Published in final edited form as:
Neuropsychology. 2015 March ; 29(2): 274–281. doi:10.1037/neu0000097.

Preserved Meaning in the Context of Impaired Naming in Temporal Lobe Epilepsy

Michele Miozzo[a,b] and **Marla J. Hamberger**[c]

[a]Department of Psychology, Columbia University, New York, NY

[b]Department of Cognitive Science, Johns Hopkins University, Baltimore, MD

[c]Department of Neurology, Columbia University Medical Center, New York, NY

Abstract

Objective—Word-finding difficulties are a common complaint among individuals with left (domain) temporal lobe epilepsy (TLE). We tested the hypothesis that these difficulties stem from a deficit in semantic processing.

Method—We tested and compared semantic processing in left and right TLE patients and healthy controls. To avoid the confound of word retrieval, we used two semantic tasks (semantic priming and picture-matching) that did not require spoken word production. In addition to accuracy, we recorded response time (RT) in an effort to achieve a sensitive assessment of semantic processing

Results—Semantic priming was in all respects comparable between left TLE patients with documented word-finding difficulty and right TLE patients without word finding difficulty. Similarly, performances were comparable between groups on picture matching, which demanded knowledge of detailed semantic features for decisions regarding subtle differences in semantic relatedness.

Conclusions—Overall, these results, which demonstrate a relative preservation of semantic processing in left TLE, suggest that the probable cause of word-finding difficulty in this group relates to processes that follow semantic retrieval in word production, involving the retrieval of lexical/phonological information. In addition to clinical implications for remediation, these results refine our understanding of the neurocognitive organization of temporal mechanisms supporting spoken word production.

Keywords

Temporal lobe epilepsy; Naming deficits; Semantic processing; Lexical processing

---

Word-finding difficulty is among the top cognitive complaints reported by individuals with temporal lobe epilepsy (TLE) (Thompson & Corcoran, 1992). Although numerous investigations have confirmed objective word finding or naming difficulty in patients with left (dominant) TLE (LTLE) (Bell, Herman, Woodard, Jones, Rutecki, Sheath, Dow, &

Corresponding author: Michele Miozzo Department of Cognitive Science Johns Hopkins University 237 Krieger Hall 3400 North Charles Street Baltimore, Maryland 21218 Phone: 410-516-5250 Fax: 410-516-8020 mm1150@columbia.edu.

Seidenberg, 2001; Chelune, Naugle, Lauders, & Awad, 1991; Davies, Maxwell, Beniak, Destafney, & Fiol, 1995; Giovagnoli, 2005; Giovagnoli, Erbetta, Villani, & Avanzini, 2005; Hamberger & Seidel, 2003; Hermann & Wyler, 1988; Howell, Saling, Bradley, & Berkovic, 1994; Langfitt & Rausch, 1996; Mayeux, Brandt, Rosen, & Benson, 1980; Raspall et al., 2005; Saykin, Stafiniak, Ronison, Flannery, Gur, O'Connor, & Sperling, 1995; Schwartz, Devinsky, Doyle, & Perrine, 1998), few have attempted to identify the particular linguistic problem(s) that underlie word finding failure in this population. This is important clinically, as finer characterization of the specific mechanisms of word production that are impaired in LTLE could potentially be used to remediate word-finding difficulty in these patients. Additionally, such knowledge would further refine our understanding of temporal lobe mediation of word finding, and shed light on long-term effects of seizures and interictal electrophysiological abnormalities on neural structures supporting language.

Current neurocognitive theories of language view word production as a process involving a complex array of mechanisms leading to the identification of the word that best matches a specific meaning (semantics), and to the retrieval and realization of word sounds (phonology) (Caramazza, 1997; Damasio, Tranel, Grabowski, Adolphs, & Damasio, 2004; Dell, 1986; Levelt, Roelofs, & Meyer, 1999). A large body of evidence indicates that these mechanisms are supported by partially distinct brain regions; specifically, acquired brain deficits can selectively affect the retrieval of word semantics versus phonology (Hillis, Rapp, Romani, & Caramazza, 1990; Kay & Ellis, 1987), neurodegenerative pathologies have been shown to more severely impair semantics versus phonology (Gorno-Tempini et al., 2008; Patterson, Nestor, & Rogers, 2007), and, more recently, neuroimaging results show responsiveness to semantic and phonological features of words in distinct brain regions (Indefrey & Levelt, 2004; Indefrey, 2011; Vigneau et al., 2006).

Our clinical observations of LTLE patients during both naming assessment and spontaneous speech suggest that most patients struggle to access the particular word; however, they do not appear to struggle with its meaning. For instance, in a tip-of-the-tongue state, patients typically gesture the use of an object or describe the item. In fact, they often state, “I know what it is, but I can't remember what it is called.” Thus, it is surprising that few of the studies that have examined linguistic subprocess of naming in TLE have concluded that TLE patients have deficits in semantic processing. For example, by analyzing the level of detail provided in spoken definitions, Bell et al. (2001) found that compared to controls, TLE patients provided fewer detailed semantic features that distinctively characterize a concept, (e.g., *trunk* for *elephant*). This was interpreted to reflect an impoverished access to meaning; however, given the word retrieval demands embedded in the task itself, it is possible that the relatively impoverished responses actually reflected word-finding difficulty rather than reduced semantic knowledge. Additionally, this study did not examine performance separately in (dominant) left and (nondominant) right TLE (RTLE) patients; thus, it is not possible to understand these results in the context of lateralized language function. Giovanoli et al. (2005) eliminated the verbal word retrieval confound by utilizing mainly nonverbal responses (e.g., pointing) in a series of tasks requiring semantic judgments in LTLE and RTLE patients. LTLE patients showed deficits on a subset of these tests; however, the absence of a more generalized deficit raises the possibility that the poorer performances were due to task-specific characteristics rather than a true semantic impairment.

In the present investigation, we aimed to conduct a valid assessment of the integrity of the semantic system in LTLE. In addition to multiple naming measures, we administered a set of linguistic tasks that tap semantic knowledge and processing without requiring verbal responses, thereby minimizing the contribution of phonological retrieval. One semantic task (lexical decision) assessed automatic semantic priming processes, and a second required a conscious decision regarding relative differences in semantic relatedness. These tasks, which utilized both words and pictures, as well as automatic and conscious processing, provided a well-rounded examination of semantic processing. Further, we recorded response time (RT) as well as response accuracy, as a more sensitive measure of timing would increase the likelihood of detecting milder, yet genuine deficits.

We suspected that despite the presence of a naming deficit, semantic processing is nevertheless, intact in LTLE. As (nondominant) RTLE patients do not exhibit naming impairment, and therefore, would not be expected to have semantic deficit, we compared naming and semantic processing between LTLE and RTLE patients, as this would control for potential, nonspecific epilepsy-related factors that could theoretically, affect task performance. We included a healthy control group as well, to serve as a frame of reference for normal task performance. However, analyses between LTLE and RTLE patients yield a more rigorous comparison.

We hypothesized that LTLE patients would perform poorly on measures of word finding, yet would exhibit performance patterns on semantic tasks comparable to RTLE patients. That is, we anticipated a dissociation between impaired naming and relatively spared semantic processing within the LTLE group.

Methods

Participants

Patients—Thirty-three consecutive patients with medically intractable, unilateral TLE (17 LTLE, 15 RTLE) undergoing evaluation for surgical treatment at the Columbia Comprehensive Epilepsy Center participated in the study. Patient participants were required to be native English speakers and left hemisphere language dominant as determined by the results of Wada testing, fMRI (Binder, Swanson, Hammeke, & Sabsevitz, 2008) or postictal language testing (Privitera, Morris, & Gilliam, 1991). Lateralization of seizure onset was established based on continuous video-EEG monitoring. Patients were excluded if MRI revealed contralateral structural abnormalities.

Healthy controls—Seventeen healthy adults were recruited to match patient participants in age and education. Individuals with a history of learning disability, language problems, head injury, stroke or other neurological disorders were excluded. Healthy adults reported themselves to be native English speakers.

All participants were required to have a minimum education level of 8 years and a minimum scaled score of 7 (low average range) on the WAIS-III Vocabulary subtest. Demographic data for all three groups are shown in Table 1. There were no group differences in age, education, nonverbal reasoning, or Full Scale IQ; however, vocabulary was significantly higher in controls compared to LTLE patients. There were no significant differences between patient groups with respect to demographic data.

Tasks

Naming Tasks—Three different naming tasks were administered to determine whether the current LTLE group demonstrated naming difficulties comparable to those reported in prior studies.

1. Boston Naming Test (BNT): The BNT (Kaplan, Goodglass, & Weintraub, 1983) was included due to its widespread use in naming assessment, and therefore, its utility in comparing naming performance of the current patient group with that reported previously. The BNT is comprised of 60 line drawn objects varying in familiarity and with names varying in word frequency. Correct responses produced within 20 seconds from picture presentation are scored for accuracy.

2. Computerized Picture Naming: In this object-naming task, naming RTs were recorded via voice activated timer to examine the ubiquitous effect of word frequency, demonstrated by an inverse correlation between naming RTs and name frequencies (Almeida, Knobel, Finkbeiner, & Caramazza, 2007; Jescheniak, & Levelt, 1994). Stimuli consisted of line drawn common objects selected from Snodgass and Vanderwart (1980). Half of the pictures (N=40) had low-frequeny names (<7 occurrences per million words), and the other half (N=40) had high-frequency names (>32 occurrences per million words). High- and low-frequency pictures were matched for three measures that could affect naming RTs: (a) visual complexity (a rating of the complexity of a drawing, as defined by the number of lines in a drawing and their intricacy); (b) image agreement (a rating of the accuracy with which an object is depicted); and (c) name agreement (a measure of the consistency with which a name is used to identify the picture). Measures of frequency, visual complexity, and image and name agreement were from Snodgass and Vanderwart (1980) (see Table 2 for summary). Pictures were shown individually, centered on a computer screen. Naming RTs corresponded to the time elapsed from picture presentation to response onset. Participants were instructed to name the pictures as quicky as possible without sacrifizing accuracy. Only accurate responses were included in naming latency analyses.

3. Auditory Naming and Visual Naming Tests: These naming tasks consist of 50 orally presented descriptions and 50 line drawn objects, the target words of which are matched for word frequency, enabling comparison of auditory-description and visual-object naming performance (Hamberger, Goodman, Perrine, & Tammy, 2001; Hamberger & Seidel, 2003). Mean word frequency for both tasks is higher than that of the BNT, minimizing the potential confounds of education and vocabulary. All target words corresponded to concrete objects. Descriptions were designed to be brief (presentable within 4 seconds) and to provide key features for correct concept identification (e.g., “What a king wears on his head”).

Descriptions were presented orally by the experimenter, and participants were instructed to initiate their responses as quickly as possible. Descriptions were structured such that the final word of the descriptions was necessary for accurate identification of the item (e.g., "the yellow part of an egg," "the hard outside edges of bread"). As these tasks were developed for use in neuropsychological assessmsent or bedside testing, naming RTs are recorded via stopwatch. Naming RTs corresponded to the time between picture onset (Visual Naming), or the end of the verbal definition (Auditory Naming), and response onset. Participants were permitted a maximum of 20 seconds to respond. If the correct word was not provided, the trial was coded as incorrect, and a phonemic cue was presented (e.g., "ha" for "hammer"). If the correct word was produced within 5 seconds from cue presentation, the response was scored *correct with phonemic cue*. These items, togeher with items named > 2 sec but < 20 sec from item presentation were summed together for a tip-of-the-tongue (TOT) score (i.e., item names that are within the subject's mental lexicon, yet required additional time or phonemic cueing for retrieval; for a more detailed description, see Hamberger & Seidel, 2003). Normative data are provided for accuracy, mean response time and TOT; however, as TOT scores have been shown to be the most sensitive of the three performance measures (Hamberger & Seidel, 2003; Hamberger et al., 2005), we utilized TOT scores in the current study.

Semantic Tasks

1. Semantic Priming: Prime-target pairs (N=200) were visually presented. Primes and 50% of the targets (N=100) were real words. The other 50% of targets were pronounceable nonwords obtained by changing a letter from existing words (limp → *kimp*; soup → *roup*). Thirty-four of the word primes were paired to semantically related target words to create related pairs (*tree-leaf*). These 34 primes and targets were randomly re-paired to form semantically unrelated pairs (*night-leaf*) that served as baseline. The same 34 primes were presented a third time paired with nonwords. The remaining pairs included word primes (N=98), word targets (N=32), and nonword targets (N=66) presented only once.

Latent Semantic Analysis (LSA; Landauer & Duamis, 1997), which provides semantic relatedness scores based on co-occurrence frequencies in large text corpora, was used to quantify the degree of semantic relatedness between primes and targets. LSA scores, which range from 0 (maximum semantic dissimilarity) to 1 (maximum semantic similarity), were significantly higher for related compared to unrelated pairs (means: 0.48 vs. 0.11; $t(31)=11.18$, $P<.0001$).

Target-word pairs were distributed across four blocks under the constraints that (a) a word appeared no more than once per block, (b) related pairs occur with equal frequencies (8 times) within blocks, and (c) there were no more than three consecutive responses of the same type (i.e., word vs. nonword). Words and nonwords were 3–8 letters and were presented on a computer screen in Times New Roman font, size 72. A fixation cross appeared for 300 ms, followed by a 200 ms prime word, then a 200 ms ISI, followed by the target word on screen for 2 seconds. The inter-trial interval was set at 1 second. Word/nonword decisions were expressed by pressing distinct keys of the computer keyboard, with the left and right hand, respectively.

Participants were told that a series of word pairs would be presented, one word at a time, with the first word disappearing very quickly and the second word remaining longer on the screen. Participants were advised that the second word would be either a real word or a nonword. Right-handed participants were instructed to press number *one* on the response box if the second word was not a real word, and to press number *two* if it was a real word. This pattern was reversed for left-handed participants. Participants were instructed to respond as quickly and accurately as possible.

2. Picture Matching: Participants decided which of two pictures was more closely related to a third picture (the probe). For example, *mop* instead of *broom* was the correct response with the probe *bucket*. Because *mop*, *broom*, and *bucket* are all items used in cleaning, deciding between *mop* and *broom* required the availability of specific and detailed semantic knowledge. LSA scores (Landauer & Duamis, 1997) confirmed that probes were more similar to targets relative to foils (means: 0.39 vs. 0.19; $t(36)=6.01$, $P<.0001$; comparison based on 37/44 pairs available). This type of fine-tuned semantic cognizance is highly vulnerable to semantic deficit (Patterson et al. 2007), and patients with semantic damage have shown impaired accuracy in this type of picture-matching task (Bozeat et al., 2000). Response times were also recorded to render the task sensitive to even mild semantic deficits. In each of 44 trials, the probe picture appeared in the upper half of the computer screen, and the two picture choices appeared in the lower half, one on the left, the other on the right. Participants pressed a left or right computer key to indicate their selection. Response handedness was counterbalanced across trials.

Statistical analyses

In keeping with our hypothesis, the critical comparisons across tasks involve the two patient groups, which were carried out using t-tests with a significance criterion of $P=.05$. For sake of completeness, we also report effects of Group (controls, RTLE and LTLE patients) obtained from ANOVAs across tasks.

Results

Naming tasks

Results from all naming tasks are shown in Table 3, separately for each group. We analyzed naming accuracy in the BNT, naming accuracy and latency in Computerized Picture Naming, and TOT scores in Auditory and Visual Naming. Effects of Group (controls vs. RTLE patients vs. LTLE patients) were significant across tasks (BNT: $F(2, 47)=5.3$, $P=.008$; Computerized Picture Naming: accuracy ($F(2, 47)=6.7$, $P=.002$), latency ($F(2, 47)=3.87$, $P=.02$); TOTs: Visual Naming ($F(2, 47)= 4.36$, $P=.01$); Auditory Naming ($F(2, 47)=5.42$, $P=.007$)), due to the expected, poorer naming performance of LTLE patients. Results in Table 3 show that for the LTLE group, naming was significantly less accurate, slower and with more TOTs relative to RTLE patients. None of the comparisons between RTLE patients and controls were significant. In summary, results from these naming tasks, which tap similar as well as different aspects of naming, are consisent with previously reported findings in showing naming difficulty in LTLE patients relative to RTLE patients (and normal controls). Thus, it appears safe to suggest that the current LTLE patients show a relative impairment in naming, and can be considered a representative sample, comparable to LTLE pateints in the general naming literature.

Significant (P=.01) effects of Word Frequency, a well-established finding in healthy adults reflecting faster naming responses to pictures with high vs. low frequency names, were observed within each group (normal controls: 46 ms; RTLE patients: 45 ms; LTLE patients: 61 ms). Furthermore, Group (controls vs. RTLE patients vs. LTLE patients) × Frequency (high vs. low) interaction was not significant for naming accuracy nor naming latency, as revealed by ANOVA. As suggested by these latter results, the slow responses by LTLE for both frequency levels imply widespread naming difficulties among LTLE patients, similarly affecting the retrieval of both high and low frequency words (i.e, no benefit for high frequency items).

Semantic tasks

A summary of the results in the semantic tasks is presented in Table 4.

1. Semantic Priming—Lexical decision RTs were comparably accurate (~95%) and rapid between RTLE and LTLE patients. Analyses of the response RTs of normal controls, conducted to validate the suitability of the priming task, revealed a significant priming effect of 19 ms. Priming effects were significant within both LTLE patients (17 ms) and RTLE patients (16 ms). Priming effects were comparable in size across groups, as indicated by the lack of interaction between Group and Prime (related vs. unrelated; $F(2, 44)=.03$, $P=97$). This priming effect in LTLE patients constrasts with naming results, which revealed consistently poorer LTLE perforamce relative to naming performance of the other two groups.

2. Picture matching—Semantic relatedness decisions were comparable for both accuracy (mean = 97%) and speed between RTLE and LTLE patients. The means of the LTLE group fall witihn the 95% confidence intervals calculated for the RLTE patients, suggesting strong similarities, both in terms of accuracy and RTs, between the responses of patients groups. The effect of Group was not significant for decisions RTs ($F(2, 45)=1.56$, $P=.22$), again in sharp contrast to naming task results.

Discussion

With the overall goal of elucidating the linguistic mechanism(s) that underlie the word-finding difficulty that is commonly observed in LTLE, the current investigation aimed to assess the integrity of semantic processing in LTLE patients with documented word finding deficits. Prior work that linked word-finding difficulty in LTLE to semantic deficits (Bell et al., 2001) assessed semantic functioning with tasks that required word retrieval, which confounded the assessment of semantic processing with word finding. In the current study, we administered multiple naming measures, and a set of linguistic tasks that tap the semantic system without requiring verbal responses. Additionally, we collected response times (as well as accuracy) to enable detection of subtle, yet genuine deficits, and utilized different types of materials (written words and pictures), and different paradigms, requiring both automatic priming (lexical decision) and conscious decision making (picture-matching), for a well-rounded examination of semantic functioning.

The current results revealed a clear dissociation in LTLE patients between naming performance, which was impaired, and semantic processing, which was intact, and comparable to that of RTLE patients and healthy controls. Thus, while LTLE patients showed naming deficits that were comparable in severity to those of prior studies, their performance on semantic tasks appeared to be relatively spared. It is also worth mentioning that while the performance of LTLE patients was consistently worse relative to normal controls in naming tasks, no significant differences appeared in the semantic tasks. Given the response time patterns demonstrated by LTLE patients on tasks requiring the retrieval of very specific semantic features, semantic impairment does not appear to be the probable cause of the naming deficits in LTLE. Rather, we would infer that naming deficits stem from damage to lexical mechanisms that follow semantic retrieval and culminate in sound articulation. Lexical mechanisms encompass retrieval and integration of various features of words, including syntactic, morphological, phonological, and phonetic information. Although our findings do not clarify which of these mechanisms is impaired in LTLE, they circumscribe the damage responsible for naming deficits to the lexical level.

The sharp dissociation in LTLE between semantic processing and word retrieval resembles analogous dissociations documented in neuropathologies as diverse as stroke and semantic dementia. Hence, the current results add to a pre-existing and growing literature suggesting that partially distinct neural structures mediate semantic processing and word retrieval, such that the retrieval of either semantics or words can be selectively impaired or preserved.

Findings from lesion studies, neuroimaging and electrophysiological investigations reveal a superior-inferior gradient in the temporal area, implicating the posterior middle and inferior temporal (i.e., ventral) region as essential for semantic processing, whereas temporal regions superior to those associated with semantic processing appear to be involved in the processing of word phonology in word production (Binder et al., 2009; Graves et al., 2007; Indefrey, 2011; Martin, 2007; Vigneau et al., 2006). It has further been proposed that the functional distinction involving these temporal regions reflects a more general organization of the language system via independent dorsal and ventral processing streams, similar to that described for the visual system (Hickok and Poeppel, 2004; Saur et al., 2008). Specifically, the superior temporal structures are connected via the dorsal pathway (presumably involving parts of the superior longitudinal fasciculus) to premotor cortex crossing inferior parietal cortex (Frederici, 2012; Hickok & Poeppel, 2007).

Within this framework, unimpaired semantic functioning in LTLE would reflect relatively intact functioning in inferior temporal areas, and by contrast, their naming difficulties would reflect dysfunction involving the superior temporal region, or components of the dorsal language network. Accordingly, recent DTI work has shown structural compromise to the left arcuate fasciculus (i.e., a component of the dorsal stream) in TLE, and moreover, the integrity of the left arcuate fasciculus has been shown to be a strong predictor of naming scores in TLE patients (McDonald, et al., 2008). Furthermore, both ictal and interictal EEG discharges in TLE have been shown to more frequently propagate anteriorly than posteriorly

(Emerson et al., 1995), thus, more likely disrupting processing along anterior rather than posterior-inferior projecting pathways. The current results, together with these other lines of investigation, suggest relatively intact posterior inferior temporal semantic processing, yet relatively impaired superior temporal, phonological processing, potentially underlying the well-established naming deficit in LTLE.

Limitations

The relatively small sample of LTLE patients precludes definitive determination of whether the integrity of the semantic system is a general feature of LTLE, or whether semantic impairment might be present in a subset of LTLE patients. Additionally, the strength of our conclusions about semantic processing depends crucially on the sensitivity of the semantic tasks utilized. We selected these particular tasks because they have yielded robust semantic effects in the healthy individuals, they test detailed semantic features that are particularly susceptible to semantic deficits, and, in the case of semantic priming, tap processes largely unaffected by strategic control. Nevertheless, they cannot guarantee the detection of subtle semantic deficits. Furthermore, the results from these semantic tasks rest on medium effect sizes. The semantic priming had a medium effect size (Cohen's d=.30), as estimated from the results of our normal control. The same holds for the comparisons between LTLE and RTLE patients in Picture Matching (Cohen d=.27). Certainly, larger effect sizes would be desirable. Nevertheless, the fact that convergent results appeared in our study from two distinct tasks engenders a reasonable level of confidence in the current results.

Clinical implications

Despite the prevalence of word finding difficulty and its associated psychological distress in TLE (Thompson & Corcoran, 1992), we are aware of no studies aimed to remediate word finding difficulty in this population. In fact, a recent evidence-based review of cognitive rehabilitation in medical conditions affecting cognitive function found only five papers regarding cognitive remediation in epilepsy that met criterion for review, three of which were case studies(Langenbahn, Ashman, Cantor, & Trott, 2013). Most relevant, all five studies focused on memory and attention, with none addressing naming difficulty, despite its reliable ranking as a top complaint among epilepsy patients. Although this lack of attention to naming likely reflects, primarily, the seemingly more dramatic effects of memory dysfunction, we speculate that this might also reflect the mistaken assumption that naming difficulty in epilepsy stems from an impoverished semantic system, which could be considered more difficult to remediate. Certainly, further work is necessary to confirm and more precisely define the particular aspects of lexical processing that are disrupted in TLE. Nevertheless, by identifying a locus of impairment, the current findings provide a first and necessary step toward the development appropriately targeted remediation strategies for naming difficulty in TLE.

Closing comments

Word finding difficulty is a serious cognitive deficit and source of distress in LTLE. Although word finding dysfunction in TLE is a reliable and robust finding, minimal efforts have been directed toward understanding the source of naming dysfunction in TLE, and there have been no systematic attempts to remediate naming in this population. Expressive verbal skills are essential for normal academic, occupational and social functioning, and thus, naming deficits warrant attention. The current findings, suggesting intact semantic functioning in LTLE, shifts the focus of these efforts to post semantic, lexical/phonological processing and dorsal language stream functioning, consistent with neuroimaging studies demonstrating the association between reduced integrity in this region and naming difficulty in TLE. Future work can aim to identify the particular components of lexical processing that disrupt word retrieval and their neural substrates, and to determine how best to remediate or compensate for these difficulties to ultimately improve word retrieval and expressive language in individuals with LTLE.

Acknowledgements

We thank Alicia C. Williams for subject testing and data management, and gratefully acknowledge the participants in this study for their time and effort. This work was supported The National Institute of Neurological Disorders and Stroke, Grant Number NIH R01 NS35140 (MH).

References

Almeida J, Knobel M, Finkbeiner M, Caramazza A. The locus of the frequency effect in picture naming: When recognizing is not enough. Psychological Bulletin. 2007; 14:1177–1182.

Bell BD, Herman BP, Woodard AR, Jones JE, Rutecki PA, Sheth R, Dow CC, Seidenberg M. Object naming and semantic knowledge in temporal epilepsy. Neuropsychology. 2001; 15:434–443. [PubMed: 11761032]

Binder JR, Desai RH, Graves WW, Conant LL. Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. Cerebral Cortex. 2009; 19:2767–2796. [PubMed: 19329570]

Binder JR, Swanson SJ, Hammeke TA, Sabsevitz DS. A comparison of five fMRI protocols for mapping speech comprehension systems. Epilepsia. 2008; 49:1980–1997. [PubMed: 18513352]

Bozeat S, Lambon Ralph MA, Patterson K, Garrad P, Hodges JR. Non-verbal semantic impairment in semantic dementia. Neuropsychologia. 2000; 38:1207–1215. [PubMed: 10865096]

Caramazza A. How many levels of processing are there in lexical access? Cognitive Neuropsychology. 1997; 14:177–208.

Chelune G, Naugle R, Lauders H, Awad I. Prediction of cognitive change as a function of preoperative ability status among temporal lobectomy patients seen at 6-months follow-up. Neurology. 1991; 41:399–404. [PubMed: 2006008]

Damasio H, Tranel D, Grabowski T, Adolphs R, Damasio A. Neural systems behind word and concept retrieval. Cognition. 2004; 92:179–229. [PubMed: 15037130]

Davies KG, Maxwell R, Beniak T, Destafney E, Fiol M. Language function after temporal lobectomy without stimulation mapping of cortical function. Epilepsia. 1995; 36:130–136. [PubMed: 7821269]

Dell GS. A spreading-activation theory of retrieval in sentence production. Psychological Review. 1986; 93:283–321. [PubMed: 3749399]

Emerson RG, Turner CA, Pedley TA, Walczak TS, Forgione M. Propagation patterns of temporal spikes. Electroencephalography and Clinical Neurophysiology. 1995; 94:338–48. [PubMed: 7774520]

Frederici AD. The cortical language circuit: from auditory perception to sentence comprehension. Trends in Cognitive Science. 2012; 16:262–268.

Giovagnoli AR. Characteristics of verbal semantic impairment in left hemisphere epilepsy. Neuropsychology. 2005; 19:501–508. [PubMed: 16060825]

Giovagnoli AR, Erbetta A, Villani F, Avanzini G. Semantic memory in partial epilepsy: verbal and non-verbal deficits and neuroanatomical relationship. Neuropsychologia. 2005; 43:1482–1492. [PubMed: 15989938]

Gorno-Tempini ML, Brambati SM, Ginex, Ogar J, Dronkers NF, Marcone A, Perani D, Garibotto V, Cappa SF, Miller BL. The logopenic/phonological variant of primary progressive aphasia. Neurology. 2008; 71:1227–1234. [PubMed: 18633132]

Graves WW, Grabowski TJ, Mehta S, Gordon JK. A neural signature of phonological access: distinguishing the effects of word frequency from familiarity and length in overt picture naming. Journal of Cognitive Neuroscience. 2007; 19:617–631. [PubMed: 17381253]

Hamberger MJ, Cole J. Language organization and reorganization in epilepsy. Neuropsychological Review. 2011; 21:240–251.

Hamberger MJ, Goodman RR, Perrine K, Tammy T. Anatomical dissociation of auditory and visual naming in lateral temporal cortex. Neurology. 2001; 56:56–61. [PubMed: 11148236]

Hamberger MJ, Seidel WT. Auditory and visual naming tests: Normative and patient data for accuracy, response time, and tip-of-the-tongue. Journal of the International Neuropsychological Society. 2003; 9:479–489. [PubMed: 12666772]

Hamberger MJ, Seidel WT, Goodman RR, Williams A, Perrine K, Devinsky O, McKhann GM II. Evidence for cortical reorganization of language in patients with hippocampal sclerosis. Brain. 2005; 130:2942–2950. [PubMed: 17704527]

Hermann BP, Wyler AR. Effects of anterior temporal lobectomy on language function: A controlled study. Annals of Neurology. 1988; 23:585–588. [PubMed: 3408239]

Hickok G, Poeppel D. The cortical organization of speech perception. Nature Review Neuroscience. 2007; 8:393–402.

Hillis A, Rapp E, Romani B, C. Caramazza A. Selective impairment of semantics in lexical processing. Cognitive Neuropsychology. 1990; 7:191–243.

Howell RA, Saling MM, Bradley DC, Berkovic SF. Interictal language fluency in temporal lobe epilepsy. Cortex. 1994; 30:469–478. [PubMed: 7805387]

Indefrey P, Levelt WJM. The spatial and temporal signatures of word production components. Cognition. 2004; 92:101–144. [PubMed: 15037128]

Indefrey P. The spatial and temporal signatures of word production components: a critical update. Frontiers in Psychology. 2011; 2:255. doi:10.3389/fpsyg.2011.00255. [PubMed: 22016740]

Jescheniak JD, Levelt WJM. Word frequency effects in speech production: Retrieval of syntactic information and of phonological form. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1994; 20:824–843.

Kaplan, EF.; Goodglass, H.; Weintraub, S. The Boston Naming Test. Lea & Febiger; Philadelphia (PA): 1983.

Kay J, Ellis A. A cognitive neuropsychological case study of anomia. Brain. 1987; 110:613–629. [PubMed: 3580826]

Landauer TK, Duamis ST. A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. Psychological Review. 1997; 104:211–240.

Langenbahn DM, Ashman T, Cantor J, Trott C. An evidence-based review of cognitive rehabilitation in medical conditions affecting cognitive function. Archives of Physical Medicine & Rehabilitation. 2013; 94:271–286. [PubMed: 23022261]

Langfitt JT, Rausch RR. Word-finding deficits persist after left anterotemporal lobectomy. Archives of Neurology. 1996; 53:72–76. [PubMed: 8599562]

Levelt WJ, Roelofs A, Meyer AS. A theory of lexical access in speech production. Behavioral Brain Science. 1999; 22:1–38.

Martin A. The representation of object concepts in the brain. Annual Review of Psychology. 2007; 58:25–45.

Mayeux R, Brandt J, Rosen J, Benson DF. Interictal language and memory impairment in temporal lobe epilepsy. Neurology. 1980; 30:120–125. [PubMed: 7188792]

McDonald CR, Ahmadi ME, Hagler DJ, Tecoma ES, Iragui VJ, Gharapetian L, Dale AM, Halgren E. Diffusion tensor imaging correlates of memory and language impairments in temporal lobe epilepsy. Neurology. 2008; 71:1869–1876. [PubMed: 18946001]

Author Manuscript
Author Manuscript
Author Manuscript

Patterson K, Nestor PJ, Rogers TT. Where do you know what you know? The representation of semantic knowledge in the human brain. Nature Review Neuroscience. 2007; 8:976–987.

Privitera MD, Morris GL, Gilliam F. Postictal language assessment and lateralization of complex partial seizures. Annals of Neurology. 1991; 30:391–396. [PubMed: 1952827]

Raspall T, Donãte M, Boget T, Donaire MCA, Agudo R, et al. Neuropsuchological tests with lateralizing value in patients with temporal lobe epilepsy: Reconsidering material-specific theory. Seizure. 2005; 14:569–576. [PubMed: 16269253]

Raven, J.; Raven, JC.; Court, JH. Manual for Raven's Progressive Matrices and Vocabulary Scales. Harcourt Assessment; San Antonio, TX: 2003.

Saur D, Kreher BW, Schnell S, Kümmerer D, Kellmeyer P, Vry M-S, et al. Ventral and dorsal pathways for language. Proceedings of the National Academy of Sciences of the United States of America. 2008; 105:18035–18040. [PubMed: 19004769]

Saykin AJ, Stafiniak P, Ronison LJ, Flannery KA, Gur RC, O'Connor MJ, Sperling MR. Language before and after temporal lobectomy: Specificity of acute changes and relation to early risk factors. Epilepsia. 1995; 36:1071–1077. [PubMed: 7588450]

Schwartz TH, Devinsky O, Doyle W, Perrine K. Preoperative predictors of anterior temporal language areas. Journal of Neurosurgery. 1998; 89:962–970. [PubMed: 9833823]

Snodgrass JG, Vanderwart M. A standardized set of 260 pictures: norms for name agreement, image agreement, familiarity, and visual complexity. Journal of Experimental Psychology: Human Learning. 1980; 6:174–215.

Thompson PJ, Corcoran R. Everyday memory failures in people with epilepsy. Epilepsia. 1992; 33:S18–S20. [PubMed: 1486831]

Wechsler, D. Wechler Adult Intelligence Scale – III manual. Psychological Corporation; New York (NY): 1997.

Vigneau M, Beaucousin V, Herve PY, Duffau H, Crivello F, Houde O, et al. Meta-analyzing left hemisphere language areas: phonology, semantics, and sentence processing. Neuroimage. 2006; 30:1414–1432. [PubMed: 16413796]

Table 1

Demographic Data and Test Scores– Mean (SD)

	Controls	RTLE	LTLE	F	P
Age[a]	33.8 (12.5)	42.1 (9.7)	41.7 (14.5)	2.3	.11
Education[a]	16.8 (2.2)	15.5 (3.0)	15.8 (2.5)	1.1	.33
Epilepsy Onset Age [a]		22.8 (18.0)	19.6 (12.8)[b]		
Vocabulary[c]	14.5 (3.0)	12.2 (3.5)	10.4 (2.5)	8.0	.0009
Matrix Reasoning [d]	13.8 (2.9)	12.4 (2.3)	11.8 (2.6)	2.6	.09
FSIQ[e]	114.6 (6.6)	109.7 (11.3)	108.7 (8.6)	2.1	.14

[a]Years.

[b]Onset age, LTLE vs. RTLE, t<1.

[c]Vocabulary subtest scaled score (Wechsler, 1997).

[d]Matrix Reasoning subtest scaled score (Wechsler, 1997).

[e]WAIS III Full Scale IQ (Wechsler, 1997) or North American Adult Reading Test (Blair and Spreen, 1989).

Table 2

Characteristics of Picture Stimuli Shown for Spoken Naming

Picture Features	Mean/Name Frequency [a]	
	High	Low
Visual Complexity	2.7	2.8
Image Agreement	3.5	3.7
Name Agreement (H)	.50	.61
Name Frequency [b]	112.7	2.2

[a]Pictures and norms from Snodgrass and Vanderwart (1980).

[b]Counts per million words.

Table 3

Naming Tasks – Controls, LTLE and RTLE Patients

Naming Task	Mean (SD), 95% Confidence Intervals/Group			RTLE vs. LTLE
	Controls	RTLE	LTLE	(Cohen's d)
Boston Naming Task	94% (6.0)	92% (6.0)	87% (9.1)	t(31)=2.24 P=.03 (.65)
	91–97%	89–96%	81–91%	
Picture Naming Task				
Accuracy	91% (3.7)	93% (3.2)	87% (6.9)	t(31)=3.18 P=.003 (.80)
	90–93%	91–95%	84–90%	
Naming RTs (ms)	708 (87)	703 (66)	765 (89)	t(31)=2.43 P=.02 (.79)
	663–753	666–740	727–827	
Visual Naming Task				
Tip-of-the-tongues (N)	2.0 (1.6)	1.1 (1.7)	3.5 (3.3)	t(31)=2.56 P=.01 (.94)
	1.2–2.8	0.2–2.0	1.9–5.1	
Auditory Naming Task				
Tip-of-the-tongues (N)	3.0 (3.4)	3.1 (3.7)	6.7 (4.7)	t(31)=2.58 P=.01 (.92)
	1.3–4.8	1.1–5.1	4.7–7.2	

Table 4

Response Accuracies and RTs in Semantic Tasks – Controls, LTLE and RTLE Patients

A. Semantic Priming

Overall Responses	**Mean (SD), 95% Confidence Intervals/Group**			**RTLE vs. LTLE**
	Controls	**RTLE**	**LTLE**	**(Cohen's d)**
Accuracy	98% (1.8)	96% (3.9)	95% (2.7)	t(28)=1.03 P=.31
	97–99%	93–98%	93–96%	
RTs (ms)	570 (52)	620 (115)	671 (126)	t(28)=1.14 P=.23 (.27)
	543–579	545–695	609–735	

Prime-Target	**Mean RTs (ms)/Group**		
	Controls	**RTLE**	**LTLE**
Related	517	572	593
Unrelated	536	588	610
Prime Effect	*19*	*16*	*17*
	t(16)=2.11 P=.05	t(12)=2.17 P=.05	t(16)=2.59 P=.01

B. Picture Matching

	Mean (SD), 95% Confidence Intervals/Group			**RTLE vs. LTLE**
	Controls	**RTLE**	**LTLE**	**(Cohen's d)**
Accuracy	98% (1.6)	97% (2.4)	97% (3.2)	t(30)=0.77 P=.44
	98–99%	96–99%	94–98%	
RTs (ms)	1277 (261)	1373 (325)	1457 (307)	t(30)=0.74 P=.46 (.27)
	1143–1411	1185–1516	1299–1615	