserved semantic knowledge and phonological output (pure anomia). Semantically guided lexical retrieval was explored with tasks designed to detect possible domain-specific deficits for living versus nonliving things, as well as with tasks suitable for identifying selective impairments in comprehension/production of semantic attributes relating either to objects' functional/associative or visual/perceptual features. Previous studies have documented that temporal lobe damage can produce both a selective impairment in naming living things and a disproportionate difficulty in processing the visual/perceptual attributes of objects (e.g., Basso, Capitani, & Laiconi, 1988; Borgo & Shallice, 2003; Breedin, Saffran, & Coslett, 1994; Cardebat, Demonet, Celsis, & Puel, 1996; Coltheart et al., 1998; Gainotti, 2000; Gainotti & Silveri, 1996; Humphreys & Forde, 2001; Humphreys & Riddoch, 2003; Humphreys, Riddoch, & Price, 1997; Lambon Ralph, Howard, Nightingale, & Ellis, 1998; Lambon Ralph, Patterson, Garrard, & Hodges, 2003; Marshall, Pring, Chiat, & Robson, 1996; Moss, Tyler, Hodges, & Patterson, 1995; Tyler & Moss, 1997). Such deficits are typically attributed to central semantic impairment, although they have also been described in the context of pre-semantic deficits involving stored structural descriptions of visual object forms (Humphreys & Forde, 2001; Humphreys & Riddoch, 2003; Humphreys et al., 1997). Semantic knowledge in our patients was also explored with word and picture comprehension tasks that did not require explicit production of verbal labels. Based on our previous study (Antonucci et al., 2004), it was hypothesised that unilateral damage to the left inferior temporal lobe would result in anomia in the presence of relatively well-preserved semantic knowledge. The behavioural profile that would support this hypothesis is characterised by frequent production of semantically appropriate circumlocutions, with lexical retrieval facilitated by phonemic cueing. Performance on tests of word/picture comprehension should be preserved. In contrast, semantic anomia would be characterised by a large proportion of semantic naming errors or empty circumlocutions, failure to benefit from phonemic cueing, poor performance

on comprehension tests, and evidence of domain-specific or attribute-specific semantic impairment.

METHOD

Participants

A total of 16 participants with circumscribed damage to the left temporal lobe were recruited: 8 individuals who underwent surgical resection of the left anterior temporal lobe (L ATL) as treatment for temporal lobe epilepsy, and 8 individuals with damage due to ischaemic or haemorrhagic stroke within the left posterior cerebral artery (L PCA) territory. All participants were right-handed, native English speakers.

Left anterior temporal lobectomy participants—The L ATL group included five males and three females. The mean age of this group was 42 years (range: 20–57), with a mean education level of 13 years (range: 12–20) (Table 1). Time since surgery for the L ATL participants ranged from 12 to 81 months (“Time post onset” in Table 1). Pre-surgical MRI scans were reported to be “normal” for five out of eight L ATL participants, with only mild left hippocampal sclerosis noted for the remaining three participants. All L ATL participants demonstrated left language dominance during pre-surgical WADA testing and none demonstrated neurological disease other than the seizure disorder that necessitated surgery. Functional Standard IQ scores (*Wechsler Adult Intelligence Scales*) for six of eight L ATL participants were within the normal range (≥ 90). Participant L ATL 6 received a somewhat lower FSIQ score (69), likely due to his Verbal IQ (66), which was reduced relative to his Performance IQ (78). Neuropsychological data were not available for L ATL 8, however, presurgical level of education (PhD) suggested that this participant’s cognitive and memory skills were within the normal range. Furthermore, both of these participants performed within the normal range for their ages on a test of nonverbal cognition, the *Raven’s Coloured Progressive Matrices* (Raven, 1938,1960) (Table 1).

Left posterior cerebral artery stroke participants—All eight of the participants in the L PCA group were males. The mean age of the L PCA group was 71 (range: 51–86), and the mean level of education in this group was 14 years (range: 11–18) (Table 1). As a group, the L PCA participants were older than participants in the L ATL group, $t(14) = 5.14, p < .001$. There was no significant difference in years of education between the two patient groups, $t(14) = 0.712, p = .49$. Time post onset in the L PCA group ranged from 1 to 171 months (Table 1). Seven participants had infarctions within the L PCA territory, while the remaining participant developed a left temporal lobe haematoma associated with anticoagulation treatment.

Control participants—A total of 16 right-handed individuals (seven males and nine females) without a history of neurological impairment were recruited as controls. All were native English speakers. The mean age of the controls was 55.56 (range: 19–81), with a mean level of education of 14.06 years (range: 12–18). There was no statistically significant difference between left temporal lobe patients and controls for either age, $t(30) = 0.15, p = .88$, or education, $t(30) = -0.35, p = .73$.

Lesion analyses

High-resolution T1 MRI scans were collected for 14 of 16 patients, consisting of a set of 120 contiguous sagittal slices ($1 \times 1 \times 1.5$ mm) using a three-dimensional fast spoiled gradient echo sequence (SPGR). MRI scanning was contra-indicated for two L PCA participants, so lesions were identified from clinical CT scans for those individuals. Scans were obtained at least 6 months post onset for all but one participant. For L PCA 5, who was tested and imaged

approximately 1 month post onset of stroke, an additional T2-weighted MRI scan was also acquired to assist in determining lesion boundaries.

Patient scans were imported into MRIcro software (Rorden & Brett, 2000) and lesions were mapped directly onto the digital radiological image using the region of interest (ROI) drawing tool. To allow for comparison across patients, spatial normalisation was performed for each 3D volume and each 3D lesion ROI using the smoothed T1 template in SPM2 (Statistical Parametric Mapping; Wellcome Department of Cognitive Neurology, <http://www.fil.ion.ucl.ac.uk/spm>). The 3D lesion ROI was used to mask the lesion during normalisation to minimise the influence of abnormal tissue on the alignment process (Brett, Leff, Rorden, & Ashburner, 2001). For the two individuals who had CT rather than MRI scans, lesions were manually transferred onto the standard T1 template in MRIcro that is aligned in stereotactic space (Montreal Neurological Institute). MRIcro ROI comparison functions were used to determine regions of overlap and regions of unique damage using the normalised ROI lesion maps. Normalised lesion volumes (cc) and percent damage to select Brodmann areas were calculated within MRIcro.

Assessments

Administration of the entire assessment battery was divided across three sessions so that tasks that utilised the same stimuli were not administered during the same session. Order of administration was counterbalanced within each group (patients and controls).

Standardised assessments of language and cognition—The *Western Aphasia Battery* (WAB, Kertesz, 1982) was administered to left temporal lobe damaged participants as a measure of receptive and expressive language function. WAB scores confirmed that all participants were fluent speakers with good auditory comprehension, both for single words and for lengthier questions and instructions (Table 1). Aphasia quotients ranged from 84.7 (anomic aphasia) to 100 (unimpaired).

The *Boston Naming Test* (BNT, Kaplan, Goodglass, & Weintraub, 1983) was also administered only to left temporal lobe damaged participants as an additional test of confrontation naming that included low-frequency items (e.g., palette, abacus). Errors were classified in the following categories: semantic circumlocutions (e.g., hammock: *You use it to sleep on*), empty circumlocutions/no response (e.g., *Sure, I know what that is*), semantic errors (e.g., beaver: *chipmunk*), visual errors, and phonemic paraphasias. Differentiation between semantically meaningful circumlocutions and empty circumlocutions was based on a judgement of the communicative effectiveness of the response, specifically whether the response contained semantically relevant and appropriate information.

The *Raven's Coloured Progressive Matrices* (RCPM) was administered to all participants as a measure of visual processing and nonverbal cognitive function (Table 1). There was no statistical difference between the performance of the left temporal lobe damaged patients (mean = 31.44) and matched controls (mean = 33.38), $t(30) = -1.73$, $p = .094$.

The *Mini-Mental State Examination* (Folstein, Folstein, & McHugh, 1975) was administered to screen control participants for adequate memory and cognitive functioning. All controls performed within the normal range according to the criterion ($>27/30$) suggested by Kukull and colleagues (2001).

Experimental lexical retrieval battery—Three tasks that utilised the same 36 stimuli were administered to test semantically guided lexical retrieval: confrontation naming, naming to verbal definition, and verbal description. The 36 items were chosen to probe for domain-specific deficits (i.e., living vs nonliving) and deficits to semantic attribute knowledge (i.e.,

functional/associative vs visual/perceptual). Living items ($n = 18$) were selected from the categories of “animals” ($n = 9$) and “plants” ($n = 9$), while nonliving items ($n = 18$) were vehicles ($n = 4$), tools/household objects ($n = 12$), plus “sun” and “moon”. Living and nonliving items were balanced as far as possible for age of acquisition (Morrison, Chappell, & Ellis, 1997), name agreement, familiarity, and visual complexity (Rossion & Pourtois, 2004). Only common living and nonliving items were chosen that could be equally well described based on either perceptual or functional information independently. In other words, test items were judged to have both functional and perceptual distinguishing features. Functional/associative information included function, action, contextual information (e.g., where the item originates) or “encyclopaedic” information (e.g., pumpkin: associated with Halloween). Perceptual information was considered to be any information pertaining to visually perceived attributes such as colour, shape, size, part/whole description, or component property. The distinction between functional/associative and visual/perceptual attributes corresponds to the “non-sensory” versus “sensory” attribute definitions described by Caramazza and Shelton (1998). These distinctions were used when creating definitions for the naming to definition task and for evaluating type of information provided during the verbal description task.

Confrontation naming—Confrontation naming was assessed for all items in the experimental lexical retrieval battery. The majority of stimulus pictures (30/36) came from a Snodgrass and Vanderwart set, revised by Rossion and Pourtois (2004) to contain surface detail and colour, which the authors reported resulted in significantly improved naming performance in normal participants. Six of the items chosen were not part of the coloured Snodgrass and Vanderwart pictures, so coloured line drawings that clearly represented the target and best matched the style of the other pictures were downloaded from the internet (<http://dgl.microsoft.com>). The confrontation naming task was administered on the final day of testing for each participant because the items served as stimuli for other tasks in the battery.

Naming to definition—Two definitions were created for each item in the experimental lexical retrieval battery, one containing functional/associative information, the other containing visual/perceptual information. For example, *pencil* was defined as “an object used to write and erase” (functional), and “a yellow object with a lead point” (perceptual). The functional/associative and visual/perceptual definitions for each living and nonliving item were balanced for level of superordinate information, length of definition, and amount of information provided. Administration of definitions was counterbalanced within groups, and participants were presented with the functional and perceptual definitions for a given item during different sessions. Before testing began, the task was explained and two practice trials were given with feedback provided. Participants responded to functional and perceptual definitions for 18 of the 36 items; the remaining 18 items were used in a subsequent verbal description task so that participants were not asked to describe items for which they had already heard definitions, or vice versa. Administration of living and nonliving items chosen for naming to definition versus verbal description was counterbalanced within each participant group.

Verbal description—A verbal description task was implemented in which participants were asked to describe orally presented items. To confirm that participants heard the stimulus correctly they were asked first to repeat the name, and then were given a general prompt: “Tell me about a(n) _____; pretend I don’t know anything about it.” As with the naming to definition task, participants were provided with feedback to responses on two practice items in order to model appropriate responses. Participants were encouraged to provide enough information that a naive listener would recognise the item they were describing. Participants were also encouraged during practice to provide information both about the function of items and their physical appearance. No time limit was imposed. Scoring of correct or incorrect responses for the description task was based on a judgement of whether or not a listener would be able to

identify the correct item based solely on the description, rather than according to a priori criteria. To do so, responses were transcribed and all instances in which the stimulus name was stated were deleted. Scorers were asked to identify the item they thought was being described. Due to the relatively subjective nature of the scoring procedure, inter-rater reliability data were collected. The data from two L ATL, two L PCA, and four control participants (25% of total sample) were selected and the transcripts of their verbal descriptions were each scored by four individuals in addition to the principal scorer (SMA), so that for each data set, there were a total of five independent raters. Accurate identifications were scored as correct; inaccurate or uncertain identifications were scored as incorrect. Percent agreement with the principal scorer was calculated for each item. Total inter-rater reliability was calculated at 92.21%, with inter-rater reliability for patients at 90% and inter-rater reliability for controls at 96.67%. Evidence of word-finding difficulty was apparent in verbal descriptions, but participants were not penalised for word retrieval difficulty when the description was adequate. For example, for the target “candle”, L PCA 1 demonstrated difficulty retrieving the words “wick” (“something in the centre to light up”) and “wax” (“as that lights, it melts the material and it burns”), but his description was considered adequate to be scored correct. In addition to overall accuracy, the type of information provided in correct verbal descriptions was also examined. Using a procedure similar to that described by Hodges, Salmon, and Butters (1992b), the number of correct functional/associative and visual/perceptual features were tallied for participants’ correct descriptions of living and nonliving items.

Verbal fluency—The experimental lexical retrieval tasks were complemented by verbal fluency tasks for the four semantic categories from which the majority of living and nonliving items were chosen: animals, plants, vehicles, and tools. Participants also completed the FAS letter fluency task in which they were asked to produce words that began with the letters F, A, and S respectively (Borkowski, Benton, & Spreen, 1967). Verbal fluency tasks were time sensitive, measuring the number of items participants named in 1 minute, and were included as a relatively rigorous measure of lexical retrieval. Category fluency tasks were always administered as the first of the lexical retrieval tasks, as they were considered the least likely to prime responses in the other tasks that used the same items. The presentation order of categories was counterbalanced within groups.

Standardized assessment of word and picture comprehension—Semantic knowledge was also assessed with comprehension tests that did not require the production of verbal labels. These included the picture version of the *Pyramids and Palm Trees Test* (*P&PTT*, Howard & Patterson, 1992) and the *Arizona Semantic Test* (*AST*, Beeson, unpublished). The *P&PTT*, the most commonly cited test of semantic association, requires participants to recognise the semantic relationship between a stimulus picture and one other picture in the presence of one distractor. The *AST* similarly tests nonverbal semantic relations, but includes three distractor items for each item, which are either semantically or visually related, or unrelated to the target. The *PALPA 49 – Auditory Synonym Judgement* (Kay, Lesser, & Coltheart, 1992) was also administered. This test requires participants to judge whether pairs of concrete (e.g., cash – money) or abstract (e.g., idea – notion) spoken words have similar or unrelated meanings.

RESULTS

Lesion characterisation

Lesion analyses, conducted in standard stereotactic space (Montreal Neurological Institute), confirmed that all patients had damage to the left inferior temporal lobe. L ATL participants demonstrated resection of portions of the temporal pole (BA 38), entorhinal cortex (BA 28/34), anterior parahippocampal gyrus/perirhinal cortex (BA 35/36), anterolateral temporal cortex

(BA 20/21), and fusiform gyrus (BA 20). Inferior–superior extent of lesions in the L ATL group ranged from $z = -42$ to $z = -7$, with lesion volumes in this group ranging from 9 cc to 34.5 cc. Lesions in the L PCA group were concentrated in left inferior temporo-occipital cortex, including the lingual (BA 18/19), fusiform/inferior temporal (BA 37/20), and posterior parahippocampal gyri (BA 30/35). Brain damage in the L PCA group extended farther superior ($z = -39$ to $z = 28$) than in the L ATL group, with the most dorsal damage being restricted to the left occipital lobe. Lesion volumes tended to be larger in the L PCA group, with a range of 8 cc to 65.2 cc. However, there was no statistically significant difference in total lesion volumes between the two patient groups (L ATL mean = 21.93 cc, L PCA mean = 36.41 cc), $t(14) = -1.64$, $p = .12$. As demonstrated in Figure 1, the region of greatest overlap between the L ATL and L PCA groups was in BA 20, with no significant difference in mean percent damage to this region between the two groups, L ATL mean = 25.12% (range: 9–38.3%), L PCA mean = 20.06% (range: 1.8–56.4%), $t(14) = 0.60$, $p = .56$. By contrast, damage to BA 37 was essentially limited to the L PCA group, whereas L ATL patients had more extensive damage to polar (BA 38), anteromedial (BAs 28/34, 35/36) and anterolateral temporal cortex (BA 21).

Boston Naming Test

Performance on the *BNT* ranged from moderately impaired to unimpaired within each patient group (Figure 2). Mean raw scores were 46.75/60 (range: 36–60) for the L ATL group and 44.38/60 (range: 26–60) for the L PCA group. An independent *t*-test revealed no statistical difference between performance of the patient groups, $t(14) = 0.46$, $p = .65$. To quantify further the severity of anomia in each group, *z*-scores were calculated using age- and education-matched norms reported by Tombaugh and Hubley (1997). Calculation of *z*-scores demonstrated that five of eight L ATL participants and five of eight L PCA participants performed at least 2 standard deviations below the normative mean. Consistent with analysis of raw *BNT* scores, there was no statistical difference between the *z*-scores of the two patient groups (mean *BNT z* score L ATL group = -2.24 , mean *BNT z* score for L PCA group = -1.99), $t(14) = -0.233$, $p = .819$. Additional analyses indicated that for patients who made errors, the provision of phonemic cues significantly improved naming accuracy, $t(13) = 6.23$, $p < .001$.

Percentages of error types for both patient groups are displayed in Figure 3. Independent *t*-tests revealed no significant differences between the two patient groups for any of the error types. The largest proportion of errors in both patient groups was semantically appropriate circumlocation (>75%). In the infrequent instances when semantic errors were made (<10% of errors), they tended to be coordinate semantic errors and patients typically spontaneously indicated that they were aware they had produced an incorrect response. For example, for “octopus” L PCA 4 said, “squid, which is, there’s a better name for it”; for “globe” L ATL 2 said, “I want to call it an atlas, but it’s not”.

The *BNT* results confirm the findings of Antonucci et al. (2004) and several other studies demonstrating significant anomia in patients with focal damage to left inferior temporal cortex. Our findings also suggest that the nature and severity of the naming impairment were similar in the L ATL and L PCA patient groups. Evidence that patients were able to benefit from phonemic cueing and that the predominant naming error type in both groups was semantically appropriate circumlocation was consistent with the profile of pure anomia and suggested that the naming impairment occurred in the context of relatively well-preserved semantic knowledge with disrupted access to phonological word forms.

Experimental lexical retrieval battery

Results of tasks in the experimental lexical retrieval battery are shown in Figures 4a–d and in Table 2. Analyses of these data were first conducted with all left temporal lobe damaged patients as a single group and comparing them with age- and education-matched controls (see

Figures 4a–d). These were followed by direct contrasts between the L ATL and L PCA groups to discern potential differences in performance related to differences in lesion aetiology or location (Table 2). Post hoc tests performed to follow-up on significant main effects or interactions demonstrated by ANOVAs utilised alpha levels adjusted by the Bonferroni procedure.

Confrontation naming

Confrontation naming: Patients vs controls: As shown in Figure 4a, all participants performed well on this task, most likely reflecting the fact that the test stimuli were common, familiar items. It is notable, however, that whereas normal controls performed flawlessly in naming pictures of both living and nonliving items, patients with left temporal lobe damage had greater difficulty in naming stimuli from living categories $t(15) = -2.82, p = .013$.

Confrontation naming: L ATL vs L PCA: A 2 (group) $\times 2$ (domain: living vs nonliving) ANOVA revealed no main effect of group, but demonstrated a main effect of domain, $F(1, 14) = 7.522; p = .016$. There was no evidence of a group $\times$ domain interaction. These findings suggest that L ATL and L PCA patients had equivalent levels of difficulty in naming pictures of living items compared to nonliving items.

Confrontation naming: Discussion: Consistent with the results of the *BNT*, evidence from the experimental confrontation naming task indicated that naming performance was quantitatively and qualitatively similar in L ATL and L PCA patients. There was some evidence that the naming deficit of our patients may be greater for living as opposed to nonliving categories, although the possible influence of semantic domain in normal controls could not be assessed due to ceiling effects.

Naming to definition

Naming to definition: Patients vs controls: Figure 4b displays naming to definition performance of both groups. A 2 (group) $\times 2$ (domain: living vs nonliving) $\times 2$ (attribute: functional/associative vs visual/perceptual) ANOVA revealed main effects of group, domain, and attribute, with interactions between group $\times$ domain, group $\times$ attribute, and domain $\times$ attribute (see Table 3). Post hoc comparisons (corrected alpha = 0.006) confirmed that patients performed more poorly than controls when naming from definitions referring to living items, $t(30) = -3.76, p < .001$, and when naming from definitions that contained visual/perceptual information, $t(30) = -3.99, p < .001$. Within-group comparisons revealed that patients experienced greater difficulty naming from definitions of living items than definitions of nonliving items, $t(30) = -3.22, p = .003$, and that patients experienced greater difficulty with definitions that contained visual/perceptual information than with those that contained functional/associative information, $t(30) = -4.90, p > .001$. Neither effect was demonstrated in controls. Finally, to follow up on the domain $\times$ attribute interaction, tests of simple effects (corrected alpha = .0125) indicated that, for patients with left temporal lobe lesions, naming living things from visual/perceptual definitions was significantly worse than naming these items from functional/associative definitions $t(30) = -7.149, p < .001$. By contrast, semantic attribute did not have a significant influence on accuracy of naming from definitions of nonliving things. Naming of living things from visual/perceptual definitions was also less accurate than naming of nonliving items from visual/perceptual definitions, $t(30) = -5.826, p < .001$, whereas there was no difference in naming accuracy for living versus nonliving things from functional/associative definitions.

Naming to definition: L ATL vs L PCA: Comparison of the two patient groups on the naming to definition task was performed using a 2 (group) $\times 2$ (domain) $\times 2$ (attribute) ANOVA. No main effect of group was revealed but main effects of domain $F(1, 14) = 12.296; p = .003$, and

attribute, $F(1, 14) = 28.606$; $p < .001$, were demonstrated. There were no group $\times$ domain or group $\times$ attribute interactions, suggesting that L ATL and L PCA patients had similar difficulty in naming living items and in naming from visual/perceptual definitions.

Naming to definition: Discussion: Results from the naming to definition task were consistent with confrontation naming performance in that patients with left inferior temporal lobe damage seemed to experience more difficulty in naming items from living categories. However, we also obtained evidence that this domain-specific effect was influenced by the type of semantic attribute information contained in the definitions, as patients demonstrated difficulty with living items only when the definitions contained visual/perceptual information. These observations are consistent with the notion that the loss of visual/perceptual attribute knowledge is particularly detrimental to the identification of living things, whereas semantic representations for nonliving things primarily emphasise functional/associative information (e.g., Beeson, Patel, & Holland, 1997; Farah & McClelland, 1991; Humphreys & Riddoch, 2003; Vinson, Vigliocco, Cappa, & Siri, 2003).

Verbal description

Verbal description Patients vs controls: Accuracy of verbal description responses is displayed in Figure 4c. A 2 (group) $\times$ 2 (domain: living vs nonliving) ANOVA was used to compare performance of patients to controls. A main effect of group, $F(1, 30) = 12.097$; $p = .002$, was demonstrated such that patients provided fewer accurate verbal descriptions than controls. There was no main effect of domain and no interaction between group and domain, suggesting that the living/nonliving distinction did not affect verbal description accuracy. A separate analysis of the type of information provided in correct verbal descriptions (Figure 4d) was also performed. A 2 (group) $\times$ 2 (domain: living vs nonliving) $\times$ 2 (attribute: functional/associative vs visual/perceptual) ANOVA demonstrated no main effect of group or attribute, with a main effect of domain, $F(1, 30) = 6.417$; $p = .017$, such that all participants provided less information for nonliving items.

Verbal description: L ATL vs L PCA: Relative to overall accuracy of patients' responses, a 2 (group) $\times$ 2 (domain) ANOVA indicated no main effect of group or domain. Comparison of the type of information provided in patients' correct verbal descriptions using a 2 (group) $\times$ 2 (domain) $\times$ 2 (attribute) ANOVA revealed no main effect of group. Main effects of domain (living > nonliving), $F(1, 14) = 6.768$; $p = .021$, and attribute (functional/associative > visual perceptual), $F(1, 14) = 5.486$; $p = .034$, were demonstrated, with no interaction between the two. There were also no group $\times$ domain or group $\times$ attribute interactions. Taken together, these findings indicate that both patient groups generated less information for nonliving items and that they also provided less visual/perceptual information than functional/associative information.

Verbal description: Discussion: Results from the verbal description task provided additional evidence of impaired lexical retrieval in patients with left inferior temporal lobe lesions compared to controls, although all participants provided less information for nonliving compared to living items. This finding is consistent with results of semantic feature generation studies demonstrating that normal participants produce a greater number of semantic properties for living than nonliving items (Garrard, Lambon Ralph, Hodges, & Patterson, 2001; McRae & Cree, 2002; Moss, Tyler, & Devlin, 2002; Zannino, Perri, Pasqualetti, Caltagirone, & Carlesimo, 2006). Relative to the type of information provided in correct verbal descriptions, patients provided less visual/perceptual than functional/associative information, an effect that was not observed in normal controls. It appeared that patients were able to rely on circumlocution and the inclusion of functional/associative information when describing both

living and nonliving items so that the domain effect observed on naming tasks that required retrieval of specific lexical labels was not evident on this task.

Verbal fluency

Verbal fluency: Patients vs controls: For comparisons of verbal fluency performance, shown in Figure 5, semantic category fluency was analysed separately from letter fluency. For semantic category fluency, a 2 (group) $\times$ 2 (domain: living vs nonliving) ANOVA revealed main effects of group, $F(1, 30) = 17.948$; $p < .001$, and domain, $F(1, 30) = 65.614$; $p < .001$, and an interaction between group and domain, $F(1, 30) = 4.485$; $p = .043$. Post hoc comparisons (corrected alpha ≤ 0.0125) demonstrated that patients generated significantly fewer items than controls only for living categories (animals and plants), $t(30) = -3.665$, $p < .001$. Relative to nonliving items (vehicles and tools), the difference between patients and controls was not significant at the corrected alpha level, $t(30) = -2.326$, $p = .027$. That participants with left temporal lobe damage had more difficulty generating living than nonliving items relative to controls was further confirmed by a comparison of patient z -scores for the two domains (mean z -scores for living categories = -1.60 , mean z -scores for nonliving categories = -1.18); $t(15) = -2.23$, $p = .04$. Additional within-group comparisons indicated that both patients, $t(30) = -4.23$, $p < .001$, and controls, $t(30) = -7.225$, $p < .001$, generated fewer nonliving than living items. With respect to letter fluency, an independent samples t -test revealed that patients generated significantly fewer items than controls, $t(30) = -2.483$, $p < .019$. Although patients were impaired relative to controls in both category and letter fluency tasks, comparison of z -scores indicated more significant impairment on the category fluency task (mean z -score for category fluency = -1.56 , mean z -score for letter fluency = -0.76); $t(15) = -4.59$, $p < .001$.

Verbal fluency: L ATL vs L PCA: Comparison between the patient groups on semantic category fluency tasks was conducted using a 2 (group) $\times$ 2 (domain) ANOVA. Main effects were demonstrated for group, $F(1, 14) = 8.05$; $p = .013$, and domain, $F(1, 14) = 33.82$; $p < .001$, as well as an interaction between group and domain, $F(1, 14) = 11.89$; $p = .004$. Post hoc comparisons (corrected alpha ≤ 0.0125) indicated that L PCA patients generated significantly fewer living items than L ATL patients, $t(14) = -2.93$, $p = .011$. Within-groups comparisons demonstrated no significant difference between the number of living and nonliving items generated by L PCA patients, whereas L ATL patients generated more exemplars from the living category $t(14) = 6.55$, $p < .001$. In addition, an independent t -test revealed that L PCA patients generated significantly fewer items than L ATL patients during letter fluency tasks, $t(14) = -3.76$, $p = .002$. As the verbal fluency tasks were timed, it was hypothesised that the time constraint may have had a greater detrimental effect on the performance of the older L PCA patients. In fact, when comparison of the two groups was performed with participant age entered as a covariate, adjusted means for the two patient groups were not significantly different for either semantic domain—living, $F(1, 13) = 0.34$, $p = .57$, nonliving, $F(1, 13) = 0.87$, $p = .37$, or for letter fluency, $F(1, 13) = 0.91$, $p = .36$.

Verbal fluency: Discussion: The results from the verbal fluency tasks confirmed that left temporal lobe damaged patients had significant naming deficits compared to controls. Both patients and controls generated more living than nonliving items and this finding may be related to the fact that the living categories (animals and plants) were significantly broader and therefore had more potential exemplars than the nonliving categories (vehicles and tools) (e.g., Hodges et al., 1992b). However, the fact that patients were relatively more impaired for living items compared to controls is consistent with the domain effects demonstrated in the confrontation naming and naming to definition tasks. We also obtained evidence that semantic category fluency was overall more impaired than letter fluency, consistent with the pattern documented in other patients with semantic impairment due to temporal lobe lesions (Rogers, Ivanoiu, Patterson, & Hodges, 2006; Troyer, Moscovitch, & Winocur, 1998).

Assessments of word and picture comprehension

Patients vs controls—Table 4 displays mean participant performance on the three standardised tests of semantic comprehension. Independent samples *t*-tests revealed a statistically significant difference between patients and controls on the *Pyramids & Palm Trees Test (P&PTT)*, $t(30) = -3.72$, $p = .001$, and the *PALPA 49: Auditory Synonym Judgement*, $t(30) = -2.41$, $p = .023$. No significant difference was demonstrated between patients and controls on the *Arizona Semantic Test (AST)*.

L ATL vs L PCA—There was no difference between the patient groups on the two picture tests of semantic knowledge (*P&PTT* or the *AST*). Independent *t*-tests indicated that the only statistical difference between the two patient groups was on the auditory synonym judgement test (*PALPA 49*), $t(14) = -2.757$, $p = .015$, with L ATL patients (mean = 55.1 out of 60) performing more poorly than L PCA patients (mean = 58.0 out of 60).

Lexical-semantic comprehension vs production

To examine further the relationship between lexical-semantic comprehension and production in the left temporal lobe damaged patients, composite *z*-scores were calculated for tests of semantic knowledge (*P&PTT*, *AST*, *PALPA*) and semantically guided lexical retrieval (*BNT*, naming to definition, verbal description, category fluency). We were unable to calculate *z*-scores for the experimental confrontation naming test as there was no variance in the performance of the control group. Overall, mean production *z*-scores (-2.15) were significantly lower than comprehension *z*-scores (-1.06), $t(15) = -2.95$, $p = .01$, indicating greater impairment on tasks involving explicit lexical retrieval. Severity of naming impairment, as reflected in production *z*-scores, was not significantly correlated with comprehension *z*-scores, $r = .378$, $p = .15$.

GENERAL DISCUSSION

The results of this study confirm that focal damage to left inferior temporal cortex is associated with significant anomia. Our findings also contribute to a better understanding of the cognitive mechanisms responsible for the naming impairment. We found that individuals with left inferior temporal lobe lesions predominantly produced semantically appropriate circumlocutions on the *BNT* and that picture-naming performance significantly improved with phonemic cueing. Semantic naming errors were rare and patients almost never produced phonemic errors. At first glance, these findings seem consistent with our earlier proposal (Antonucci et al., 2004) that the naming impairment of patients with left inferior temporal lobe lesions is primarily post-semantic in nature and is likely to reflect a disconnection between relatively preserved semantic representations and phonological word forms. However, the more stringent assessment of lexical-semantic processing carried out within the context of the current investigation revealed evidence suggestive of mild central semantic impairment. In particular, we found that naming of items from living categories was more impaired than the naming of items from nonliving categories, and our patients demonstrated defective knowledge of visual/perceptual as opposed to functional/associative semantic attributes. Category-specific semantic deficits for living things and impaired visual/perceptual attribute knowledge have both been described in patients with inferior temporal lobe lesions and it has been proposed that these impairments reflect damage to the ventral visual pathway critical for object vision (e.g., Basso et al., 1988; Borgo & Shallice, 2003; Breedin et al., 1994; Cardebat et al., 1996; Coltheart et al., 1998; Gainotti, 2000; Humphreys & Riddoch, 2003; Lambon Ralph et al., 1998; Lambon Ralph, Graham, & Patterson, 1999; Lambon Ralph et al., 2003; Moss et al., 1995; Tyler & Moss, 1997). The neuroanatomical findings from our study are consistent with this view, as our patients had extensive damage to inferior and anteromedial temporal lobe regions that are critical components of the visual object recognition pathway. The loss of fine-

grained visual/perceptual knowledge may have a particularly devastating impact on the recognition and naming of living things because visual features appear to play a more salient role in the conceptual representation of animals and plants and also because members of living categories are more visually similar than members belonging to nonliving categories (e.g., Farah & McClelland, 1991; Humphreys & Riddoch, 2003; Vinson et al., 2003). We note, however, that although impaired recognition of living things and poor visual/perceptual knowledge frequently coexist, both types of deficits can occur in isolation, suggesting that their association may not be obligatory (e.g., Barbarotto, Capitani, Spinnler, & Trevelli, 1995; Caramazza & Shelton, 1998; Lambon Ralph et al., 1998; Marshall et al., 1996). In addition to demonstrating attribute- and domain-specific deficits, our patients also showed other evidence of semantic impairment including difficulty on word/picture comprehension tests and disproportionate impairment on tests of category fluency compared to letter fluency.

It is evident from the preceding discussion that the lexical retrieval performance of our patients is difficult to classify as it showed some features consistent with pure anomia, while there was also evidence of semantic impairment that is more typically associated with semantic anomia. Although one could explain this mixed profile by postulating a combination of post-semantic and semantic deficits, it may be more parsimonious to view these findings as arising from damage to a single cognitive component implicated in naming. In particular, we agree with the proposal of Lambon Ralph and colleagues (Lambon Ralph, Sage & Roberts, 2000; Lambon Ralph et al., 2001) that pure anomia and semantic anomia may represent two endpoints along a continuum of semantic impairment rather than corresponding to distinct neuropsychological syndromes with fundamentally different underlying mechanisms. Along these lines, we suggest that the types of naming errors produced by patients with damage to inferior temporal cortex can provide important clues about the integrity of the underlying semantic representations. With mild damage to semantic representations, patients only have difficulty retrieving the most unique and distinctive verbal label corresponding to the core semantic concept: the individual name. The relative integrity of semantic representations in these patients is indicated by the abundant production of semantically appropriate circumlocutions. Reduced activation of phonological word forms in patients with mild semantic deficits may be overcome by phonemic cueing. Thus, individuals with mild semantic impairment can present with a profile considered typical of pure anomia. With increasing amounts of semantic degradation, patients produce a higher proportion of coordinate semantic naming errors reflecting difficulty in distinguishing between exemplars within a category and, with more severe damage, superordinate responses may predominate indicating that only knowledge pertaining to broad semantic categories is preserved. In patients with this profile of “semantic anomia” phonological cues are no longer effective in aiding lexical retrieval. Finally, patients with the most severe semantic impairment produce empty circumlocutions in lexical retrieval tasks or fail to respond altogether (Graham, Patterson, & Hodges, 1995; Hodges et al., 1992a; Jeffries & Lambon Ralph, 2006; Lambon Ralph et al., 2001; Rogers et al., 2004).

In addition to these characteristic production features reflecting different degrees of semantic impairment, one also observes a concomitant though nonlinear decline in comprehension. An important caveat here is that comprehension tests are always easier and therefore less sensitive to semantic degradation than lexical production tasks (Lambon Ralph et al., 2000; Rogers et al., 2006). The discrepancy between production and comprehension scores is likely to be particularly noticeable in individuals with relatively mild semantic deficits, and near-normal performance on picture/word comprehension tests in patients who otherwise show the typical production features of pure anomia may lead to the erroneous conclusion that semantic knowledge is wholly preserved (Graham et al., 1995; Lambon-Ralph et al., 2001; Tyler, Moss, Patterson, & Hodges, 1997). This asymmetrical relationship was clearly observed in our patients who demonstrated greater impairment in lexical production than in word/picture comprehension and failed to show a significant correlation between the two measures.

As noted earlier, the most dramatic cases of semantic anomia are observed in patients with bilateral temporal lobe damage due to herpes encephalitis or semantic dementia (Davies et al., 2004; Hodges et al., 1992a; Hodges & Patterson, 1996; Lambon Ralph et al., 2001; Moss et al., 2005; Mummery et al., 1999, 2000; Pietrini et al., 1988; Schmolck et al., 2002; Tyler et al., 2004; Warrington & Shallice, 1984). In fact, our findings indicate that focal left temporal lobe lesions may not be sufficient to produce the degree of semantic impairment that typically accompanies semantic anomia. In this context, we note that Lambon Ralph et al. (2001) identified two subgroups of semantic dementia patients. The performance of patients with predominantly left-sided temporal lobe atrophy was very similar to the pattern documented in our patients with focal left temporal lobe lesions: disproportionate impairment in naming relative to comprehension and a tendency to produce semantically appropriate circumlocutions rather than frank semantic errors. By contrast, semantic dementia patients with greater right- than left-sided temporal lobe atrophy showed a commensurate decline in naming and comprehension scores and predominantly produced semantic naming errors. Right temporal lobe damage may also play a critical role in producing a disproportionate impairment in recognising living things that are primarily differentiated on the basis of their visual/perceptual features (Brambati et al., 2006). While the unilateral left temporal lobe damaged patients in our study demonstrated greater difficulty in naming living things, along with a loss of knowledge for visual/perceptual semantic attributes, the impairment was relatively mild. It may be that right temporal involvement is required to produce more severe domain- and attribute-specific semantic deficits. Taken together, these findings support the notion that the severe semantic impairment that characterises semantic anomia requires bilateral temporal lobe lesions.

It may seem surprising that despite differences in lesion aetiology and location, the L ATL and L PCA groups performed similarly on tests of lexical retrieval and semantic processing. This apparent paradox can be resolved by considering that both groups showed equivalent amounts of damage to anterior inferior temporal cortex, including anterior fusiform gyrus (BA 20) that is also a frequent site of damage in patients with herpes encephalitis or semantic dementia (Davies et al., 2004; Galton et al., 2001; Moss et al., 2005; Mummery et al., 1999, 2000; Pietrini et al., 1988; Schmolck et al., 2002; Tyler et al., 2004; Warrington & Shallice, 1984; Williams, Nestor, & Hodges, 2005). The fact that the greatest degree of lesion overlap was observed in anterior temporal lobe regions implicated in semantic processing is consistent with our hypothesis that degradation of semantic representations played a role in our patients' naming impairment. It should be noted, however, that category-specific deficits for living things and disproportionate impairment in processing the visual/perceptual attributes of objects have also been reported in patients with damage to more posterior temporo-occipital cortical regions (Humphreys & Forde, 2001; Humphreys & Riddoch, 2003; Humphreys et al., 1997). The mechanism of impairment in these patients is purported to be pre-semantic in origin and reflect damage to stored structural descriptions of visual object forms (Humphreys & Forde, 2001; Humphreys & Riddoch, 2003; Humphreys et al., 1997). Because damage to more posterior visual association areas was present in our patients with L PCA strokes, we cannot exclude the possibility that such pre-semantic deficits may also have contributed to the naming impairment demonstrated by these individuals. However, the fact that poor performance was also observed in language tasks that did not utilise visual stimuli seems more consistent with an amodal semantic deficit.

In conclusion, naming deficits in patients with inferior temporal lobe lesions reflect a continuum of semantic impairment ranging in severity from pure anomia at one extreme to semantic anomia at the other. Many patients fall between these two extremes and therefore present with a mixed clinical profile. Our patients with focal left temporal lobe lesions demonstrated relatively mild semantic deficits, consistent with partial damage to cortical regions involved in semantic processing. More extensive damage to left temporal lobe semantic

networks would be expected to result in more substantial degradation of semantic knowledge. However, severe semantic impairment seems to require bilateral temporal lobe damage.

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Figure 1.

Regions of damage between L ATL & L PCA. Areas of brain damage in the two patient groups. Light yellow areas demarcate regions of damage unique to the L ATL group, while light blue areas demarcate regions of damage unique to the L PCA group. Overlapping areas of damage between the two patient groups (localised to BA 20) are shown in purple.

Figure 2.

Patient *BNT* performance ordered from moderately impaired to unimpaired. *Indicates impairment based on *z*-score ((patient raw *BNT* score – normative mean)/normative standard deviation), norms reported in Table 1 of Tombaugh and Hubley (1997). Participants were considered impaired if their individual *z*-score was ≥ 2 standard deviations below the normative mean.

Figure 3.
BNT error responses of patient groups

Figure 4.

a: Spoken Confrontation Naming Accuracy. b: Naming to Definition Accuracy. c: Verbal Description Accuracy. d: Types of Information Provided in Correct Verbal Descriptions

Figure 5.
Participant performance on verbal fluency tasks

TABLE 1

Participants' demographic information and performance on the Western Aphasia Battery (WAB) & Raven's Coloured Progressive Matrices (RCPM)

	Age (years)	Education (years)	Time Post Onset (months)	WAB AQ	RCPM (36/36)
L ATL 1	47	12	80	99.2	35
L ATL 2	40	12	81	93.1 [*]	33
L ATL 3	48	14	72	95.0	34
L ATL 4	57	12	12	97.2	26 [†]
L ATL 5	34	12	39	99.9	33
L ATL 6	45	12	68	97.8	35
L ATL 7	20	12	47	100.0	34
L ATL 8	46	20	76	99.9	32
L PCA 1	77	18	39	94.2	31
L PCA 2	62	12	25	100.0	34
L PCA 3	82	16	40	93.4 [*]	33
L PCA 4	73	12.5	69	97.4	33
L PCA 5	86	14.5	1	84.7 [*]	27
L PCA 6	51	18	35	100.0	34
L PCA 7	70	12	115	95.0	24 [†]
L PCA 8	66	11	171	98.6	25 [†]

^{*} indicates impairment – classification of anomic aphasia.

[†] indicates below normal performance based on age-, education-, gender-specific normative data reported by Measso and colleagues (1993).

TABLE 2
Performance of L ATL and L PCA patients on the experimental lexical retrieval battery and verbal fluency tasks

Experimental Lexical Retrieval Tasks	L ATL patients	L PCA patients
<i>Confrontation Naming Accuracy (out of 18)</i>		
Living	17.38 (0.92)	16.75 (1.17)
Nonliving	18.00 (0.00)	17.63 (0.74)
<i>Naming to Definition Accuracy (out of 9)</i>		
Living – Functional/Associative	8.75 (0.71)	8.50 (0.76)
Living – Visual/Perceptual	7.38 (1.41)	6.50 (1.69)
Nonliving – Functional/Associative	8.88 (0.35)	9.00 (0.00)
Nonliving – Visual/Perceptual	8.25 (0.71)	8.38 (0.74)
<i>Verbal Description Accuracy (out of 9)</i>		
Living	8.38 (0.52)	6.88 (1.73)
Nonliving	8.00 (1.07)	8.00 (1.07)
<i>Verbal Description Type of Information Provided (# information units)</i>		
Living – Functional/Associative	3.91 (1.12)	4.57 (1.65)
Living – Visual/Perceptual	3.96 (1.38)	3.09 (1.77)
Nonliving – Functional/Associative	3.75 (1.53)	3.73 (1.38)
Nonliving – Visual/Perceptual	3.04 (1.07)	3.62 (2.32)
<i>Verbal Fluency (# items generated)</i>		
Living	32.00 (7.43)	18.75 (7.12)
Nonliving	20.75 (6.34)	15.88 (6.33)
FAS	38.00 (10.57)	21.50 (6.48)

TABLE 3

Naming to Definition - Main effects and interactions for comparison between left temporal lobe damaged patients and matched controls

Effect or Interaction	F (degrees freedom)	p
Main effect (group)	22.85 (1, 30)	.000
Main effect (domain)	12.81 (1, 30)	.008
Main effect (attribute)	37.166 (1, 30)	.000
group $\times$ domain	8.197 (1, 30)	.008
group $\times$ attribute	13.77 (1, 30)	.001
domain $\times$ attribute	7.026 (1, 30)	.013

TABLE 4

Participant performance on word and picture comprehension tests

	Pyramids & Palm Trees Test (Total Possible: 52)	Arizona Semantic Test (Total Possible: 40)	PALPA 49: Auditory Synonym Judgement (Total Possible: 60)
Left temporal lobe damaged patients	49.5 (1.63)	39.25 (1.18)	56.56 (2.50)
Controls	51.25 (0.93)	39.56 (1.03)	58.44 (1.86)