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Category-Specific Naming and Recognition Deficits in Temporal Lobe Epilepsy Surgical Patients

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Abstract

Objective—Based upon Damasio's "Convergence Zone" model of semantic memory, we predicted that epilepsy surgical patients with anterior temporal lobe (TL) seizure onset would exhibit a pattern of category-specific naming and recognition deficits not observed in patients with seizures arising elsewhere.

Methods—We assessed epilepsy patients with unilateral seizure onset of anterior TL or other origin ($n = 22$), pre- or postoperatively, using a set of category-specific items and a conventional measure of visual naming (Boston Naming Test: BNT).

Results—Category-specific naming deficits were exhibited by patients with dominant anterior TL seizure onset/resection for famous faces and animals, while category-specific recognition deficits for these same categories were exhibited by patients with nondominant anterior TL onset/resection. Patients with other seizure onset did not exhibit category-specific deficits. Naming and recognition deficits were frequently not detected by the BNT, which samples only a limited range of stimuli.

Interpretation—Consistent with the "convergence zone" framework, results suggest that the nondominant anterior TL plays a major role in binding sensory information into conceptual percepts for certain stimuli, while dominant TL regions function to provide a link to verbal labels for these percepts. Although observed category-specific deficits were striking, they were often missed by the BNT, suggesting that they are more prevalent than recognized in both pre- and postsurgical epilepsy patients. Systematic investigation of these deficits could lead to more refined models of semantic memory, aid in the localization of seizures, and contribute to modifications in surgical technique and patient selection in epilepsy surgery to improve neurocognitive outcome.

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Keywords

semantic memory; temporal lobe epilepsy; category-specific deficits; epilepsy surgery; naming deficits

While several models of semantic memory exist, most agree that the temporal lobes play an important role in supporting this cognitive construct (Caramazza & Shelton, 1998; H. Damasio, Tranel, Grabowski, Adolphs, & Damasio, 2004; Gainotti, 2006). Research suggesting a role for the temporal lobes in semantic memory includes a variety of studies demonstrating deficits in this area in patients with TL impairment (Bayles, Tomoeda, & Trosset, 1990; Chan et al., 1993; Garrard, Lambon, Patterson, Pratt, & Hodges, 2005; Graham, Patterson, Pratt, & Hodges, 1999; Laws & Sartori, 2005). There are also a number of functional neuroimaging and electrophysiological studies that highlight the importance of these regions (Elfgren et al., 2006; Martin, Wiggs, Ungerleider, & Haxby, 1996; Perani et al., 1999; Turk, Rosenblum, Gazzaniga, & Macrae, 2005). Although the temporal lobes represent the most common site of onset for complex partial seizures, and these regions are routinely resected in an effort to achieve seizure control (G. A. Ojemann & Valiante, 2006), the status of semantic memory in epilepsy is not fully understood. In the current study, we employed Damasio's framework of semantic memory as a heuristic tool for exploring object recognition and naming in patients with seizure disorder.

Damasio's Convergence Zone (CZ) Model of Semantic Memory

Damasio and colleagues proposed that semantic memories are subserved by distributed neural networks (A. R. Damasio, 1989; H. Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996; H. Damasio et al., 2004; Tranel, Damasio, & Damasio, 1997; Tranel et al., 2003). These networks involve the motor or sensory regions that were originally involved in the perception of a given object or concept. Recall of a specific semantic memory requires the reactivation of these regions, which are believed to be located in the primary and first-order sensory association and motor cortices of both cerebral hemispheres as well as some subcortical nuclei. It is proposed that certain regions of the brain serve as "convergence zones," by reactivating these distributed networks and serving to "bind" sensory and motor input to allow us to form conceptual impressions of our inner and outer worlds. Convergence zones can serve as third-party "mediational zones," acting to coordinate the application of lexical labels to conceptual constructs (i.e., mediating between classic language regions and the proposed distributed neural networks that represent specific semantic memories). While Damasio and colleagues posit the existence of a number of convergence/mediational zones throughout the brain, their work with lesion analysis and functional neuroimaging has suggested critical roles for the inferotemporal (IT) and temporal-polar (TP) cortices in the case of recognizing and naming concrete entities (H. Damasio et al., 2004; Tranel, Logan, Frank, & Damasio, 1997; Tranel et al., 2003).

Based on the CZ model, several sites in the left temporal lobe appear to play a critical role in applying names to visually presented items belonging to several specific semantic categories (H. Damasio et al., 1996). Patients with anterior left temporal lobe lesions tended to exhibit naming deficits for unique persons and/or animals while those with more posterior lesions (i.e., maximal overlap in the left occipital-temporal-parietal junction) tended to exhibit deficits in naming tools. While these patients were unable to name the specified objects, they retained the capacity to recognize them, as demonstrated by their ability to provide an accurate object description. The importance of these brain regions was further supported by a parallel functional imaging study (using PET) in healthy comparison subjects, which showed that retrieval of words for entities from distinct conceptual categories was correlated with activation of neural sites comparable to those identified in the lesion study (H. Damasio et al., 1996).

Tranel et al. (1997) demonstrated that there are also sites in both the left and right temporal lobes (as well as other brain regions) whose function appears to involve unifying sensory and motor input into a conceptual percept at a pre-lexical level, as demonstrated by an inability to either name or recognize a given object. More specifically, patients with unilateral brain lesions who exhibited recognition deficits for unique persons exhibited maximal lesion overlap in the right temporal pole, while patients who exhibited recognition deficits for tools exhibited maximal lesion overlap in the left occipital-temporal-parietal junction. For those exhibiting recognition deficits for animals, lesion overlap was maximal in bilateral mesial occipital lobe regions extending into the right mesial ventral temporal region.

As the temporal lobes purportedly contain many of these convergence zone sites, patients with temporal lobe epilepsy (TLE) might exhibit predictable category-specific recognition and naming deficits if this model is accurate. This would be particularly true of patients who have undergone surgery for seizure control, as some of these sites are routinely resected during standard temporal lobe operations. Nevertheless, little research has examined semantic memory in epilepsy, and this construct is usually neglected in the clinical assessment of epilepsy surgical patients.

Evidence of Category-Specific Deficits in TLE Patients

A few researchers have attempted to explore some aspect of category-specific naming deficits in patients undergoing TL resection (Lu et al., 2002; Luckhurst & Lloyd-Jones, 2001; Strauss et al., 2000; Tippett, Glosser, & Farah, 1996). Many of these studies lacked pre-surgical performance data, control for atypical language lateralization, adequate measures of semantic processing, and post-operative neuroimaging to quantify surgical lesions. More importantly, these studies have focused on broad categorizations of objects, primarily “living” versus “non-living” items, rather than more specific subcategories. They have also tended to restrict their examination to patients undergoing left TL resection due to the preconception that failure on naming tasks primarily reflects a classic language disturbance (e.g., dysnomia) that will only be observed following dominant hemisphere resection. There has also been little attention paid to the distinction between naming (i.e., retrieving the lexical label that corresponds to an entity) and recognition (i.e., retrieving conceptual/semantic knowledge that allows the understanding of what an entity is), with most studies focusing exclusively on naming. Despite these limitations, each study found some evidence for category-specific naming deficits in post-surgical epilepsy patients, although the results of these studies have often conflicted and the magnitude of the observed deficits appears to have been greatly underestimated.

Research examining category-specific recognition deficits in epilepsy has been restricted to three studies exploring the recognition of famous faces (Glosser, Salvucci, & Chiaravalloti, 2003; Seidenberg et al., 2002; Viskontas, McAndrews, & Moscovitch, 2002). All three found recognition of famous faces to be worse for patients who have undergone right TL resection. Two of these studies suggested that the ability to name famous faces is worse following left TL resection but this has not been systematically explored (Viskontas et al., 2002; Seidenberg et al., 2002). Glosser and colleagues (2003) provided evidence suggesting that the anterior TL plays a role in both naming and recognition of famous faces. Performance of epilepsy patients undergoing TL resection was worse on these tasks than in a group of unoperated patients. Glosser et al. (2003) interpreted this to indicate that it was the removal of anterior TL structures that contributed to the observed deficit, although this was not conclusively established.

Current hypotheses

The three main conceptual categories used by Damasio and colleagues (i.e., famous faces, animals, man-made objects) were employed in order to determine whether category-specific recognition and naming deficits occur in TLE surgical patients either pre- or post-resection.

This is the first study to systematically explore these specific categories in a clinical epilepsy surgical sample while drawing comparisons to a normative group. Patients with seizures arising outside of the anterior TL were examined, providing an additional comparison group (i.e., Other Seizure Onset: OSO). We predicted that TL epilepsy patients would demonstrate a pattern of recognition and naming deficits consistent with the semantic memory model of Damasio and colleagues (H. Damasio et al., 1996; Grabowski et al., 2001; Tranel, Damasio et al., 1997), while OSO patients would not exhibit any significant deficits on these tasks:

Hypothesis #1

Epilepsy patients with dominant anterior TL seizure onset will exhibit significant deficits in their ability to name famous faces and non-unique animals both pre- and post-operatively as compared to TLE patients with nondominant seizure onset, OSO epilepsy patients, and normative data, but will have intact recognition of these stimuli. In contrast, they will not exhibit deficits in the naming or recognition of man-made objects as compared to these other groups.

Hypothesis #2

Epilepsy patients with nondominant anterior TL seizure onset will exhibit significant deficits in their ability to recognize famous faces both pre- and post-operatively as compared to epilepsy patients with dominant anterior TL seizure onset, OSO epilepsy patients, and normative data. In contrast, they will not exhibit deficits in the recognition or naming of man-made objects as compared to these other groups. Recognition of animals could potentially be impaired in this nondominant TL seizure onset group as well, if electrical disruption or surgical resection involving the IT region extends far enough posteriorly (i.e., mid to posterior inferior temporal gyrus).

Hypothesis #3

Significant category-specific naming deficits will be more prevalent among the TLE patient groups than will deficits observed on a standard clinical naming task (i.e., Boston Naming Test), as we believe that the BNT is restricted in the range of sampled categories (i.e., mostly includes man-made objects).

Methods

Subjects

Semantic memory performance in 22 pre- or post-surgical epilepsy patients with seizure onset involving the anterior temporal lobes ($n = 16$) or seizure onset involving other brain regions ($n = 6$) were evaluated. An effort was made to assess all epilepsy surgical patients who were seen during a 15-month span of time who were willing to participate. All patients had seizures of unilateral onset as determined by video-EEG monitoring. All patients completed our standard neuropsychological battery, intracarotid amobarbital (Wada) assessment, and an MRI of the brain. Additional studies were required to determine seizure localization in some patients (e.g., intracranial monitoring, PET or SPECT scans). Patients with dominant hemisphere seizure onset also underwent intraoperative cortical stimulation language localization. All patients were left-hemisphere dominant for speech as determined by the Wada procedure. The 16 TLE patients included ten individuals with seizures lateralized to the left hemisphere and six individuals with seizures lateralized to the right hemisphere. The six epilepsy patients with seizure onset involving brain regions other than the temporal lobes included three individuals with seizures lateralized to the left hemisphere and three individuals with seizures lateralized to the right hemisphere. Eight of the TLE patients and three of the OSO patients had already undergone cortical resection while all other patients had undergone preoperative work-up for

epilepsy surgery and were awaiting surgery. Post-operative patients were assessed approximately one year after surgery ($M = 13.2$ months, $SD = 3.6$). Including both pre- and post-operative patients in this study provided an opportunity to get preliminary data about the possible impact of surgery versus the impact of epilepsy and disease progression. It is possible that electrical activity, structural lesions, and the impact of surgery may all have an impact upon the naming and recognition skills presumed to be coordinated by these brain regions.

Most patients (19 of 22) experienced seizure onset as adults while the remaining three experienced seizure onset during infancy. There were no differences between the left TLE patients, right TLE patients, and the OSO patients in terms of gender, number of antiepileptic medications, age of seizure onset, educational attainment, or age at the time of testing. There was a slight but non-significant trend for the left (dominant) TLE group to perform worse on the BNT (Kaplan, Goodglass, & Weintraub, 1983) than the other two groups. Exclusionary criteria used for the current study included atypical speech lateralization ($n = 1$), impaired primary visuo-perception or visual-spatial processing ($n = 1$), English as a second language ($n = 1$), and presence of aphasia ($n = 2$). Demographic information and seizure-related variables are presented in Table 1.

We have provided a general description of the region of brain impairment in Table 2 that is based on neuroimaging and both ictal and interictal video-EEG results. For post-surgical patients, Table 3 contains a description of their surgical resections. This includes the location and extent of each resection. Although the surgical resections at our Center involve a tailored approach that is based on electrocorticography (McKhann, Schoenfeld-McNeill, Born, Haglund, & Ojemann, 2000; G. Ojemann, Ojemann, Lettich, & Berger, 1989), most of the temporal lobe resections (particularly the nondominant ones) included in the current study were fairly standard in nature. These resections all included from 40 to 50 mm of middle and inferior temporal gyrus (lateral resection), 50 to 70 mm of basal TL (medial resection), and 20 to 30 mm of hippocampus. Otherwise, this sample includes two TL resections that were more selective in nature, one posterior TL resection, and two frontal lobe resections. The details of these latter resections are provided in Table 3. MRI images from one of the typical ATL resections and one of the selective TL resections are included in Figure 1. Of note, all of the ATLs included resections of the temporal pole and the inferior temporal gyrus. All surgeries were performed by one of three of the authors (GAO, JGO, & DLS).

Procedures

All patients who agreed to participate in the current study were screened for aphasia using select subtests from the Multilingual Aphasia Exam (Benton, Hamsher, & Sivan, 1983) and measures of generative fluency (both letter and semantic: Benton, Hamsher, & Sivan, 1983; Spreen & Strauss, 1998). They were screened for deficits in primary visuo-perception and visual-spatial processing using the Facial Recognition Test (Benton, Hamsher, Varney, & Spreen, 1983), the Judgment of Line Orientation Test (Benton, Hamsher, Varney et al., 1983), and an assessment of visual acuity (Snellen eye chart). Some of these tests were included in the standard neuropsychological assessment completed with both pre- and post-operative epilepsy patients.

All patients meeting inclusion criteria were assessed using category-specific stimuli covering one unique (famous faces) and two non-unique (animals, man-made objects) object categories. All stimuli were obtained from Damasio and colleagues at the University of Iowa College of Medicine, and have been well validated in a series of studies completed in their laboratory (Tranel, Logan et al., 1997). These stimuli have been widely used to study recognition and naming in these three categories. Visual stimuli included pictures of animals, man-made objects, and famous faces, presented on a laptop computer. The pictures of animals ($n = 94$) and man-made objects ($n = 101$) were originally drawn from the Snodgrass and Vanderwart

(1980) line drawings and from a set of photographs prepared by Damasio et al. (1996). The animal domain included several subcategories, including mammals, birds, reptiles, and insects. The man-made object category included a variety of manipulable objects, including common objects used by both genders (e.g., flashlight, shoes, toothbrush). The famous faces ($n = 155$) subtest included individuals known for their involvement in sports, politics, or entertainment (actors/actresses, musicians). The famous faces subtest includes persons who were famous during the first half of the 20th century (e.g., Charlie Chaplin, Winston Churchill) through the current era (e.g., Madonna, George W. Bush, Mel Gibson). No contextual information was included in any of these pictures that could provide clues to their background or reason for notoriety. Examples of each object class can be reviewed in Figure 2, Figure 3, and Figure 4.

For each stimulus, the patient was asked to name the pictured object/person as quickly and accurately as possible. If the initial response was incorrect or if the patient produced a vague or superordinate response (e.g., “animal” or “movie star”), they were prompted to “be more specific; tell me exactly who [what] you think that [thing] is.” If they still did not come up with the specific name, they were asked to describe the object as completely as possible: “Please describe the object [person] in as much detail as possible, so that I will know that you recognize it [them], even if you cannot recall its [their] specific name.” After each response had been completed, the patient was asked if the object or person was familiar to them (e.g., “Is this someone [something] that you have seen before? Does this person [object] seem familiar to you?”). If they indicated that they were even vaguely familiar with an object or person (even if they did not recognize/identify the object or person), this item was included in later analyses. In contrast, if they denied ever seeing the object or person before, the item was dropped from later analysis for that subject. Familiarity ratings were almost 100% from all three patient groups for animals and man-made objects. However, each patient rated at least some of the famous faces as unfamiliar to them. This is not surprising, as many younger individuals may not have seen some of the famous persons from earlier decades (e.g., Winston Churchill, Johnny Carson), while older subjects tended to indicate that they had never seen some of the younger entertainers and sports figures (e.g., Dennis Rodman). Familiarity ratings were not significantly different for the three patient groups for the famous faces subtest, although the right TLE group produced familiarity scores that were slightly lower than the other two groups (84% versus approximately 90% for each of the other groups). Prior to beginning each of these category-specific tests, each subject was given a practice item, with examples of how the stimuli might be described had they not been able to think of its name.

Time limits were not imposed for any of these category-specific naming and recognition tasks. Responses were tape-recorded and transcribed for later scoring. Scoring methodology was generally consistent with the procedures used by Damasio and colleagues (H. Damasio et al., 1996; Tranel, Damasio et al., 1997). Familiarity for each item was a completely subjective rating provided by the patient according to the procedures described above. To receive credit for a correct naming response, subjects were required to provide complete object names and both the first and last names of individuals (except ones for whom one name is typical, e.g., “Madonna,” “Cher”). If a patient correctly named an item, then they automatically received credit for recognition and familiarity, which were assumed to be required for accurate naming. For items that were not correctly named, the patients' transcribed responses were presented to raters who determined what the stimulus was from the description alone, without having in front of them either the stimulus or its name. If this could be done, the item was scored as a correct recognition; if it could not, then the item was scored as a recognition failure.

Examples of recognition responses for each of the category-specific subtests are provided in Table 4 in order to clarify this scoring process. Patients were excluded from the study who exhibited aphasia, so we do not believe that any patients had language deficits that would preclude them from providing adequate verbal descriptions of the test stimuli. As can be seen

from reviewing specific patient responses in these tables, correct recognition responses had to be specific enough to be applicable to a single stimulus. For example, “a furry animal with whiskers” would not be specific enough to accurately establish that the patient had recognized the picture of a cat. However, adding the phrase “that likes to drink milk, purrs, and chases rats” would be adequate. Similarly, it was not enough to simply provide a superordinate description of an object or person as some prior studies have done (e.g., “He is a male vocalist” would not be considered an accurate recognition for Michael Jackson, while “he is a rock star who was famous for dancing backwards and wearing a single glove” would be). In no case did a patient receive credit for a correct recognition simply by describing a picture’s visual features.

We next calculated accuracy scores for both recognition and naming. The recognition accuracy score was based only on familiar objects, and was calculated by dividing the total number of objects correctly recognized by the total number of familiar objects and multiplying by 100. We based the recognition accuracy score only on the items that were familiar to each patient, as we did not want to penalize them for not having been previously exposed to a given object. We next calculated a percent accuracy naming score based only on the recognized objects by adding the total number of objects correctly named and dividing this total by the number of recognized objects and multiplying by 100.

We compared group performance on the three naming and recognition tests using an appropriate nonparametric test (Kruskal Wallis Test). Nonparametric tests were used because these measures are not normally distributed and our sample size was small. Planned Mann-Whitney post-hoc comparisons were made for those analyses that proved significant.

In order to examine the level of performance of each individual patient as compared to normative data, patients were classified in relation to normative data collected at the University of Iowa College of Medicine. Classification ratings were made for all patients on all three measures of naming and recognition. Performance ratings were assigned for each subject according to the following classification system: normal (scores no more than 1 SD below the mean of normal subjects), mildly impaired (1 to 1.5 SD below the mean of normals), moderately impaired (1.5 to 2 SD below the mean of normals), or severely impaired (>2 SD below the mean of normals) for both naming and recognition scores. Chi-square analyses were used to determine whether the level of impairment distribution differed across the three groups. As the sample size was small, there was no attempt to complete post-hoc comparisons. The performance of the TLE groups on the two naming tests (BNT and category-specific tests) was compared using a McNemar Test. All statistical analyses were completed using SPSS version 12.0 (SPSS & Inc., 2003).

Results

When comparing the mean scores on the famous faces subtest of the three patient groups using a Kruskal-Wallis Test, significant differences were observed across groups for both naming, $\chi^2(2, 22) = 12.04, p = .002$, and recognition, $\chi^2(2, 22) = 10.14, p < .007$. Planned Mann-Whitney Test comparisons revealed that the nondominant TLE patients performed significantly worse on the recognition of famous faces task than did the dominant TLE patients ($p = .003$) or the OSO group ($p = .004$). In contrast, the dominant TLE patients exhibited significantly greater naming dysfunction for famous faces as compared to the nondominant TLE patients ($p < .002$) or the OSO group ($p = .005$). Group level performances on the famous faces naming and recognition tasks are presented in Table 5.

Impairment rating classifications are presented for each of the three patient groups in Table 6. These are based on healthy control data for both recognition and naming of famous faces. Chi-square analyses revealed that the famous face naming performance of the three patient groups

was significantly different from one another in relation to the healthy control data, $\chi^2 (6, N = 22) = 17.36, p < .008$. As only the dominant TLE group demonstrated impairment on the naming task, it is clear that they performed significantly worse than the other two groups. Chi-square analysis was significant for the recognition of famous faces as well, $\chi^2 (6, N = 22) = 17.26, p < .008$. As only the nondominant TLE group demonstrated impairment on this recognition task, it is clear that they performed significantly worse than the other two groups.

The same analyses were performed for the recognition and naming accuracy of these patient groups with animal stimuli. When comparing the mean scores on the animal subtest of the three patient groups using a Kruskal-Wallis Test, significant differences were observed across groups for both recognition, $\chi^2 (2, 22) = 13.21, p = .001$, and naming, $\chi^2 (2, 22) = 10.65, p = .005$. Planned Mann-Whitney Test comparisons revealed that the nondominant TLE patients performed significantly worse on the recognition of animals task than did the dominant TLE patients ($p = .001$) or the OSO group ($p < .007$). In contrast, the dominant TLE patients exhibited significantly worse naming dysfunction for animals as compared to the nondominant TLE patients ($p < .005$) or the OSO group ($p < .002$). See Table 5 for the group level performances on the animal naming and recognition tasks.

Impairment rating classifications for each of the three patient groups for the recognition and naming of animals are presented in Table 6. Chi-square analyses revealed that animal naming performance of the three patient groups was significantly different from one another in relation to the healthy control data, $\chi^2 (6, N = 22) = 14.3, p = .006$. As only the dominant TLE group demonstrated any significant impairment on the naming task, it is clear that this group performed significantly worse than nondominant TLE and OSO groups. Chi-square analysis was also significant for the recognition of animals, $\chi^2 (6, N = 22) = 20.65, p < .002$. The greatest level of impairment once again occurred among nondominant TLE patients, with minimal impairment in the dominant TLE group and no impairment observed in the OSO group.

The same analyses were performed for the recognition and naming accuracy of these patient groups with man-made object stimuli. The three patient groups did not demonstrate any significant differences in their ability to name or recognize the man-made object stimuli. However, a small number of patients from the dominant TLE group exhibited mild to moderate limitations in both naming and recognition in this domain. See Table 5 for the group level performances on the man-made object naming and recognition tasks.

Impairment rating classifications for each of the three patient groups for the recognition and naming of man-made objects category are presented in Table 6. Chi-square analyses did not demonstrate any significant difference between the three patients groups in relation to the healthy control data on either recognition or naming of man-made objects. Only the dominant TLE group exhibited any degree of impairment on either the recognition or naming components of this task.

For patients experiencing impairment in more than one category of object, the combination of deficits that occurred in each group was assessed. For the dominant TLE sample, six patients exhibited deficits in the naming of both famous faces and animals, three patients exhibited at least mild deficits in all three categories (severe deficits for both famous faces and animals and either mild or moderate deficits for man-made objects), and one patient performed normally on all naming tasks. For the nondominant TLE sample, five patients exhibited some degree of recognition dysfunction for both famous faces and animals while one patient performed normally for all categories. The OSO patients performed normally on virtually all naming and recognition measures.

We examined the level of impairment ratings for the pre- and post-operative groups separately in order to determine if these findings were maintained in the pre-operative groups. As this

created very small sample sizes for each group, we collapsed them into two samples in accordance with our hypotheses. For example, as we predicted that the right TLE group would exhibit recognition deficits, we compared this group to the left TLE and OSO groups combined for the recognition comparisons. In contrast, as we predicted that the left TLE group would exhibit naming deficits, we compared this group to the right TLE and OSO groups combined for the naming comparisons. Given that virtually all performances were normal on the man-made objects subtest, we did not complete these analyses for this measure. Results of these analyses ran separately for the pre- and post-operative patient groups were consistent with our analyses for the entire sample, and can be examined in Tables 7 and 8 (seven of eight analyses remained significant despite the limitations of sample size). We feel that these analyses provide preliminary evidence that our pattern of results will hold up for both pre- and post-operative epilepsy patients.

There was no attempt to statistically evaluate potential differences between the performance of our pre- and post-surgical patients on the category-specific measures due to the limited sample size. Nevertheless, some information can be qualitatively gleaned about the potential impact of surgery by reviewing Tables 7 and 8, which display the rates of impairment for the various groups on the category-specific measures. While the two preoperative nondominant TLE patients exhibited only mild to moderate object recognition deficits, all four of the post-operative nondominant TLE patients demonstrated moderate to severe impairment on at least one of the sampled categories. Similarly, in the case of the dominant TLE patients, all four of the post-surgical patients performed in the severely impaired range on the naming of famous faces and animals, while their pre-operative counterparts exhibited performances ranging from normal to severely impaired. The two pre-operative dominant TLE patients with severe deficits on these naming measures both exhibited anterior TLE lesions on MRI.

Performance on the category-specific naming measures was compared to performance on the BNT in the TLE patients. Eleven of the 16 (68.8%) TLE patients exhibited at least mild impairment on one or more of the category-specific naming measures while only five of 16 (31.3%) exhibited at least mild impairment on the BNT. Level of impairment was established by comparing current scores to healthy adult normative data available for both of the measures (H. Damasio et al., 1996; Heaton, Grant, & Matthews, 1991; Tranel, Damasio et al., 1997). This difference in performance outcome was demonstrated to be significant using a McNemar Test ($p = .03$), with patients exhibiting greater naming impairment on the category-specific tests as compared to the standard visual naming task.

Discussion

To summarize the findings, most epilepsy patients with dominant anterior TL seizure onset/resection exhibited significant deficits in their ability to name famous faces and animals, while showing normal performance or only mild impairment in their ability to name man-made objects. As a whole, this group exhibited very few recognition deficits of any severity on any of the category-specific subtests. In contrast, almost all epilepsy patients with nondominant anterior TL seizure onset/resection exhibited normal naming performances across all three sets of category-specific stimuli (one nondominant TLE patient exhibited a mild deficit naming animals). In contrast, the nondominant TL seizure onset/resection group made significant recognition errors on the famous faces and animals subtests while producing normal scores on the man-made object subtest. The OSO patients performed normally on all category-specific recognition and naming tasks. These findings appear consistent with the anatomical predictions we made based on the CZ model of semantic memory of Damasio and colleagues (A. R. Damasio, 1989; H. Damasio et al., 1996; H. Damasio et al., 2004; Tranel et al., 2003).

We should point out that multiple models of semantic memory exist, and our findings could also be consistent with some of these other models (recent reviews of semantic memory models include: Gainotti, 2006; Hart et al., 2007; Simmons & Barsalou, 2003). Several of the existing models do not make specific neuroanatomical predictions regarding semantic memory, but rather focus more on the cognitive processes or perceptual features that might give rise to categories in the brain. For example, the pioneering theory of Warrington and Shallice (1984), often referred to as the Sensory/Functional Theory, suggests that there is a distinction between animate and inanimate objects with the conceptualization of animate objects based more on sensory (primarily visual) features of processing and that of inanimate objects being based on functional properties (i.e., uses of the object). Caramazza and colleagues (Caramazza & Shelton, 1998) on the other hand have focused on the possible role of evolutionary pressures in concept formation (i.e., to insure survival, it is important to recognize certain types of objects as potential food sources and certain animals or persons as threats to safety). Tyler and colleagues (Tyler, Moss, Durrant-Peatfield, & Levy, 2000) have suggested that categories actually reflect correlational relationships between object properties (e.g., objects with similar visual appearance will be processed in similar brain regions). Such theories are not mutually exclusive, and there is a growing movement to find common ground between them (Simmons & Barsalou, 2003). Our decision to primarily focus on the Damasio model was based on its clear neuroanatomical predictions and the potential relevance of these predictions for TLE patients.

Our results are important from a clinical perspective, as there are no prior reports suggesting that category-specific recognition and naming deficits might be commonplace findings in patients with TLE both pre- and post-operatively. The current sample represents a near consecutive sample of TLE patients observed at our Center, and ten of ten (100%) of the dominant TLE cases exhibited naming deficits on at least one of the category specific tests while five of six (83%) of the nondominant TLE cases exhibited recognition deficits. By contrast, only five of the ten dominant TLE patients (50.0%) exhibited deficits on the BNT, and there was no indication that any of the nondominant TLE patients experienced recognition problems on this measure.¹ This suggests that the deficits observed on the category-specific naming and recognition tests are likely missed by this commonly employed naming measure. As a striking example, one patient with 18 years of education and employed in the field of education, performed normally on the BNT, yet exhibited severe naming impairment on the famous faces and animal naming tests. He was only able to name 13 of 155 famous faces and 62 of 94 animals although he was able to recognize most of the items from both domains. This patient was unable to name numerous individuals from various time periods who would be recognized by most individuals in our society (e.g., George W. Bush, Saddam Hussein, Marilyn Monroe, Oprah Winfrey) and several common animals (e.g., elephant, crab). Thus, the category-specific naming and recognition tests flushed out defects that would have been missed with standard clinical measures.

The possibility that the category-specific naming and recognition tests may be more sensitive than the BNT to anterior temporal lobe dysfunction is not surprising based on the semantic memory model of Damasio and colleagues (H. Damasio et al., 2004). As noted, they have previously demonstrated that the ability to name man-made objects seems to be disrupted by lesions occurring in posterior temporal regions (e.g., OTP junction), while famous faces and animals seem to be more impacted by anterior temporal lesions (H. Damasio et al., 1996; Tranel, Logan et al., 1997). Given that most standard language measures, such as the BNT, are

¹Although the BNT is not intended as a measure of recognition, it appears safe to assume that recognition is necessary for accurate naming. Four of the five nondominant TL patients performed normally on the BNT, suggesting that they adequately recognized the test stimuli. The fifth nondominant patient exhibited mild naming problems, but it was clear from his responses that the test stimuli were accurately recognized. All but one of these five individuals exhibited recognition deficits on one or more of the category-specific tests.

comprised primarily of objects that fall in the man-made category (e.g., BNT – 44/60 items, Visual naming from the Multilingual Aphasia Examination – 20/30 items), with remaining items spread across several categories (e.g., animals, body parts, edible items, plants), it appears that the typical neuropsychological assessment of epilepsy has been using the wrong stimuli to examine the more pressing region of interest in epilepsy surgery (i.e., anterior temporal lobe). This criticism would also apply to most language mapping paradigms using electrocorticography. It is also likely that using a broader range of stimuli would also improve diagnostic accuracy and monitoring progression in other diseases that impact the anterior temporal lobes (e.g., Alzheimer's disease, frontotemporal dementia, HSV encephalitis).

Our decision to include impairment ratings for several levels of performance was driven by the qualitative nature of errors made in persons whose total score was still only mildly to moderately impaired quantitatively. As a good example, despite only making a moderate number of errors on the animal recognition subtest, one pre-operative right TLE patient made a number of qualitatively striking errors. For example, he mistook an ostrich for a turkey. When this erroneous response was queried further, the patient responded, "That's the bird most Americans eat on Thanksgiving day." Similarly, he mistook a flamingo to be a canary. Once again, when queried, he responded, "That's one of those little birds that you get from the pet store and keep in a cage in your house." Similarly, other persons with "mild" naming deficit scores on the famous faces subtest were missing individuals such as George W. Bush. We hope that examining these levels of impairment, including the qualitative aspects of patient responses, may prove clinically useful for better lateralizing/localizing seizure focus in an epilepsy setting.

Several TLE patients experienced deficits in more than one category of object, with the most frequent combination involving famous faces and animals. For example, six of the ten dominant TLE patients exhibited naming deficits for both famous faces and animals while five of the six nondominant TLE patients exhibited recognition deficits for these items. However, certain combinations of deficit never emerged. For example, no one exhibited deficits in only famous faces and man-made objects. If patients exhibited deficits in these two categories, they always exhibited deficits in the animal category as well. This would again support the idea that recognition and naming zones may be arranged in a spatial pattern that ranges from the temporal pole to the OTP junction. If we assume that lesions to the temporal pole lead to category-specific deficits involving famous faces while more posterior lesions are related to similar deficits involving man-made objects, it would require a larger region of disruption to lead to deficits in both categories in the same patient. As it is proposed that animals are represented by a zone lying between the other two item classes (e.g., inferior temporal gyrus is presumed to be related to animal naming), one would assume that a single lesion disrupting the other two categories would impact this category as well.

As there are several theories of semantic memory functioning (Caramazza & Shelton, 1998; Barsalou, Simmons, Barbey, & Wilson, 2003), there is a great deal of speculation about the possible reasons for the patterns of visual object recognition and naming distributions that are emerging across studies. We believe that there are several plausible explanations for these patterns that need to be explored in future studies. One possibility is that the recognition and naming of famous faces and animals requires making greater distinctions between visual features than do man-made objects (e.g., recognizing the difference between the facial features of two different persons is much more complex than distinguishing an umbrella from a carpet). The inferior visual ("what is it") pathway has been shown to be involved in more refined perceptual distinctions as one moves in a posterior to anterior direction (Riesenhuber & Poggio, 2000; Kobatake & Tanaka, 1994). Therefore, it seems possible that the links between basic visuo-perceptual processing of objects and higher cognitive abilities such as recognition and naming follow a similar neuroanatomical substrate of complexity. Many man-made objects

are also thought to have some representation in premotor areas of the frontal lobes due to the motor planning that is involved in their use (Chao & Martin, 2000). This apparent redundancy of representation could also make them more resistant to decline.

Current object recognition results provide some tentative evidence that epileptogenic seizure activity and/or underlying pathology related to seizure onset involving the nondominant anterior TL may be sufficient to disrupt the recognition of famous faces and animals. Recognition deficits for animals and famous faces did not result from lesions/dysfunction involving the frontal lobes or dominant TL. Two patients that had undergone dominant TL resection exhibited mild recognition deficits for man-made objects, while no other patient groups exhibited recognition deficits for this category of objects. These findings are again consistent with our anatomical predictions based upon the CZ model of semantic memory, with the possible exception of the mild recognition deficits in the two dominant anterior TL resection patients. The CZ model does predict that recognition of man-made objects is a dominant hemisphere function, but places the locus of this dysfunction in the posterior TL (i.e., OTP junction). It is possible that the anterior TL lesions created by these resections were beginning to encroach upon a CZ important for the recognition of man-made objects. Other possibilities are that these patients actually had seizure-related pathology that extended more posteriorly, or that their surgical lesions somehow disrupted connections with more posterior regions.

Our results also highlight the need to focus more attention on the possibility of unrecognized deficits associated with nondominant TL seizure onset, as it appears that recognition deficits may be a common problem among such patients. If such deficits are found to occur prior to surgical resection, assessment of object recognition could be of lateralizing value for determining seizure focus. In addition, it would be helpful to determine if recognition deficits occur following nondominant TL resection, and to assess the impact of such deficits on everyday functioning. At least one other study has suggested that patients undergoing nondominant TL resection experience deficits in their ability to recognize famous faces (Glosser et al., 2003). These authors suggest that this impairment could create significant limitations in social functioning, although no objective research has been completed to verify this possibility.

The relatively small, cross-sectional sample used, limited our ability to make statistical comparisons between pre-operative and post-operative patients. Nevertheless, there appeared to be a trend for many of the worst naming and recognition deficits to occur among post-operative TLE patients. Ultimately, assessing both pre- and post-operative performance in the same patients is necessary to definitively attribute such deficits to the impact of resective surgery. If such a study were to be performed, it would be helpful to evaluate potential intervening variables that might impact outcome on these category-specific measures (e.g., age of seizure onset, early risk factors for epilepsy, impact of primary pathologies leading to epilepsy), as these factors have proven to impact performance outcome using standard naming measures (Davies, Risse, & Gates, 2005; Saykin et al., 1995; Yucus & Tranel, in press)

Although some of the newer antiepileptic drugs (AEDs) appear to negatively impact language functioning (e.g., topiramate, zonisamide: Kockelmann, Elger, & Helmstaedter, 2003; L. M. Ojemann et al., 2001), this finding has primarily involved verbal fluency rather than confrontation naming. Nevertheless there were no significant differences across groups in the number of total AEDs administered. In addition, three of the four patients who were taking one of these medications produced normal naming performances across tasks. Two of these were from the OSO group (patients #17 & #18) and one was from the nondominant anterior TLE group (patient #11). Therefore, it appears unlikely that the use of any specific AED had any significant impact on the differential naming and recognition performances observed between groups.

One last methodological issue worth considering is our use of “familiarity” in the current study. While the concept of familiarity has been used in cognitive neuroscience paradigms (e.g., studies exploring preserved recognition memory in amnesic patients) (Reed, Hamann, Stefanacci, & Squire, 1997), clinical studies have often neglected to consider object familiarity when exploring recognition and/or naming ability. Failing to take familiarity into account can lead to over-estimates of naming and/or recognition deficits (i.e., someone is inevitably penalized for not being able to recognize or name someone that they have never seen before). As described in the methodology section, we define familiarity as simply having the sense that an object has been seen before (even in the absence of accurate recognition/identification). If patients have significant awareness deficits, this could lead to an underestimation of recognition problems. If anything, therefore, one might argue that our documentation of recognition deficits in right TLE patients is somewhat conservative (which would only further strengthen our hypotheses). While we observed a slight tendency for right TLE patients to exhibit a lower familiarity score for famous persons as compared to the other two groups, this pattern was not statistically significant in the current study. A recent meta-analytical review study of famous face recognition reported that familiarity ratings were worse for patient with right TL lesions (Gainotti, 2007).

Future research could explore recognition and naming using large samples of patients with focal seizure onset who are assessed both pre- and postoperatively with a wide range of category-specific objects. As unrecognized category-specific naming and recognition deficits may be occurring in patients undergoing epilepsy surgery, the functional impact of such deficits needs to be determined. It would also be important to predict which patients are at significant risk of decline in these areas in order to develop strategies for minimizing such deficits. For example, it might prove helpful to use a wider range of objects in preoperative neurocognitive assessment, during the intracarotid amobarbital (Wada) procedure, and during intra- or extraoperative mapping of language functions. If these deficits prove to substantially impact functional status, it could also be worthwhile to consider altering surgical approach to avoid their occurrence whenever possible. Future studies also need to assess semantic memory constructs more comprehensively in those individuals exhibiting naming or recognition deficits. For example, we should seek to determine if someone who cannot recognize or name an object by confrontation retains an underlying conceptualization of that object that can be expressed in some other fashion. If semantic concepts remain intact despite naming or recognition problems for those concepts, this would appear more consistent with the distributed neural network models of semantic memory that allow for a variety of dissociational syndromes resulting from lesions in different parts of these systems. Elucidating these constructs in an epilepsy population will lead to more precise models of semantic memory, and may optimize neurocognitive outcome.

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Figure 1.

Figure 2.

Figure 3.

Figure 4.

Table 1

Demographic and Seizure-Related Variables of the Epilepsy Study Participants.

	Dominant TL (n = 10)		Nondominant TL (n = 6)		Other Seizure Onset (n = 6)		f	p
	X	(SD)	X	(SD)	X	(SD)		
Age	40.1	(13.8)	38.7	(10.2)	30.0	(11.6)	1.33	0.29
Education	13.3	(2.2)	13.8	(2.9)	11.8	(1.6)	1.31	0.29
Seizure Onset	29.2	(16.5)	17.1	(13.6)	19.4	(13.2)	1.50	0.25
BNT Performance	48.8	(6.3)	54.0	(4.8)	54.7	(3.1)	3.07	0.07
Number of AEDs	1.90	(0.6)	1.83	(0.8)	2.00	(0.9)	0.08 ^a	0.92
Gender	7 males/3 females		3 males/3 females		3 male/3 females		χ^2	p
MTS	2 of 10 patients		3 of 6 patients		0 of 6 patients		4.35	0.11
Postsurgical	4 of 10 patients		4 of 6 patients		3 of 6 patients		1.07	0.59

Notes. TL = Temporal Lobe; BNT = Boston Naming Test; AEDs = antiepileptic drugs; MTS = mesial temporal sclerosis. Group differences on demographic variables were not significant using analysis of variance or chi square procedures as appropriate.

^aThis comparison was also nonsignificant when using nonparametric statistics, which were employed due to the restricted range of this variable.

Table 2 Description of Brain Dysfunction Apparent in Preoperative Seizure Patients Based on Neuroimaging and Video-EEG Monitoring.

Patient #	Region of Brain Dysfunction	Basis of Group Assignment			MRI Results
		EEG Findings		Interictal	
1	Anterior Left TL	Anterior left TL discharges	no discharges	no discharges	Normal
2	Anterior Left TL	left ant. & mid-TL discharges	no discharges	no discharges	Normal
3	Anterior Left TL	Anterior left TL discharges	Infrequent bitemporal lobe spikes		Cavernous angioma involving left temporal pole
4	Anterior Left TL	Anterior left TL discharges	no discharges		Hippocampal atrophy
5	Anterior Left TL	Anterior left TL discharges ^a	Bitemporal lobe spikes		Mild diffuse volume loss associated with TBI
6	Anterior Left TL	Anterior Left TL discharges	Left basal TL spikes		Normal
7	Anterior Left TL	Anterior Left TL discharges	No discharges		Left MTS
8	Anterior Left TL	Anterior Left TL discharges	Left basal TL spikes		Normal
9	Anterior Left TL	Anterior Left TL discharges	Left basal TL spikes		Left Anterior TL astrocytoma (2.8 × 4.1 × 4.9 cm)
10	Anterior Left TL	Anterior Left TL discharges	Left basal TL spikes		Normal
11	Anterior Right TL	Anterior Right TL discharges	Bitemporal lobe spikes		Right Anterior TL encephalomalacia
12	Anterior Right TL	Anterior Right TL discharges	No discharges		Right MTS
13	Anterior Right TL	Anterior Right TL discharges	Right basal TL spikes		Normal
14	Anterior Right TL	Anterior Right TL discharges	Right basal TL spikes		Right MTS
15	Anterior Right TL	Anterior Right TL discharges ^b	Bitemporal lobe spikes (left > right)		Right TL abnormality
16	Anterior Right TL	Anterior Right TL discharges	No discharges		Right MTS
17	Right FL	Right Hemisphere discharges of unclear origin ^c	No discharges		Right Frontal dysplasia
18	Posterior Right TL	Right Occipital-TL discharges ^d	Right Occipital discharges		Normal
19	Left FL	Left FL discharges	Left FL discharges		Left FL glioma
20	Left FL	Diffuse EEG discharges ^e	No discharges		Normal
21	Right FL	Right midline FL discharges ^f	Right midline FL discharges		Right FL abnormality
22	Left FL	Left FL discharges	Left FL discharges		Left FL tumor

Note. EEG = electroencephalogram; MRI = magnetic resonance imaging; TL = temporal lobe; FL = frontal lobe; TBI = traumatic brain injury; MTS = mesial temporal sclerosis. As all patients exhibited left-hemisphere dominance for language on Wada testing, left and right TL can be viewed as dominant and nondominant TL respectively.

^aPatient 5 also underwent a PET scan and intracranial monitoring (bilateral strips), which revealed left hypometabolism and left anterior TL seizure onset, respectively.

^bPatient 15 also underwent intracranial monitoring (grid and bilateral strips), which confirmed right anterior TL ictal discharges only.

^cPatient 17 also underwent intracranial monitoring (grid and bilateral strips), which confirmed right FL ictal discharges only. In addition, hyperperfusion was observed on SPECT scan involving the right FL.

^dPatient 18 also underwent intracranial monitoring (grid), which revealed right ictal seizure activity involving the occipital-parietal-temporal lobe regions.

^ePatient 20 also underwent intracranial monitoring (grid), which revealed left FL discharges.

^fPatient 21 also underwent a PET scan and intracranial monitoring (grid and bilateral strips), which revealed right FL hypometabolism and right FL seizure onset, respectively.

Table 3

Description of the Location and Extent of each Patient's Surgical Resection.

Patient #	Type of Resection	Seizure Outcome
1	selective left ATL (20-40 mm lateral, 40 mm medial, 34 mm hippocampus)	SI
5	selective left ATL (30 mm lateral, 30 mm medial, 24 mm hippocampus)	SI
7	standard left ATL	SF
8	standard left ATL	SF
12	standard right ATL	SF
13	standard right ATL	SF
15	standard right ATL	SF
17	standard right ATL	NSI
20	posterior right TL (20 mm × 20 mm × 40 mm resection of the posterior inferior temporal gyrus, which was just anterior to the OTP junction)	NSI
21	right frontal (30 mm superior frontal, 20 mm middle frontal)	SI
22	left frontal (40 mm superior frontal, 60 mm middle frontal, 20 mm medial frontal)	SI

Note. ATL = anterior temporal lobe; mm = millimeters; TL = temporal lobe; SF = Seizure Free; SI = Seizure Improvement (greater than 75% reduction in seizures); NSI = No Significant Improvement (less than 75% reduction in seizures); OTP = occipital-temporal-parietal. As all patients exhibited left-hemisphere dominance for language on Wada testing, left and right ATL can be viewed as dominant and nondominant ATL respectively. Standard resections included approximately 40-50 mm of middle and inferior temporal gyrus (lateral resection), 50-70 mm of basal TL (medial resection), and 20-30 mm of hippocampus.

Table 4

Examples of Correct and Incorrect Recognition Responses Made by Epilepsy Patients on Each of the Category-Specific Semantic Memory Subtests.

Test Stimuli	Patient Responses
Famous Faces Subtest	Correct Recognition
Clint Eastwood	"He's an actor. He was in the <i>Dirty Harry</i> movies and in <i>Dead Pool</i> . He's also been a director of movies and mayor of a California town."
Prince Charles	"He's the Prince of England. His wife is the one that was killed in a car wreck...The whole world was saddened. They had two sons who are grown now"
George H. W. Bush	"Former U.S. President. He's the father of the current one. Both from Texas, but I can't think of their names."
Famous Faces Subtest	Recognition Errors
Bill Clinton	"This guy is the host of a daytime talk show."
George Foreman	"He's a prize fighter...a renegade...He's been to prison maybe 2 to 3 times. He's known for biting off another guys' ear during a fight."
Oprah Winfrey	"I know this one. She sang with a vocal group during the '70s."
Animals Subtest	Correct Recognition
Chicken	"A type of bird. You'd find it in a barnyard. It lays eggs."
Elephant	"...An extremely large animal that lives in Africa. They have long tusks made of Ivory."
Lion	"Oh...the king of the jungle. It roars and has a thick mane."
Animals Subtest	Recognition Errors
Fox	"That looks like a large squirrel of some sort. It lives in trees and all that."
Aardvark	"It's a kangaroo. They have pouches for their young and hop on their rear legs."
Fly	"It's a bumblebee..It has a stinger."
Man-Made Objects Subtest	Correct Recognition
Gavel	"That's a type of hammer that judges bang to call their courtrooms to order."
Corkscrew	"...Apparatus to remove a cork from a wine bottle."
Flashlight	"You put batteries in it and it makes a beam of light. Those are handy if the power goes out."
Man-Made Objects Subtest	Recognition Errors
Rubber Band	"That's a piece of rope."
Tongs	"That's a pair of vice grips. You use them to hold something in place."
Can Opener	"It's a wrench of some sort. Use it to tighten or loosen things."

Table 5

Category-Specific Object Recognition and Naming Performances By Seizure Onset/Resection Location For Famous Faces, Animals, and Man-Made Objects.

		Recognition Accuracy		Naming Accuracy	
		(Percent Recognized of Familiar Objects)		(Percent Named of Recognized Objects)	
	<i>n</i>	<i>X</i>	(<i>SD</i>)	<i>X</i>	(<i>SD</i>)
Famous Faces					
Dominant Anterior TL	10	78.3% ^a	(7.4)	55.3%	(28.4)
Nondominant - Anterior TL	6	58.1%	(12.3)	90.5% ^b	(3.8)
Other Seizure Onset	6	80.4% ^a	(7.7)	87.9% ^b	(4.5)
		$\chi^2 = 10.14$		$\chi^2 = 12.04$	
		$p = .007$		$p = .002$	
Animals					
Dominant Anterior TL	10	91.2% ^c	(SD)	81.0%	(SD)
Nondominant - Anterior TL	6	78.7%	(2.6)	94.8% ^d	(11.7)
Other Seizure Onset	6	93.1% ^c	(9.1)	92.6% ^d	(3.5)
		$\chi^2 = 13.21$	(1.1)	$\chi^2 = 10.65$	(1.9)
		$p = .001$		$p = .005$	
Man-Made Objects					
Dominant Anterior TL	10	96.8%	(SD)	91.5%	(SD)
Nondominant - Anterior TL	6	98.5%	(3.7)	96.0%	(6.7)
Other Seizure Onset	6	98.3%	(0.8)	95.6%	(1.7)
		$\chi^2 = 0.51$	(1.2)	$\chi^2 = 3.80$	(2.2)
		$p = \text{n.s.}$		$p = \text{n.s.}$	

Notes. TL = temporal lobe. Groups with matching superscripts did not significantly differ using Mann-Whitney Tests for planned post-hoc comparison.

Category-Specific Object Recognition and Naming Performances for the 3 Epilepsy Groups as Compared to Healthy Control Data for the Famous Faces, Animals, and Man-Made Objects Subtests.

Famous Faces									
	n	Recognition			Naming				
		Normal	Mildly Impaired	Moderately Impaired	Severely Impaired	Normal	Mildly Impaired	Moderately Impaired	Severely Impaired
Dominant Anterior TL	10	10	0	0	0	1	1	2	6
Nondominant Anterior TL	6	1	1	1	3	6	0	0	0
Other Seizure Onset	6	6	0	0	0	6	0	0	0
Animals									
	n	Recognition			Naming				
		Normal	Mildly Impaired	Moderately Impaired	Severely Impaired	Normal	Mildly Impaired	Moderately Impaired	Severely Impaired
Dominant Anterior TL	10	8	2	0	0	1	3	0	6
Nondominant Anterior TL	6	0	1	3	2	4	2	0	0
Other Seizure Onset	6	6	0	0	0	6	0	0	0
Man-Made Objects									
	n	Recognition			Naming				
		Normal	Mildly Impaired	Moderately Impaired	Severely Impaired	Normal	Mildly Impaired	Moderately Impaired	Severely Impaired
Dominant Anterior TL	10	8	2	0	0	7	1	2	0
Nondominant Anterior TL	6	6	0	0	0	6	0	0	0
Other Seizure Onset	6	6	0	0	0	6	0	0	0

Note. TL = temporal lobe.

Table 7
Recognition and Naming of Famous Faces Re-examined on the Basis of Surgical Status.

	n	Famous Faces – Recognition					χ^2	p
		Normal	Mildly Impaired	Moderately Impaired	Severely Impaired			
Presurgical Nondominant Anterior Temporal Lobe	2	0	0	1	1		11.00	.004
All Other Presurgical Patients	9	9	0	0	0			
				Famous Faces – Naming				
		Normal	Mildly Impaired	Moderately Impaired	Severely Impaired		χ^2	p
Presurgical Dominant Anterior Temporal Lobe	6	1	1	2	2		7.64	.05
All Other Presurgical Patients	5	5	0	0	0			
				Famous Faces – Recognition				
		Normal	Mildly Impaired	Moderately Impaired	Severely Impaired		χ^2	p
Postsurgical Nondominant Anterior Temporal Lobe	4	1	0	1	2		7.22	<.03
All Other Postsurgical Patients	7	7	0	0	0			
				Famous Faces – Naming				
		Normal	Mildly Impaired	Moderately Impaired	Severely Impaired		χ^2	p
Postsurgical Dominant Anterior Temporal Lobe	4	0	0	0	4		11.00	.004
All Other Postsurgical Patients	7	6	1	0	0			

Table 8
Recognition and Naming of Animals Re-examined on the Basis of Surgical Status.

	n	Animals – Recognition				χ^2	p
		Normal	Mildly Impaired	Moderately Impaired	Severely Impaired		
Presurgical Nondominant Anterior Temporal Lobe	2	0	1	1	0	11.00	.004
All Other Presurgical Patients	9	9	0	0	0		
Animals – Naming							
Presurgical Dominant Anterior Temporal Lobe	6	1	2	0	3	5.08	<.08
All Other Presurgical Patients	5	4	1	0	0		
Animals – Recognition							
Postsurgical Nondominant Anterior Temporal Lobe	4	0	0	1	3	11.00	<.02
All Other Postsurgical Patients	7	4	3	0	0		
Animals – Naming							
Postsurgical Dominant Anterior Temporal Lobe	4	0	0	0	4	11.00	.004
All Other Postsurgical Patients	7	6	1	0	0		