Epilepsia, **47**(8):1397–1401, 2006
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Speech Recognition Impairments in Patients with Intractable Right Temporal Lobe Epilepsy

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Summary: *Purpose:* To evaluate speech recognition in patients with focal intractable epilepsy and surgical resections in the nondominant (right) hemisphere.

Methods: Speech recognition was tested prospectively, under different listening conditions, in 22 patients with right temporal lobe (11 patients) or extra–temporal lobe epilepsy. All were left-hemisphere dominant for language on preoperative intracarotid sodium amobarbital testing.

Results: All patients demonstrated normal auditory recognition of words and environmental sounds before and after surgery. However, when real-world listening conditions were simulated by using acoustically degraded (filtered) words, patients with temporal lobe epilepsy performed significantly worse than patients with frontal or parietooccipital lobe epilepsy before and after surgery ($p < 0.0001$).

Conclusions: Patients with intractable right temporal lobe epilepsy are at risk for speech recognition impairments in real-world listening environments, independent of surgery. The impact of speech recognition difficulties on verbal communication, coupled with the prevalence of adverse listening environments, underscores the importance of testing speech recognition under different listening conditions in patients with intractable right temporal lobe epilepsy. **Key Words:** Temporal lobe epilepsy—Auditory cortex—Speech perception—Right hemisphere.

Speech recognition refers to the auditory analysis and processing of spoken speech required for comprehension and has traditionally been associated with the language-dominant (left) hemisphere (1). Therefore patients with intractable nondominant (right) hemisphere seizures undergoing surgical resection have not been considered at risk for impairments. However, neuroimaging and electrophysiologic studies have implicated the right hemisphere under adverse listening conditions, including background noise (2,3), that mask or degrade high-frequency components of the speech signal (4). Moreover, speech-processing difficulties have been identified in patients undergoing right hemispherectomy or temporal lobectomy and in nonsurgical patients with right temporal lobe epilepsy (5–7).

Poor listening conditions are common, and their adverse effects on verbal communication are well established (8). It is important, therefore, to determine whether patients with right hemisphere seizures are at risk for impairment. The prospective studies needed to assess patients' presurgical speech recognition abilities and to quantify surgical effects are largely lacking. Similarly, it is not known whether atypical language lateralization may have contributed to the observed right hemisphere involvement. No systematic comparisons have been made of patients with right temporal versus extra–temporal lobe seizures to determine the specificity of seizure or surgery effects. In this study, we tested speech recognition prospectively, under different listening conditions, in left hemisphere dominant patients with intractable right temporal or extra–temporal lobe epilepsy.

METHODS

Patients

We tested 22 right-handed patients (ages 16–43 years), with medically intractable complex partial seizures originating in the right hemisphere (Table 1). Based on ictal scalp recordings and intraoperative or extraoperative intracranial recordings (subdural, depth), 11 patients had right temporal lobe epilepsy (RTLE), and 11 had right extra–temporal lobe epilepsy (RETLE) with frontal lobe (seven patients) or parietooccipital (four patients) seizure foci. All were left-hemisphere dominant for language on

Accepted January 7, 2006.
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doi: 10.1111/j.1528-1167.2006.00562.x

TABLE 1. *Patient characteristics*

Patient	Sex	Age (yr)	Epilepsy onset (yrs)	Education (yr)	VIQ	MRI	Resection
Right temporal lobe epilepsy (RTLE)							
1	M	23	11	14	109	Hippocampal atrophy	ATL
2	F	37	13	12	91[a]	Hippocampal atrophy	ATL
3	F	40	18	16	110	Hippocampal atrophy	ATL
4	F	32	5	12	91	Normal	ATL
5	F	43	6	12	85	Normal	ATL
6	M	38	35	13	114	Normal	ATL
7	F	23	11	12	91	Normal	TL
8	F	23	13	13	87	Normal	TL
9	F	30	9	12	87	Posterior TL	TL
10	M	36	12	16	99	Normal	TL
11	F	17	8	11	95	Normal	TL
Mean		31	13	13	96		
Right extra–temporal lobe epilepsy (RETLE)							
1	M	16	6	11	89	Normal	FL
2	F	42	12	12	114	Normal	FL
3	M	25	5	14	92	Normal	FL
4	F	23	14	16	112[a]	Anterior FL dysplasia	FL
5	F	30	20	12	94	Normal	FL
6	M	22	11	12	93	Normal	FL
7	M	37	28	12	87[a]	Normal	FL
8	M	18	7	12	110	Normal	POL
9	M	30	15	12	112	Grade 2 POL glioma	POL
10	F	26	15	14	87	Mesial POL sclerosis	POL
11	M	26	22	12	93[a]	Normal	POL
Mean		27	14	13	98		

ATL, Anterior temporal lobe; TL, temporal lobe; FL, frontal lobe; POL, parietal or parietooccipital lobes; VIQ, verbal intelligence quotient.
[a]Estimated from The National Adult Reading Test.

preoperative intracarotid sodium amobarbital testing and had normal hearing ($\leq$20 dB HL), cognitive function (verbal IQ, $\geq$85), and neurologic examinations. Language dominance was determined by the clinical criterion of more than one error, as compared with each patient's baseline performance, on one or more of four expressive and receptive language tasks administered after consecutive injections of sodium amobarbital to test each hemisphere. In no patient had seizures developed before age 5 years; none had a history of speech–language, motor, or attention disorders. Magnetic resonance imaging (MRI) was normal in 15 patients and showed abnormalities in seven patients in the area of epileptic activity. Group comparisons of RTLE and RETLE patients by using two-sample *t* tests and χ^2 tests yielded no significant differences in age ($p = 0.23$), sex ($p = 0.087$), verbal IQ ($p = 0.64$), years of education ($p = 0.56$), epilepsy-onset age ($p = 0.70$), epilepsy duration ($p = 0.14$), or number of medications ($p = 0.34$). All patients provided informed written consent for participation in compliance with the Institutional Review Board. Parental consent was obtained for patients younger than 20 years.

Presurgical testing

We tested patients 1–2 months before surgery in a sound-treated room by using insert earphones and a two-channel audiometer (presentation level, 50 dB HL). Patients repeated 90 digitized monosyllabic words from two standardized tests of auditory word recognition: 50 nonfiltered words to simulate good listening conditions (CID-W22 Word Lists, Vancouver, BC, Canada) (9), and 40 low-pass–filtered words (1,000-Hz cut-off, 32-dB/octave roll-off) to simulate adverse listening conditions (SCAN-A Test, San Antonio, TX, U.S.A.) (10). Low-pass–filtered speech is perceived as muffled because of the lack of high-frequency cues (>1,000 Hz). Low-pass filtering simulates the greater masking effects of background noise and other adverse listening conditions on high-frequency speech cues, which are typically less intense and therefore more vulnerable to masking than are low-frequency cues. Patients were also asked to identify verbally 15 digitized environmental sounds (e.g., dog barking). Presurgical testing included measures of verbal IQ (Weschler Adult Intelligence Scale–Revised or The National Adult Reading Test, Nelson Publishing, London, U.K.), auditory verbal working memory (Digit Span, WAIS-R, The Psychological Corporation, San Antonio, TX, U.S.A.), and receptive and expressive language (Token Test, Pro-ed, Austin, TX, U.S.A.; Boston Naming Test, The Psychological Corporation, San Antonio, TX, U.S.A.).

Surgical procedures

Six RTLE patients underwent anterior resections, and five underwent more-extensive temporal lobectomies.

Anterior temporal resections extended 4.0–5.5 cm posteriorly from the temporal pole along the middle and inferior temporal gyri, sparing the posterior temporal lobe and the entire superior temporal gyrus (four patients) or the posterior two thirds (two patients). The more extensive temporal lobectomies included resection of the entire temporal lobe (two patients) or all but the posterior one third of the superior temporal gyrus (three patients). The hippocampus and amygdala were resected in all but one patient. RETLE patients underwent tailored resections in the right frontal lobe (seven patients) or parietooccipital (four patients) region.

Postsurgical testing

We retested hearing thresholds and auditory word (filtered, nonfiltered) and environmental sound recognition 3–5 months after surgery by using the same procedures and materials as before surgery. Nine patients (four RTLE, five RETLE) had repeated neuropsychological testing as part of a separate study of cognitive function in neurosurgical patients.

Data analyses

Normal scores for nonfiltered words ($\geq$94%), filtered words ($\geq$80%), and environmental sounds ($\geq$93%) were based on published and clinical norms. We compared RTLE versus RETLE patients' scores, before and after surgery, by using a logistic regression model that allowed overdispersion to account for possible correlation among multiple test items within patients. Likelihood-ratio tests were used to test for statistical significance. Comparisons by temporal lobe resection site were performed by using the Cochran–Mantel–Haenszel χ^2 test to adjust for possible within-patient correlations between pre- and postsurgery scores.

RESULTS

Before surgery, all patients demonstrated normal recognition of nonfiltered words (Fig. 1), with no significant differences between RTLE and RETLE patients ($p \geq 0.67$). Conversely, filtered word recognition was impaired in all RTLE patients (mean, 68%), but not in RETLE patients (mean, 88%), with significant group differences ($p < 0.0001$). Environmental sound recognition was normal across both groups ($\geq$93%), with no group differences ($p = 0.098$).

After surgery, all patients were seizure free up to the time of testing. Repeated testing showed no clinical changes in hearing, language, or auditory verbal memory. Fourteen patients had no postsurgical neurologic deficits. One RETLE and six RTLE patients had left superior quadrantanopsias; one RETLE had a left homonymous hemianopsia. All patients showed normal recognition of nonfiltered words after surgery with no significant changes ($p \geq 0.74$), regardless of site of resection ($p \geq 0.53$). RTLE patients had impaired filtered-word scores (mean, 72%) that were significantly worse ($p < 0.0001$) than those of RETLE patients (mean, 87%). Both groups demonstrated normal environmental sound recognition, although RTLE patients showed a borderline significant trend toward lower scores ($p = 0.050$).

Analysis by TL resection type revealed significant improvement in filtered word scores after anterior temporal resection ($p = 0.0031$) but not after more extensive temporal lobectomy ($p = 0.17$). No significant changes were found in recognition accuracy for nonfiltered words ($p \geq 0.74$) or environmental sounds ($p \geq 0.31$).

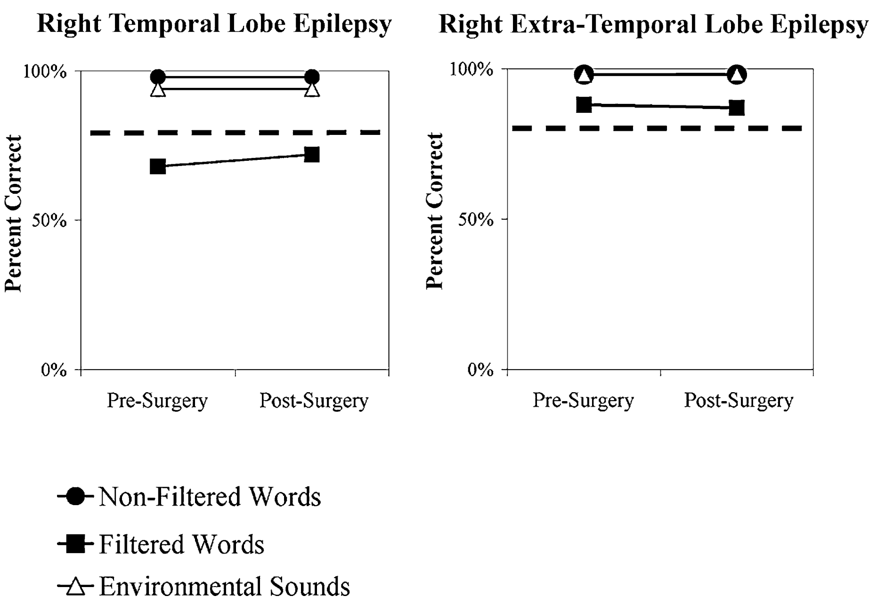

FIG. 1. Mean percentage correct auditory recognition scores, before and after surgery, for right temporal lobe epilepsy patients (n = 11) and right extra-temporal lobe epilepsy patients (n = 11). *Dashed line*, Lower limit of normal (80%) for filtered word recognition.

DISCUSSION

Our main finding is that patients with intractable RTLE demonstrate impaired speech recognition when real-world listening conditions were simulated by using degraded (filtered) speech. This finding supports and extends previous neuroimaging, electrophysiologic, and lesion studies implicating the right hemisphere under adverse speech listening conditions (2,3,5,6). In this study, speech-recognition impairments were identified only in RTLE patients and not in patients with frontal or parietooccipital lobe epilepsy, suggesting that right-hemisphere participation under adverse speech listening conditions centers on the temporal lobe. Neuroimaging studies have indicated that auditory areas in the right temporal lobe are specialized for processing fine spectral features of pitch, musical melodies, and other complex nonspeech sounds (11). Listeners may recruit these specialized right temporal lobe resources to compensate when speech cues normally processed by the left hemisphere are degraded. The absence of impairments in patients with frontal or parietooccipital lobe dysfunction further suggests that right-hemisphere recruitment is not simply in response to increased attention and auditory working-memory demands associated with adverse speech listening conditions. Although the precise contributions of right temporal lobe compensatory listening mechanisms remain to be determined, they appear to be disrupted or inaccessible in patients with intractable RTLE.

The concurrent sparing of nonfiltered word and environmental sound recognition in RTLE patients precludes a more general auditory processing impairment. Sparing of environmental sound recognition, traditionally associated with the right temporal lobe, is also consistent with recent neuroimaging findings showing this function to be distributed widely within and between the temporal lobes (12). However, we cannot rule out the possibility that other auditory functions not tested, including pitch and melodic processing, may have also been impaired in RTLE patients. Nor can we rule out visual-spatial processing or other nonauditory impairments in RETLE patients, as previously reported (13). Although the gender composition of the RETLE and RTLE groups did not differ significantly, and all patients were left-hemisphere dominant for language, subtle gender-related differences in right hemisphere dependence between the two groups may have been present, making RTLE patients (more females) more vulnerable to impairment than RETLE patients (more males). A larger sample size is needed to address this issue.

Speech recognition impairments were present preoperatively in RTLE patients and therefore cannot be attributed to surgery. Previous resection studies have rarely tested patients prospectively. However, one study reported speech recognition impairments under dichotic listening conditions before right temporal lobectomy (6), and a recent study identified subtle higher-level auditory language impairments in nonsurgical patients with intractable RTLE (7).

Although auditory cortex is located in the posterior temporal lobe, patients with anterior temporal lobe seizures also showed impairments before surgery, supporting recent evidence that seizures may exert adverse effects on distant functional centers (14). The improvement in speech recognition scores after anterior temporal resection further suggests that the associated functional impairments may be partially reversible. Although practice effects cannot be ruled out entirely, the minimum interval of 4 months between test sessions and lack of improvement after more extensive temporal lobectomy are not consistent with this view. Because our RTLE subgroups are too small for direct comparison, it is not possible to determine whether postsurgical improvements reflect reduction of seizures, removal of dysfunctional cortex, or sparing of the posterior two thirds of the superior temporal gyrus where primary auditory cortex is located.

These results demonstrate that patients with intractable RTLE have impaired speech recognition under simulated real-world listening conditions. This finding is inconsistent with early models of absolute hemispheric specialization (1) and instead supports a more dynamic view of lateralization whereby each hemisphere has access to the same auditory input but performs different functions with different outputs (15). The prevalence of adverse listening conditions, coupled with the impact of impaired speech recognition on verbal communication, underscores the importance of identifying those patients who may benefit from remediation, such as use of assistive listening devices (5) that improve signal-to-noise levels, rendering the speech signal less vulnerable to the masking effects of background noise.

Acknowledgment: This study was supported by NIH grants R01-DC005645 and R21-DC007490. We thank Dr. Stephen Reich and Jenna Los for assistance, and Cynthia Eberwein and Rachel Fotta for the audiologic evaluations.

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