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Localization of cortical dysfunction based on auditory and visual naming performance

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Abstract

Naming is generally considered a left hemisphere function without precise localization. However, recent cortical stimulation studies demonstrate a modality-related anatomical dissociation, in that anterior temporal stimulation disrupts auditory description naming ("auditory naming"), but not visual object naming ("visual naming"), whereas posterior temporal stimulation disrupts naming on both tasks. We hypothesized that patients with anterior temporal abnormalities would exhibit impaired auditory naming, yet normal range visual naming, whereas posterior temporal patients would exhibit impaired performance on both tasks. Thirty-four patients with documented anterior temporal abnormalities and 14 patients with documented posterior temporal abnormalities received both naming tests. As hypothesized, patients with anterior temporal abnormalities demonstrated impaired auditory naming, yet normal range visual naming performance. Patients with posterior temporal abnormalities were impaired in visual naming, however, auditory naming scores were intact. Although these group patterns were statistically significant, on an individual basis, auditory-visual naming asymmetries better predicted whether individual patients had anterior or posterior temporal abnormalities. These behavioral findings are generally consistent with stimulation results, suggesting that modality specificity is inherent in the organization of language, with predictable neuroanatomical correlates. Results also carry clinical implications regarding localizing dysfunction, identifying and characterizing naming deficits, and potentially, in treating neurologically-based language disorders.

Keywords

Naming, Language; MeSH: Dysnomia; Epilepsy, Temporal Lobe; Neuropsychology

The notion of cortical localization of naming is somewhat controversial, as insult to various brain areas has been associated with naming decline (Geschwind, 1965; Joseph, 1996). Additionally, naming, although seemingly automatic, is a relatively complex, multistage, dynamic process involving perceptual, semantic, lexical, phonological and motor/productive speech functions, each of which are likely mediated by different brain areas. Nevertheless, we tend to associate naming deficits with dominant (left) hemisphere dysfunction, and data from lesion (Goodglass & Stuss, 1979; Tranel et al., 1997), imaging (Bookheimer et al., 1995), electrophysiological (Sinai et al., 2005) and cortical electrical stimulation studies (Ojemann et al., 1989) implicate the language-dominant, temporal/temporoparietal region in particular.

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Considering each of these "localization" methods, direct cortical stimulation likely offers the highest spatial resolution. Stimulation studies using visual object naming, (traditionally, the most frequent means of assessing naming), have shown that electrical stimulation in posterior temporal/temporoparietal cortex typically disrupts object naming, suggesting that naming is mediated, primarily, by this region (Haglund et al., 1994; Ojemann et al., 1989). More recent investigations using both visual naming and auditory description naming (e.g., responsive naming to oral presentation of "the yellow part of an egg"; herein referred to as "auditory naming") have shown that electrical stimulation in the anterior temporal region (i.e., < 5 cm from the temporal pole) typically disrupts auditory but not visual naming, whereas stimulation in the posterior temporal/temporoparietal region tends to disrupt both visual and auditory naming (Hamberger et al., 2001; Malow et al., 1996). These findings suggest that some aspects of naming are modality specific, and that the cortical regions supporting the modality specific aspects of naming are topographically distinct.

For many patients with temporal lobe epilepsy (TLE), the antero-medial temporal region is the most common area of seizure onset, i.e., the "epileptogenic zone," with anterior (rather than posterior) propagation of both ictal and interictal EEG discharges (Emerson et al., 1995). Consequently, it is not surprising that, consistent with stimulation mapping results, auditory naming tasks have been shown to be more sensitive than visual naming tasks to naming deficits in left (language dominant) TLE patients (Bell et al., 2003; Hamberger & Seidel, 2003). Additionally, compared to visual naming, we have found that auditory naming performance more accurately differentiates left and right TLE patients (Hamberger & Seidel, 2003).

In view of the topographic differences in the cortical representation of auditory and visual naming revealed by direct stimulation, together with behavioral performance on auditory and visual naming tasks in patients with TLE, we hypothesized that patients with left anterior temporal abnormalities and patients with left posterior temporal abnormalities would show different performance patterns on auditory and visual naming tasks. Specifically, 1) patients with left anterior temporal abnormalities a) would exhibit significant differences in auditory and visual naming performance, and b) auditory naming would be impaired, yet visual naming would be within the normal range, whereas 2) patients left with posterior temporal abnormalities a) would demonstrate no significant differences between auditory and visual naming performance and b) both auditory and visual naming performance would be impaired. Abnormalities were defined either by electrophysiology (i.e., region of seizure onset) or via imaging and/or histopathology, when available.

METHODS

Subjects

Forty-eight consecutive patients with evidence of left temporal or temporoparietal abnormalities referred for neuropsychological evaluation who met inclusion criteria and completed both auditory and visual naming tests were included in this study. All patients were required to be native English speakers, or to have learned English prior to 5 years of age and to have been fully educated in English. Patients were also required to be left hemisphere language dominant, determined by either intracarotid amobarbital testing (IAT)(Wada & Rasmussen, 1960), or fMRI (Detre, 2004) and cortical stimulation language mapping. The 11 patients who did not undergo IAT were all right handed, with language fMRI considered to show unambiguous left hemisphere language dominance. Individuals with a diagnosed learning disability were excluded. Patients were excluded if neurological work-up indicated multifocal areas of brain abnormalities (e.g., bilateral seizure onset, anterior temporal lesion *and* posterior temporal seizure onset, etc.), or if the anterior/posterior distinction was ambiguous (e.g., anterior-mid temporal seizure onset or lesions spanning both anterior and posterior zones.

Thirty four patients had anterior temporal lobe abnormalities and 14 patients had posterior temporal/temporoparietal (herein referred to as "posterior temporal) abnormalities. Patients were classified as "Anterior" if 1) MRI demonstrated a structural lesion within the region < 5 cm from the anterior temporal tip (N = 5: two cavernous malformations, one cavernous hemangioma, one ganglioglioma, one oligodendroglioma), 2) subdural EEG monitoring demonstrated seizure onset within the region < 5 cm from the anterior temporal tip (N = 7) or 3) scalp EEG monitoring reflected anterior temporal seizure onset and propagation patterns, i.e., maximal onset amplitude at F7 and T7 (N = 22) (Fisch, 1999; Walczak & Jayakar, 1997). Patients were classified as "Posterior" if 1) MRI demonstrated a structural lesion within the temporal or temporoparietal region > 5 cm from the anterior temporal tip (N = 10: one arteriovenous malformation, two cavernous malformations, one cavernous hemangioma, one glioma, one ganglioma, one glioblastoma, one harmartoma, one hemangioma, one meningioma), 2) subdural EEG monitoring demonstrated seizure onset within the temporal or temporoparietal region > 5 cm from the anterior temporal tip (N = 1) or 3) scalp EEG monitoring reflected posterior temporal seizure onset, i.e., maximum onset amplitude at T5 (N = 3). For all patients who had both seizures and a structural lesion, scalp recorded EEG abnormalities were consistent with lesion location. Thirty-one Anterior patients and nine Posterior patients had seizures. Two patients, (one Anterior, evaluated due to ganglioglioma recurrence, one Posterior, evaluated due to onset of seizures following astrtocytoma resection) had prior lesionectomy without removal of normal cortical tissue. Nineteen Anterior patients and one Posterior patient had mesial temporal sclerosis (MTS).

Regarding demographic information, there were no significant group differences in age (Anterior: mean =38.59, SD =10.45, Posterior mean = 36.74, SD = 12.43; P = .58), education level (Anterior: mean = 14.88, SD =2.59, Posterior mean = 14.29, SD = 2.75; P = .48), or IQ (Anterior: mean = 99.38, SD =13.06, Posterior mean = 104.77, SD =13.86; P = .22). IQ scores were based on WAIS-III (Wechsler, 1997) Full Scale IQ (N = 43) or National Adult Reading Test (N = 5) (Nelson, 1982). For the three Anterior patients and two Posterior patients without IQ scores, we used the NART rather than IQ estimates that utilize occupational status, as the presence of recurrent seizures frequently interferes with the ability to maintain employment. All subjects gave informed, written consent. This study was approved by the Institutional Review Board at Columbia University Medical Center.

Naming Tasks

All patients were administered Auditory and Visual Naming Tests as part of their neuropsychological evaluation. These tests are described in detail in a previous publication (Hamberger & Seidel, 2003). Briefly, each test consists of 50 items, the 'target words" which are matched for difficulty level with respect to word frequency. The majority of items are in the mid to high frequency range to reduce vocabulary level as a confounding factor in test performance. The Auditory Naming Test consists of 50 brief descriptions of concrete nouns (e.g., "a household pet that purrs") and the Visual Naming Test consists of 50 common line drawn objects (e.g., hammer). Instructions emphasize speed in responding, and individuals are allowed up to 20 seconds to provide the correct response. Following 20 seconds without an accurate response, a phonemic cue, consisting of the first phoneme of the target word (e.g., "ha," for hammer) is provided.

The Auditory and Visual Naming Tests provide normative data for three scores per task: 1) Total number of items correct within 20-second time limit (Number Correct), 2) Mean response time (RT) for all correct responses (i.e., within 20 second limit), and 3) Total number of tip-of-the-tongue (TOT) responses (i.e., number of correct responses ≥ 2 seconds + number of correct responses following a phonemic cue). RT and TOT, both time-based scores, have

previously been found to be more sensitive than Number Correct to word finding difficulty (Bell et al., 2003; Hamberger & Seidel, 2003).

Statistical Analyses

To directly compare Auditory and Visual Naming performance, raw scores were converted to standard scores based on normative data (Hamberger & Seidel, 2003). Although RT was normally distributed, Number Correct and TOT scores were negatively skewed in the normative sample. This is expected, as naming and other language functions (e.g., repetition, body part naming) are not normally distributed in healthy populations (e.g., (Benton & Hamsher, 1989; Goodglass & Kaplan, 1983). Generally, Z score transformation is most appropriate when the normative data is normally distributed. However, given 1) that both tests were based on common norms, 2) that the normative sample was representative, and 3) that the skewness is expected and does not appear to be due to defects in the test, standard score transformation is considered reasonable (Anastasi & Urbina, 1997; Lezak et al., 2004). In evaluating individual scores, Z scores ≥ 1.5 were considered "impaired." Two way (Group by Task), multivariate, repeated measures ANOVA was performed to assess potential between- and within group differences in Auditory and Visual Naming Number Correct, RT and TOT scores. Significant interactions were explored via pair-wise comparisons. Fisher's exact test was used to determine the clinical utility of individual patients scores in classifying patients as having anterior versus posterior temporal abnormalities. Independent sample T-tests and Chi Square tests were used to assess other clinical and demographic group differences.

RESULTS

Auditory and Visual Naming Test scores for each performance measure are presented in Tables 1A and 1B. For number correct, higher scores indicate better performance; for RT and TOT, lower scores indicate better performance.

Results of repeated measures, multivariate ANOVA indicated no significant effect of Group. There was a main effect of Task for Number Correct [$F(1,46) = 5.53$, $P = .02$], indicating that across groups, patients obtained higher accuracy scores on Visual Naming than Auditory Naming. As hypothesized, there was a significant Group by Task interaction [Number Correct: $F(1,46) = 16.31$, $P < .001$, RT: $F(1,46) = 13.60$, $P = .001$, TOT: $F(1,46) = 17.45$, $P < .001$]. Results of planned comparisons between Auditory and Visual Naming Test scores for each performance measure are presented in Tables 1A and 1B.

As hypothesized, a) auditory and visual naming scores were significantly different in the Anterior group, and b) auditory naming scores were consistently impaired, whereas visual naming scores were within the normal range. Results for the Posterior group were partially consistent with our hypothesis, in that a) auditory and visual naming scores were not statistically different (although RT approached significance); however, b) only time-based visual naming scores were below the normal range and Number Correct approached predefined criteria.

Classification Analyses

Given the different patterns observed in the two groups, we sought to determine whether these patterns could be used to classify patients as having anterior versus posterior temporal abnormalities on an individual basis. For classification analyses, we utilized only time-based measures (RT and TOT), given their greater sensitivity to word finding difficulty (Bell et al., 2003; Hamberger & Seidel, 2003). In all instances, RT and TOT scores were consistent in direction (i.e., both scores indicated either stronger auditory or stronger visual naming performance).

We attempted to classify patients as "Anterior" if RT or TOT scores showed the same pattern as group results, i.e., impaired Auditory Naming score with normal range Visual Naming score. We classified patients as "Posterior" if RT or TOT scores showed the reverse pattern, i.e., impaired Visual Naming score with normal range Auditory Naming score. Using this classification scheme, of the 34 Anterior patients, 13 met criteria for "Anterior" classification, one showed the reverse (Posterior) pattern, and 20 fit neither Anterior nor Posterior patterns. Of the 14 Posterior patients, five met criteria for Posterior classification, two met criteria for Anterior classification and seven fit neither Anterior nor Posterior classification. Excluding patients who met neither classification criterion, Fisher's Exact indicated significant classification results (P = .004). However with 62% of the sample left unclassified, this method appeared of limited clinical utility.

Given the group finding of reversed auditory-visual naming asymmetries (i.e., Auditory Naming scores lower than Visual Naming scores in the Anterior group, and Visual Naming scores lower than Auditory Naming scores in the Posterior group) we then attempted to classify patients based on auditory-visual naming asymmetries. Previous studies that have assessed differences in naming have utilized 1 – 1.5 SD to denote a significant difference in naming performance (Hermann et al., 1994; Langfitt & Rausch, 1996; Stafniak et al., 1990). In keeping with the more conservative end of this range, we used 1.5 SD, and classified patients as "Auditory poorer than Visual" if Auditory Naming RT and/or TOT was ≥ 1.5 SD poorer than its respective Visual Naming score. Patients were classified as "Visual poorer than Auditory" if they exhibited the reverse pattern, i.e., Visual Naming poorer than Auditory Naming performance by a 1.5 SD minimum Results of this classification analysis are shown in Table 2.

Of the 48 patients in the study, 33 patients (69%) had significant asymmetry scores (i.e., 15 patients were left unclassified). Of these 33 patients, 29 (88 %) met criteria for correct classification. These included 22/23 Anterior patients and 7/10 Posterior patients (Table 2. Fisher's Exact, P = .001). One Anterior and three Posterior patients had significant asymmetries in the opposite direction, resulting in inaccurate classification. Individuals without defined asymmetry scores included 11 (33%) Anterior patients and 4 (29 %) Posterior patients. Utilizing the asymmetry-defined classification criteria applied in Table 2, we determined sensitivity and specificity values separately for "Anterior" and "Posterior" abnormalities. Anterior classification criteria showed sensitivity of 65%, specificity of 79%, and a positive predictive value of 88%. Posterior classification criteria showed sensitivity of 50%, specificity of 97% and a positive predictive value of 88%.

To explore potential differences between patients with and without defined asymmetry scores, we compared these two groups with respect to demographic and clinical characteristics, including chronological age, presence/absence of seizures, age of seizure onset, IQ, presence/absence of space occupying lesion, and presence/absence of MTS. Results of one-way, multivariate ANOVA indicated no significant differences in age, onset age, education, or IQ between patients who did and did not exhibit asymmetries (all P > .09). Although one might expect that patients with asymmetries would be more likely to have space occupying lesions, 8/17 (47%) patients with lesions and 21/31 (68%) patients without lesions had asymmetry scores meeting criteria (chi-square P = .16), suggesting that modality-related asymmetries were not merely reflective of space occupying lesions. Additionally, 26/42 (62%) patients who had seizures and 3/6 (50%) patients who did not have seizures met criteria, suggesting that modality related asymmetry scores were not related to presence/absence of seizures (Fisher's Exact P = .67). The potential influence of MTS was explored in the Anterior group as only one Posterior patient had MTS. Within the Anterior group, 13/19 patients with MTS, and 9/15 patients without MTS showed an accurate asymmetry (i.e., auditory naming poorer than visual naming) (Chi square P = .61), suggesting that the naming asymmetries were not related to presence or

absence of MTS. Finally, across the full patient sample, 11 patients had no MRI evidence of structural brain abnormalities. Eight of these patients had significant asymmetry scores, suggesting that naming asymmetries were not dependent on the presence of a structural lesion.

DISCUSSION

The cortical topography of auditory and visual naming sites revealed by stimulation mapping prompted speculation that patients with anterior and posterior temporal abnormalities would exhibit different performance patterns on auditory and visual naming tasks. Results for the Anterior group were consistent with our hypothesis, in that auditory naming was below the normal range, whereas visual naming performance was intact. For the Posterior group, as hypothesized, auditory and visual naming performances were not significantly different from each other; however, at odds with our hypothesis, Visual naming RT and TOT scores were impaired, whereas auditory naming scores were within the normal range.

With respect to individual patients, only 38% met predefined criteria for the hypothesized group patterns specifying impaired versus intact auditory and visual naming performance. On the other hand, we found that within subject, auditory-visual naming asymmetries accurately categorized a greater proportion of patients (60%), thereby providing a more clinically useful means of distinguishing between patients with anterior versus posterior temporal abnormalities. In calculating sensitivity and specificity values, we found high specificity for identification of individuals with Anterior (79 %) and Posterior (97 %) temporal abnormalities, yet poorer sensitivity levels (65% for Anterior, 50% for Posterior).

The strong positive predictive value for both Anterior and Posterior classification (88%) in the context of lower sensitivity values indicates that although asymmetries were not observed in all patients, the presence of a significant asymmetry was highly likely to accurately classify the individual.

Our finding of reduced auditory naming yet normal visual naming in Anterior patients is fully consistent with stimulation mapping results, in which anterior temporal stimulation impaired auditory but not visual naming. On the other hand, impaired visual naming yet normal range auditory naming in Posterior patients is only partly consistent with mapping results, in which posterior temporal stimulation disrupted both visual and auditory naming. Impaired visual naming performance confirms the relative “localization” findings from stimulation mapping, suggesting that visual naming is mediated by posterior temporal cortex. Perhaps the relatively stronger auditory naming performance in Posterior patients reflects some degree of compensation from auditory naming cortex in the anterior temporal region under normal (i.e, non-stimulation) circumstances. These compensatory processes might be unavailable during cortical stimulation due to current spread or insufficient time for development of compensatory activity, resulting in naming impairment in both modalities.

With regard to individual patient patterns, it is notable that the within-subject asymmetry scores proved more useful than solely the normative value comparisons in localizing dysfunction to the anterior or posterior temporal region. In part, this appeared to be due to the fact that many patients obtained relatively poor scores on both auditory and visual measures, although, as it was apparent from the asymmetry scores, one score was often considerably more impaired than the other. We believe this reflects general damage to the cognitive system involved in naming. The asymmetry scores, therefore, appear to capture the modality with greater damage, which appears to reflect anterior versus posterior localization.

Attempts to identify other factors that might account for the presence of an asymmetry indicated that asymmetries were not more frequent in patients with lesions. Further, there were no significant differences in age, presence/absence of seizures, age of seizure onset, or level of

intelligence between patients with versus without predicted asymmetries. Thus, naming asymmetries do not appear to merely reflect structural abnormalities as revealed by MRI, or any of the patient-related characteristics assessed. It appears these performance asymmetries provide a fairly sensitive measure of focal dysfunction in the anterior and posterior temporal regions.

Clinical implications and considerations

Until recently, visual confrontation naming was essentially, uncontested as the measure of choice in the assessment of naming. Visual naming is simple to administer and has been effective in eliciting dysnomia in varied neurological disorders (Gordon, 1997). Historically, auditory naming has been used primarily in the assessment of aphasic disorders (Goodglass & Stuss, 1979), although recent investigations have demonstrated its utility in patients with temporal lobe pathology (Bell et al., 2003; Hamberger & Seidel, 2003). Additionally, auditory naming, but not visual naming, has been shown to correlate with subjective word finding difficulty, possibly due to its greater "ecological" validity, i.e., naming difficulties typically occur in the context of auditory-verbal discourse rather than failed attempts to name objects in the environment (Hamberger & Seidel, 2003). The current results suggest that auditory and visual naming tasks measure cognitively and neurally distinct processes, which, in turn, suggests that a thorough assessment of naming would require utilization of both tasks. Our finding of different performance asymmetries in patients with anterior versus posterior abnormalities suggests that use of both measures might assist in localizing regions of cortical dysfunction. Additionally, information regarding modality-specific differences in naming, which would be unavailable from assessment in only one modality, could be used in devising compensatory strategies. For example, patients with relative weakness in one modality might be directed to rely more heavily on the other.

In considering the localizing value of auditory and visual naming, certainly, the introduction of high resolution imaging has led to a reduction in the use of neuropsychological assessment in lesion localization. Nonetheless, there remain some conditions in which focal dysfunction is not necessarily accompanied by abnormalities observable on MRI, as demonstrated in MRI-normal patients in the current study, and conditions in which cognitive dysfunction precedes the appearance of structural changes (Hermann et al., 2007; Kulas & Naugle, 2003). In these cases, results of neuropsychological testing do, in fact, assist in localization. As it stands, the localizing resolution of most measures of higher cortical function is typically at the hemispheric or at best, lobar level. Thus, it is rather unique that utilization of these two naming tasks can provide more fine-grained, localizing information within the temporal region. This level of resolution refines current knowledge of brain-behavior relations, and in the future, could potentially assist in differentiating among disorders involving cortical dysfunction in the temporal region. These speculations are tempered, however, given the current use of two groups with well localized pathology. More importantly, the classification criteria for Anterior and Posterior classification were based on observations from the current patient sample. To truly determine the localizing value of these two measures would require a different, unselected, heterogeneous group of patients with varied lesion (electrophysiological or histological) locations.

Theoretical considerations

Modality specific dissociations in naming and other language functions have generated two classes of theories regarding semantic-lexical organization. The unimodal view holds that the semantic system is a unitary, amodal storage system, accessible from each input modality (Caramazza et al., 1990; Hillis et al., 1995; Riddoch et al., 1988), whereas the multimodal view posits distinct visual and verbal semantic systems (Druks & Shallice, 2000; Lauro-Grotto et al., 1997; McCarthy & Warrington, 1988; Shallice, 1988). The debate between these two

classes of theories tends to remain unresolved, as results from most studies can be construed to support either model. Admittedly, the current results are no exception, as reductions in auditory or visual naming can be interpreted as either faulty modality specific access to a unimodal system, or direct impairment to a modality specific sub-system. It is notable though, that most clinical studies of semantic processing, although detailed in methodology, are lacking in resolution concerning the brain regions affected by the disease state. These studies, therefore, offer little toward discerning possible neuroanatomical substrates of the semantic system (e.g., (Druks & Shallice, 2000; Lauro-Grotto et al., 1997; Marangolo et al., 2004)). The current results, however, suggest that either, a) separate auditory and visual semantic systems, or b) a unimodal system with separate auditory and visual access mechanisms, are mediated by the anterior and posterior temporal regions. Perhaps, further analysis of these cortical regions with regard to their role in semantic processing will provide more detailed information regarding the neuroanatomical correlates of the semantic system, which, in turn, might provide a clearer picture of the system as either uni- or multimodal. Studies addressing these questions, involving both cortical stimulation and functional imaging, are currently underway in our laboratory.

Potential Limitations

As it is often the case in clinical research, patients were not randomly assigned to groups. Although groups were not significantly different in age, education or level of intelligence, group differences in the number of patients with and without space occupying lesions are a potential limitation in interpreting our results. One might argue that the Posterior group, which had more patients with frank lesions, was at a disadvantage with respect to cognitive performance, although this concern might be somewhat mitigated by the fact that IQ was comparable across groups, or perhaps, even marginally higher in the Posterior group. In this study, the overrepresentation of lesion patients in the Posterior group merely reflected the patient population to which the investigators had access. Certainly, replication of these findings with a larger posterior group, and more balanced groups with respect to pathology, is warranted.

In sum, the current naming performance asymmetries in patients with anterior versus posterior temporal abnormalities suggest that modality specificity is inherent at some level in the organization of the language system, with relatively clear neuroanatomical correlates. These findings carry clinical implications with regard to localizing dysfunction within the language dominant temporal region, identification and characterization of naming deficits, and potentially, in developing treatment programs for patients with neurologically based language disorders.

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Table 1

Auditory versus Visual Naming Performance in Patients with Anterior (1A) and Posterior (1B) Temporal Abnormalities.

A. Anterior Group			
	Auditory Naming	**Visual Naming**	**P value***
Number Correct	-2.11 (2.36)	-0.29 (1.26)	<.001
RT	1.78 (2.08)	0.77 (1.86)	.004
TOT	2.15 (2.18)	0.85 (1.76)	<.001
B. Posterior Group			
	Auditory Naming	Visual Naming	P value*
Number Correct	-0.97 (1.99)	-1.44 (3.35)	.401
RT	0.47 (1.63)	1.88 (3.71)	.051
TOT	1.12 (1.97)	2.74 (4.78)	.096

Z scores: Mean (SD),

* Paired comparisons

Table 2

Auditory-Visual Naming asymmetries as a function of Group

	Auditory Naming poorer than (≥ 1.5 SD) Visual Naming	Visual Naming poorer than (≥ 1.5 SD) Auditory Naming	No difference (< 1.5 SD)
Anterior Abnormality Patients	22	1	11
Posterior Abnormality Patients	3	7	4