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Language treatment prior to anterior temporal lobe surgery: Can naming skills be preserved?

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Abstract—Epilepsy affects 1% of the general population and is highly prevalent among Veterans. The purpose of this phase I study was to investigate a presurgical linguistically distributed language treatment program that could potentially diminish effects of proper-name retrieval deficits following left anterior temporal lobe resection for intractable epilepsy. A single-subject multiple-baseline design was employed for three individuals with late-onset chronic left temporal lobe epilepsy. Word retrieval treatment was administered prior to anterior temporal lobe resection. The primary outcome measure was confrontation naming of proper nouns. Immediately posttreatment (before surgery), there was a positive effect for all trained stimuli in the form of improved naming as compared with pretreatment. In addition, trained stimuli were found to be better after surgery than they were at pretreatment baseline, which would not be expected had language treatment not been provided. This series of case studies introduces two fundamentally novel concepts: that commonly occurring deficits associated with left temporal lobe epilepsy can be treated despite the presence of damaged neural tissue and that providing this treatment prior to surgery can lead to better preservation of language function after surgery than would be expected if the treatment were not provided.

Key words: anterior temporal lobe, aphasia, epilepsy, epilepsy surgery, language, language treatment, name retrieval, proper noun naming, rehabilitation, treatment.

INTRODUCTION

Epilepsy is a condition of recurrent, unprovoked seizures that affects 1 percent of the general population and is highly prevalent among Veterans [1–2]. In medically intractable epilepsy with unilateral temporal lobe onset, surgical removal of the anterior temporal lobe (ATL) is a highly effective treatment, with class I clinical evidence supporting its use in specific circumstances [3]. The ATL plays a critical role in the convergence of visual information and proper nouns, and in the majority of individuals, resection is commonly associated with permanent difficulties in the retrieval of proper names [4–5]. This problem is especially common in individuals undergoing surgery in the language-dominant hemisphere.

Abbreviations: ATL = anterior temporal lobe, BNT = Boston Naming Test, EEG = electroencephalogram, ES = effect size, FF = famous faces, FP = famous places, P1 = participant 1, P2 = participant 2, P3 = participant 3, PRF = personally relevant faces, SD = standard deviation, WAB = Western Aphasia Battery.

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Though proper-name retrieval deficits following left ATL resection have been widely documented, the specific role of the left ATL in proper naming remains enigmatic. Several theories in the extant literature attempt to explain the link between the left ATL and proper-name retrieval. The neural instantiation of producing words denoting concrete entities has been proposed, for the typical system, to involve the coordination of a left perisylvian system of regions supporting phonological implementation and posterior cortical systems supporting visual conceptual structure. This coordination is thought to be mediated by left extrasylvian cortical regions (convergence zones) that are anatomically connected to both regions [6–8]. The association of the left temporal pole specifically with the production of proper names for persons and places [4,8–10] may also have to do with (1) the resolution of high visual ambiguity at the apex of the ventral visual stream [7], (2) the proximity of structures involved in social-affective processing [11], and/or (3) a role for the temporal pole as an amodal semantic hub [12–14].

Regardless of the specific mechanism, ATL resection interferes with the contribution of the temporal poles to language processing, leading to impaired word retrieval for proper names. Based on principles of experience-dependent neural plasticity [15] and Hebbian learning [16], which form the current basis for rehabilitation of language following stroke [17], we sought to remediate impaired proper-name knowledge to areas outside of the ATL prior to creating a brain lesion through surgery in hopes of improving proper-name retrieval and, therefore, reducing the negative effect of surgery on this skill.

We based our therapy approach on a model of language [18] that has previously been applied to language rehabilitation trials with individuals who have aphasia from stroke [19]. Specifically, this parallel distributed processing model states that common-noun linguistic knowledge is distributed and stored as patterns of neural connectivity and connection strengths between linguistic units, not only within the domains of semantics, phonology, orthography, and articulation but also between domains (see Nadeau [18] for a detailed explanation). Within a given domain, a representation corresponds to a specific pattern of activity of all the units, hence the term *distributed representation*. For example, semantic knowledge is instantiated as the pattern of connection strengths throughout the association cortices supporting this knowledge. Processing of a representation involves engagement of connections between the relevant representations for the target modality of communication. (E.g., comprehension of an auditorily presented word is achieved through engagement of connections between acoustic representations and conceptual-semantic representations.) This simultaneous engagement of linguistic units is called a *pattern associator network*. The pattern associator network does not contain linguistic knowledge, per se, but serves only to translate between representations in different domains. During the process of learning language, or relearning in the case of injury, the strengths of the connections in the pattern associator networks are gradually adjusted so that a pattern of activity involving the units in one domain elicits the correct pattern of activity in the units of another domain.

With language treatment, we attempted to shift reliance of linguistic knowledge of proper names typically subserved by neural networks *within* the ATL to linguistic networks distributed *across* the left hemisphere (e.g., semantic features, phonology, orthography, and articulation) before ATL surgery. We envisioned that a new pattern associator network for trained proper names would be formed and, thus, retrieval of these proper names would not be as susceptible to damage following surgery as untrained items.

We predicted that three individuals who received intensive, multimodal training on naming of famous faces (FF), famous places (FP), and personally relevant faces (PRF) would show (1) improved naming performance on trained items prior to surgery with no improvement on untrained items and (2) partial maintenance of trained items following surgical resection (compared to pretreatment naming performance).

METHODS

Three individuals with intractable epilepsy who were scheduled for surgery participated in this study. The methodology related to stimuli, procedures, and analyses was essentially the same for all three participants; however, specifics regarding total number of treatment hours delivered, number of stimuli, and timing of treatment varied among each participant. Thus, methodology and results specific to each participant will be discussed in the context of three separate experiments.

Experimental Design

We employed a repeated-probe ABAA design for all three participants. During the baseline phase, trained and untrained stimuli were repeatedly probed to establish a stable baseline level of performance. During the course of treatment, repeated testing of trained and untrained stimuli was undertaken. Immediately upon treatment termination and after surgical resection, repeated probes of trained and untrained stimuli were administered. Selected subtests of the Wechsler Memory Scale-III and IV [20–21] were administered as part of clinical protocol before and after surgery. Standardized language assessments including the Western Aphasia Battery (WAB) [22] (Participant 2 [P2] only) and the Boston Naming Test (BNT) [23] were administered as part of the research protocol before therapy, immediately after therapy, and after surgery (**Table 1**).

Outcome Measures

The primary outcome measure was verbal naming accuracy for visually presented pictures of FF and FP. Verbal responses were digitally recorded using a headset microphone and transcribed off-line by a research assistant who scored each response for accuracy (incorrect if omission or semantic or phonologic substitution). Intra- and interrater scoring was performed by experienced research assistants for a portion of the data using intraclass correlations.

Stimuli

Experimental stimuli consisted of familiar FF and FP, and for Participant 1 (P1) only, PRF (e.g., family members, friends, and members of his medical team). A portion of the FP stimuli and all of the FF stimuli were gathered from Tranel's corpus [24–25]. Personally relevant stimuli were selected based on people the participant

Table 1.
Pre- and postsurgery neuropsychological scores.

Test Batteries	P1		P2			P3		
	Pre-SX	Post-SX	Pre-SX	Post-TX*	Post-SX	Pre-SX	Post-TX*	Post-SX†
WMS-III (P1, P2) WMS-IV (P3) Scale Scores‡								
Logical Memory Immediate	9	4	11	—	14	9	—	—
Logical Memory Delay	10	6	12	—	13	9	—	—
Verbal Pairs Immediate	5	3	13	—	13	4	—	—
Verbal Pairs Delay	5	4	13	—	14	5	—	—
Faces Immediate	6	7	9	—	14	N/A	—	—
Faces Delay	6	6	13	—	11	N/A	—	—
Visual Reproduction Immediate	4	2	N/A	—	N/A	12	—	—
Visual Reproduction Delay	5	6	N/A	—	N/A	7	—	—
BNT (out of 60)	59	39	50	53	53	39	50	19
WAB AQ (out of 100)‡	N/A	N/A	97.2	97.9	98.2	96	N/A	N/A
LFCN (out of 145)	100	68	123	121	125	95	105	50

Note: The inclusion of the WAB AQ and all posttreatment language measures were incorporated into the research design after P1's participation and so are only shown for P2 and P3.
*The WMS-III and WMS-IV were not administered following treatment.
†Clinical postsurgical neuropsychological testing occurs 12 mo following surgery. P3 was not yet 12 mo postoperative at the time of this publication.
‡N/A cells for the WMS-III and WMS-IV are reflective of neuropsychological testing time constraints. The WAB was administered only pre-SX to P3 because of limited available time between his recruitment into the study and his scheduled surgery.
BNT = Boston Naming Test, LFCN = low-frequency common nouns, N/A = not applicable, P1 = participant 1, P2 = participant 2, P3 = participant 3, SX = surgical, TX = treatment, WAB = Western Aphasia Battery, WAB AQ = Western Aphasia Battery aphasia quotient, WMS-III = Wechsler Memory Scale-3rd edition, WMS-IV = Wechsler Memory Scale-4th edition.

encountered in his daily life (family, friends, and medical professionals) and could recognize in response to visual stimuli but could not name. Half of each stimulus category was trained, and for control, half of each category remained untrained. Also, 145 low-frequency common nouns served as control stimuli.

Treatment Procedures

The specific number of treatment hours for each participant is subsequently outlined within each experimental section. Therapy was linguistically distributed (lexical, semantic, phonologic, orthographic) and multimodal (visual, auditory, articulatory) [26]. The treatment procedures were as follows: A picture (e.g., Meryl Streep) was shown to the participant, who was then prompted to name it (e.g., "Can you name this person?"). Regardless of naming accuracy, each subsequent step was completed. Semantic features of the picture were provided verbally (e.g., "She is an Oscar-winning actress"). Three semantic features were initially generated by the clinician, and if the participant(s) had others to add, they were added. Two additional picture exemplars of the item were shown to the participant. Next, the number of syllables in each word and the initial phoneme of each word were provided. The experimenter then provided the total number of sounds in the first and last name, and sounded out the first and last name. The picture was then shown with the written name, and the participant was asked to write the name three times and repeat the name three times while keeping the written word in view. The experimenter then moved on to the next item, following the same procedure. As the therapy progressed, the participant naturally became more active in generating the cues.

Data Analysis

Repeated probe data were analyzed in terms of effect size (ES) [27], comparing mean scores in the posttreatment probes to mean scores at baseline relative to baseline standard deviations (SDs), [$ES = (Mean_{posttreatment} - Mean_{baseline}) / SD_{baseline}$]. In the event that baselines had zero SD, a pooled ES was calculated using the following formula: [$ES = (Mean_{posttreatment} - Mean_{baseline}) / SD_{pooled}$]. ES >2.6 was considered small, >3.9 was considered medium, and >5.8 was considered large [28].

Experiment 1

Participant

P1 was a 51 yr old right-handed Caucasian male with left temporal lobe epilepsy (left temporal electroencephalogram [EEG] onset and left mesial temporal sclerosis) who contracted epilepsy at 42 yr of age. He held an associate of arts degree, had previously worked as a chef, and was unemployed at the time of enrollment in the study. He had a long-standing history of being seropositive for the human immunodeficiency virus and previously underwent surgical biopsy for a right parietal lymphoma, developing seizures several years afterward. He underwent a tailored left temporal lobectomy using speech mapping of object naming [29]. No temporal speech area was found with mapping. He had resection of the anterior 3–4 cm of middle and inferior temporal gyrus with sparing of the superior temporal gyrus and resection of the hippocampus back to the collicular plate, though without extensive hippocampal interictal abnormalities [30]. Prior to treatment, he demonstrated difficulty in naming proper nouns and PRFs (70% accuracy on the full Tranel corpus [24–25]). Lexical retrieval for common nouns was within normal limits as measured by the BNT (59/60). The participant had mild memory impairments on baseline neuropsychological testing that were apparent with both verbal and visual stimuli (**Table 1**).

Stimuli

Stimuli for P1 consisted of 20 FF, 24 FP, and 20 PRF. A portion of the FP stimuli was gathered from Tranel's corpus [24–25], and the remaining items consisted of famous world landmarks that the participant could not name.

Treatment and Outcome Measure Schedule

Repeated probes were collected prior to the start of treatment, during the course of treatment, immediately following treatment, and 8 wk following surgical resection. A total of 32 h of therapy were delivered: 2 h/d, 4 d/wk for 4 wk. Following the baseline testing phase, FF were first treated, then upon achieving criterion of 80 percent accuracy across three exposures to all treatment items (after 8 h), FP were treated, and then upon achieving criterion (after 16 h), PRF were treated (after 8 h). The treatment for PRF stimuli was terminated early as P1 underwent surgery.

Experiment 2

Participant

P2 was a 61 yr old right-handed Caucasian male with left temporal lobe epilepsy (left EEG onset and left mesial temporal sclerosis), who contracted epilepsy at 50 yr of age. He had approximately six complex partial seizures per week without generalized seizures. He was therapeutic on three anticonvulsants. He held a bachelor's degree and worked as a financial specialist. Cerebral amytal testing showed bilateral hemispheric involvement for language (but greater involvement on the right) and right dominance for memory. He underwent a left temporal lobectomy with resection of 4 cm of middle, inferior, and basal temporal gyri; 1cm of superior temporal gyrus; and approximately 3 cm of hippocampus. Prior to language treatment, he demonstrated difficulty in naming proper names (70% accuracy, full Tranel corpus [24–25]). No aphasia was present as measured by the WAB (aphasia quotient = 97.2/100), and mild common-name naming impairment was measured by the BNT (50/60) (see **Table 1** for all test results). The participant had average to high average performance on verbal and visual memory tests as compared to his age-matched control group.

Stimuli

Stimuli for P2 consisted of 10 FF and 10 FP. All stimuli were gathered from Tranel's corpus [24–25], and FF and FP were treated simultaneously (as opposed to sequentially as with P1). P2 was trained on a fewer number of items because of limited treatment time as a result of a scheduled surgical resection.

Treatment and Outcome Measure Schedule

P2 received two rounds of treatment with the same FF and FP stimuli; he elected not to undergo surgical resection following the first course of language therapy. Results from the first course of therapy were reported in an earlier article [26]. Nine months following the first course of therapy, the participant decided to undergo surgery, thus another round of treatment was delivered. For the first course of treatment, repeated probes were administered prior to the start of treatment, during the course of treatment, and immediately following treatment. Nine months later, baseline repeated probes were administered. Probes were collected during the course of treatment, immediately following treatment, and 6 wk following surgical resection. P2 received a total of 10 h of therapy over 5 d in the first course of treatment and 3 h over 2 d in the second course of treatment.

Experiment 3

Participant

Participant 3 (P3) was a 35 yr old right-handed Caucasian male with left temporal lobe epilepsy who contracted complex partial epilepsy at 33 yr of age. He had a significant medical history of sleep apnea treated with continuous positive airway pressure and episodes of depression controlled with medication. He had 12 yr of education and worked as a sheriff's deputy. Although EEG suggested left temporal onset, his magnetic resonance imaging showed only subtle anterior and mesial temporal changes and a positron emission tomography scan suggested temporal lobe hypometabolism; thus invasive monitoring with subdural electrodes was recommended. Cerebral amytal testing revealed left-sided dominance for language and memory supported by both hemispheres. After craniotomy for implantation of medial and lateral temporal lobe electrodes, seizures were mapped to the basal-mesial temporal lobe. Speech (tools and animals, primarily) was mapped extraoperatively 6 d after electrode implantation. No temporal speech area was found with mapping. He subsequently had resection of 5 cm of basal and inferior temporal gyri, 4 cm of middle temporal gyrus, and 1cm of superior temporal gyrus. Approximately 2.5 cm of hippocampus was resected. Pathology revealed dysplastic organization of the anteriomesial and basal temporal lobe.

Prior to language treatment, he demonstrated difficulty in naming proper names (16.85% accuracy on full Tranel corpus [24–25]). There was no aphasia present as shown by a score of 96/100 on the WAB aphasia quotient. Impaired common-noun naming was evident as measured by the BNT (39/60). A list of his relevant neuropsychological and language testing scores is provided in **Table 1**. The participant had very mild memory impairments on baseline neuropsychological testing that suggested dominant hemisphere dysfunction.

Stimuli

Stimuli consisted of 10 FF and 10 FP [24–25], which were treated simultaneously.

Treatment and Outcome Measure Schedule

Repeated probes were collected prior to the start of treatment, during the course of treatment, immediately following treatment, and 11 wk following surgical resection. A total of 6 h of therapy was delivered (3 treatment sessions of 2 h each).

RESULTS

Experiment 1

Reliability scoring was performed on 25 percent of the verbal naming performance data. Intraclass correlation assessing reliability was 0.99 (intrarater) and 0.99 (interrater). Results for P1 are displayed in **Table 2**.

Acquisition effects were measured by naming of trained FF, FP, and PRF items immediately following therapy. Pretreatment naming performance for trained FF was 0.00 percent (SD = 0.00), for FP was 0.00 percent (SD = 0.00), and for PRF was 18.50 percent (SD = 8.01). Naming performance immediately posttreatment for FF was 99.00 percent (SD = 3.33, ES = 26.16; large), for FP was 100.00 percent (SD = 0.00, ES = 27.32; large) and for PRF was 53.33 percent (SD = 5.77, ES = 4.36; medium). Control for treatment was measured by naming of untrained items immediately posttreatment (compared to pretreatment). Results showed: pretreatment naming accuracy for FF was 1.43 percent (SD = 3.78), for FP was 6.46 percent (SD = 3.66), and for PRF was 6.92 percent (SD = 8.55). Immediately posttreatment, naming accuracy for untrained items for FF was 6.67 percent (SD = 7.07, ES = 1.39; no effect), for FP was 16.70 percent (SD = 0, ES = 2.80; small), and for PRF was 16.70 percent (SD = 5.77, ES = 1.14; no effect) (**Figure 1)**.

The effect of training on the preservation of proper naming skills was measured by spoken word production of trained items following surgery. Immediate postsurgical naming accuracy for trained items for FF was 23.33 percent (SD = 5.77, ES = 6.17; large), for FP was 25.00 percent (SD = 8.3, ES = 6.83; large), and for PRF was 23.33 percent (SD = 5.77, ES = 0.61; no effect). Control for mitigation was measured by spoken word performance of untrained items immediately postsurgery (compared to pretreatment). Immediate postsurgical naming accuracy for untrained items for FF was 0.00 percent (SD = 0, ES = 1.39; no effect), for FP was 2.77 percent (SD = 4.79, ES = –1.01; no effect), and for PRF was 6.67 percent (SD = 5.77, ES = 1.14; no effect).

Experiment 2

Reliability scoring was performed on 15 percent of the data. Intraclass correlation assessing intrarater reliability was 0.99, and assessing interrater reliability was 0.97. Results for P2 are displayed in **Table 2** and **Figure 2**.

Acquisition effects were measured by spoken word production of trained FF and FP items immediately following therapy. Round 1 naming performance on trained items pretreatment for FF and FP (combined) was 28.00 percent (SD = 18.35) and immediately posttreatment was 87.00 percent (SD = 13.70, ES = 3.18; small). Round 2 naming performance on trained items pretreatment for FF and FP was 77.00 percent (SD = 11.60) and

Table 2.
Mean posttreatment accuracy, effect size (ES), and interpretation of ES for all participants for acquisition (posttreatment naming accuracy on trained and untrained items) and the effect of training on the preservation of naming skills (postsurgical naming accuracy of trained and untrained items).

Participant	Acquisition				Preservation			
	Trained	ES	Untrained	ES	Trained	ES	Untrained	ES
1								
FF	99.00	26.16*	6.67	1.39*†	23.33	6.17*	0.00	1.39*†
FP	100.00	27.32*	16.70	2.80	25.00	6.83*	2.77	–1.01*†
PRF	53.33	4.36*	16.70	1.14*†	23.33	0.61†	6.67	1.14*†
2	87.00	3.18*	42.00	0.75*†	70.00	2.27*†‡	47.00	1.08*†
3	100.00	17.32*	30.00	4.33	0.00	0.00†	0.00	–1.00†

Note: ES >2.6: small, >3.9: medium, >5.8: large.
*Indicates support for predictions.
†Not significant.
‡Approaching significance near 2.6 for small effect size.
FF = famous faces, FP = famous places, PRF = personally relevant faces.

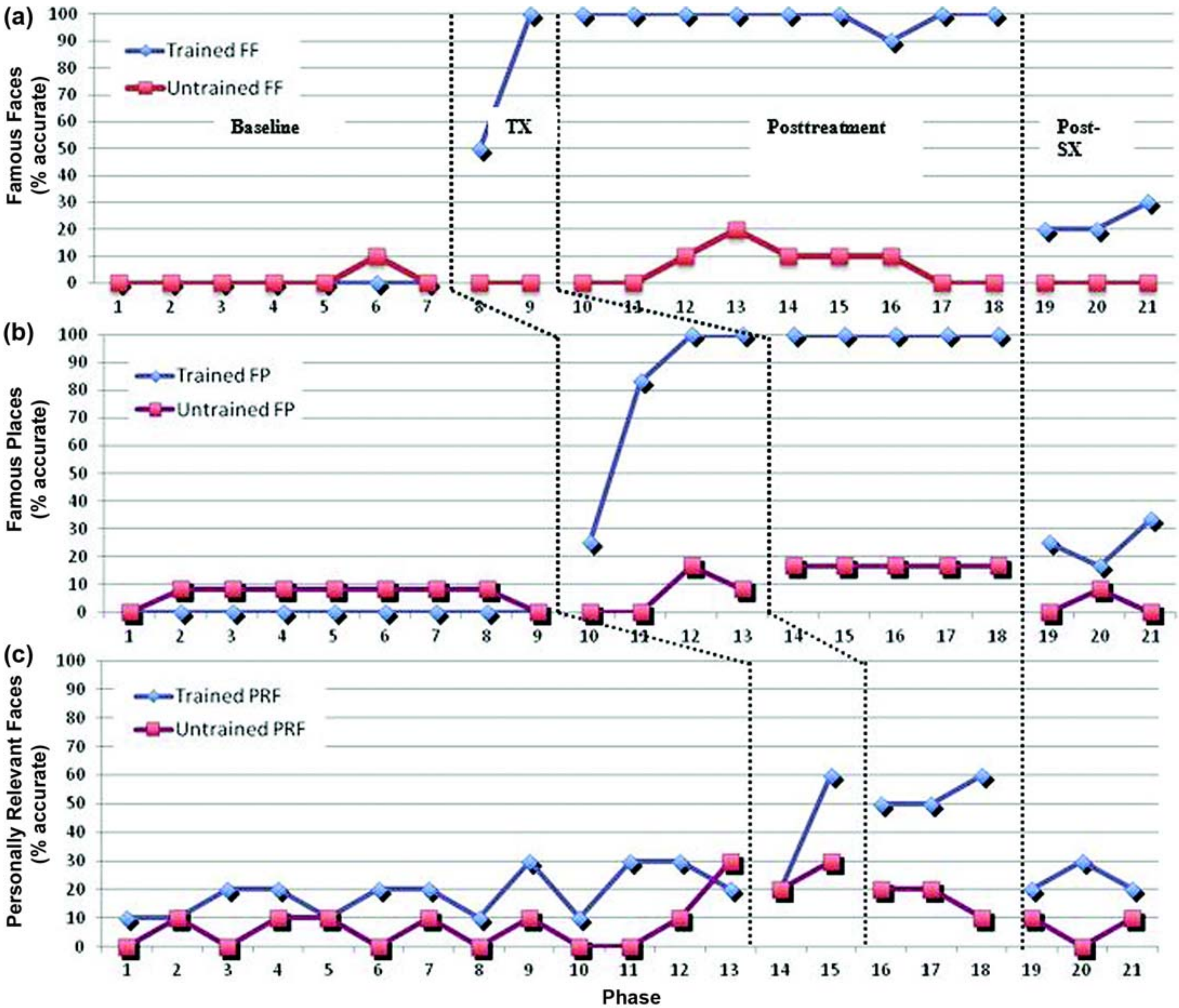

Figure 1.
Participant 1. Repeated probe data (% accurate) for **(a)** famous faces (FF, *n* = 10), **(b)** famous places (FP, *n* = 12), and **(c)** personally relevant faces (PRF, *n* = 10) during baseline, treatment (TX), posttreatment, and postsurgical (Post-SX) phases.

immediately posttreatment was 100.00 percent (SD = 0.00, ES = 2.02; no effect). Control effects for treatment were measured by naming performance for untrained items immediately posttreatment (compared to pretreatment). Results showed control was maintained for both round 1 and round 2 of treatment. Round 1 naming performance for untrained items pretreatment was 30.00 percent (SD = 15.49) and immediately posttreatment was 42.00 percent (SD = 7.50, ES 0.75; no effect). Round 2 naming performance for untrained items pretreatment was 50.00 percent (SD = 10.00) and immediately posttreatment was 65.00 percent (SD = 7.07, ES = 1.50; no effect).

The effect of training on the preservation of naming skills was measured by spoken word production for trained items following surgery. Naming performance for trained items following surgery was 70.00 percent (SD =

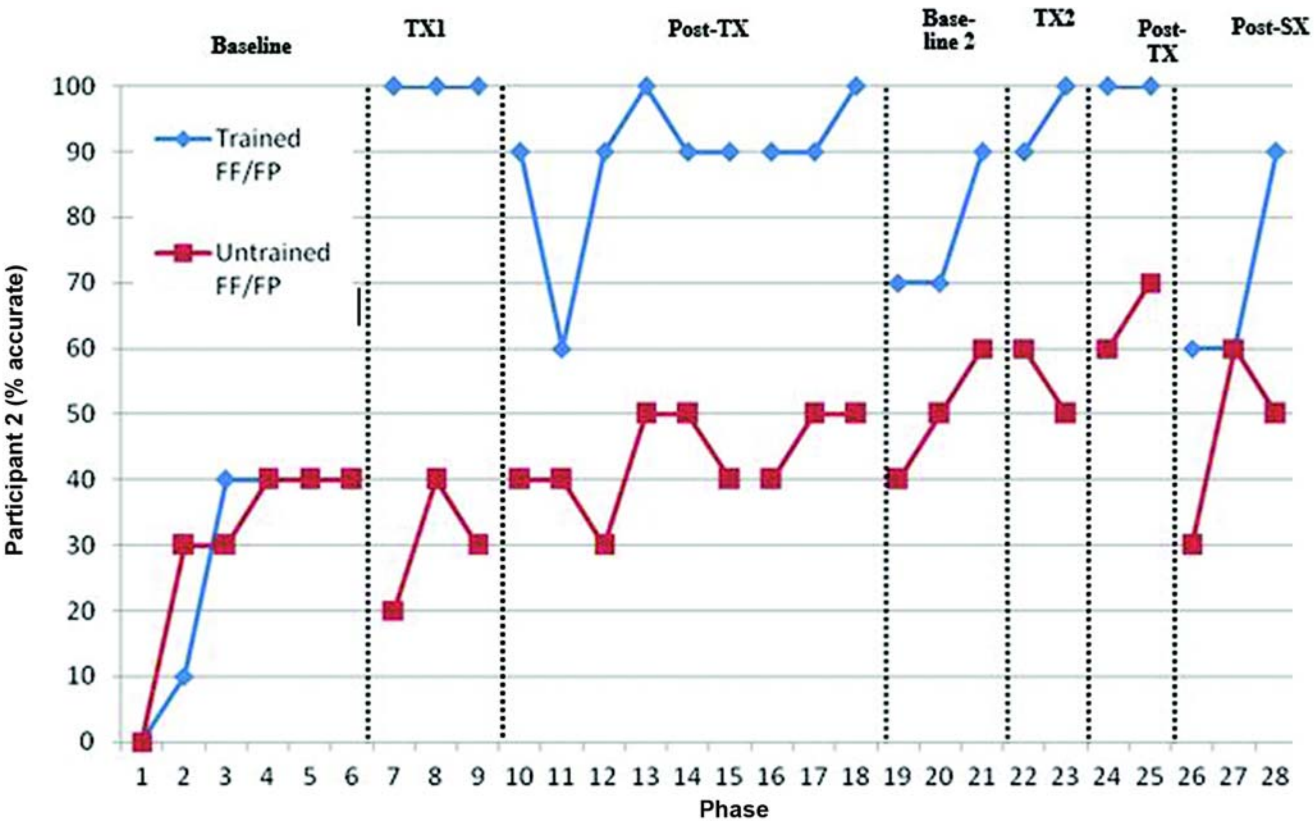

Figure 2.
Participant 2. Repeated probe data (% accurate) for famous faces (FF, n = 10) and famous places (FP, n = 10) during baseline, treatment (TX1 and TX2), posttreatment (post-TX), and postsurgical (post-SX) phases.

17.32, ES = 2.27; no effect). Control effects were measured by spoken word performance of untrained items immediately postsurgery (compared to pretreatment). Immediate postsurgical naming accuracy for untrained items was 47.00 percent (SD = 15.30, ES = 1.08; no effect).

Experiment 3

Intraclass correlation assessing intrarater reliability was 0.97, and assessing interrater reliability was 0.97. Results for P3 are displayed in **Table 2** and **Figure 3**.

Acquisition effects were measured by the naming of trained FF and FP items immediately following therapy. Naming performance for trained items pretreatment for both FF and FP was 0.00 percent (SD = 0.00) and immediately posttreatment was 100.00 percent (SD = 0.00, ES = 17.32; large). Control effects for treatment were measured by naming performance for untrained items immediately postsurgery (compared to pretreatment). Results showed control was marginally maintained for this experiment as naming performance on untrained FF and FP pretreatment was 5.00 percent (SD = 6.00) and posttreatment was 30.00 percent (SD = 0.00, ES = 4.33; medium).

The effect of training on the preservation of naming skills was measured by spoken word production for trained items following surgery. Naming performance for trained FF and FP following surgery was 0.00 percent (SD = 0.00, ES = 0.00; no effect). Control effects were measured by naming performance of untrained items immediately postsurgery (compared to pretreatment). Immediate postsurgical naming accuracy for untrained items was 0.00 percent (SD = 0.00, ES = –1.00; no effect).

DISCUSSION

The purpose of this study was to investigate whether language treatment administered prior to surgery could

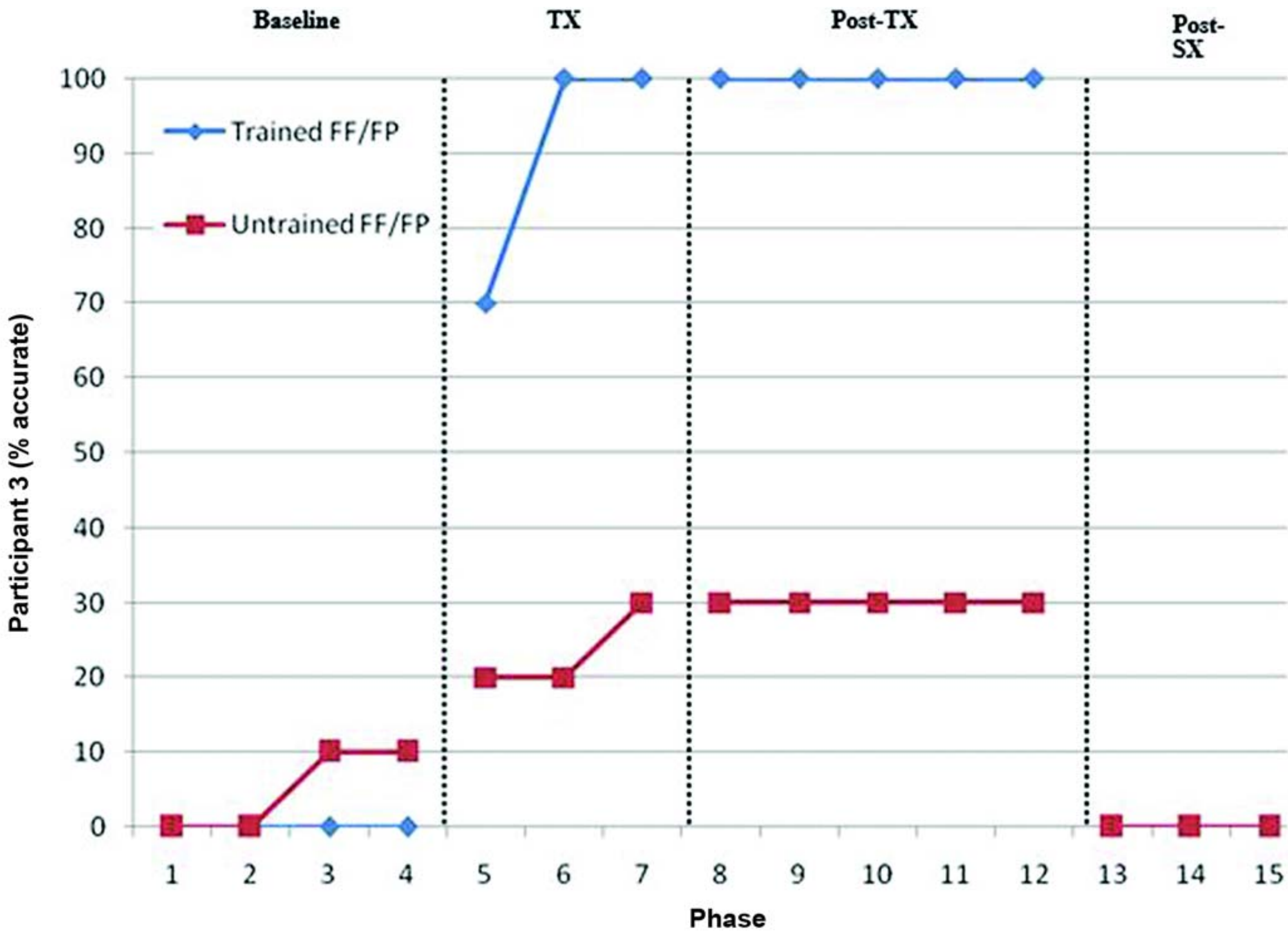

Figure 3.
Participant 3. Repeated probe data (% accurate) for famous faces (FF, *n* = 10) and famous places (FP, *n* = 10) during baseline, treatment (TX), posttreatment (post-TX), and postsurgical (post-SX) phases.

reduce naming deficits before ATL surgery and diminish the negative effects of subsequent ATL surgery on proper-noun naming. We hypothesized that (1) using a linguistically distributed treatment approach would improve proper-noun naming presurgically despite the presence of damaged neural tissue and (2) presurgical language treatment would confer a preservation advantage for trained items over untrained items. Evidence for a protective effect of preoperative language therapy would support a paradigm shift in the treatment of proper-name retrieval deficits resulting from elective neurosurgical procedures, such as ATL resection for epilepsy.

Overall, the results of this preliminary investigation provide support for the application of an intensively delivered, neurally distributed behavioral treatment that has shown success in rehabilitation of word-retrieval deficits following stroke [19]. That is, if proper-noun knowledge is documented to be a binding zone within the ATL and linguistic knowledge such as phonology and acoustic, semantic, and orthographic substrates for common nouns are documented to be distributed throughout the dominant left hemisphere [31], then through explicit training of proper-noun linguistic features, the representations of proper nouns can be expanded beyond the binding zone of the ATL. However, there is a caveat to this statement. Because we are uncertain as to how much reorganization spontaneously occurred prior to surgery, treatment may have indeed capitalized on existing neural substrates located outside of the ATL.

Presurgical Acquisition

In all cases, our participants showed improved naming performance on items trained prior to surgery, demonstrating that improved naming of faces and places can occur despite the interference of ongoing seizure activity from the left ATL. Because of an absence of shared semantic features between proper names, we predicted only items receiving training would improve. That said, there was a small effect for untrained FP items for P1, and a medium effect for untrained FP and FF items for P3. There are several possible explanations for these findings. The change in naming performance for P1 reflects improvement on one item only (which is not clinically significant), suggesting there were too few items in the training corpus. Similarly, the change in naming performance for P3 reflects improvement on only two items. The participants could have been employing strategies learned in treatment to the untrained items, or even researching the items outside of the treatment session; however, when queried as to these possibilities, they denied these actions. Another possibility to explain improvement on the untrained items could be differing levels of familiarity with the items, and we believe this to be the case for P1. A retrospective analysis of the data showed that the items that contributed to overall improvement in his score were the same three items named correctly across the repeated probe sessions. Perhaps the participant's prior knowledge of these three items was more strongly instantiated relative to the other untrained (stable) items. Further, there is also a possibility that spontaneous, presurgical bilateral hemispheric language support may have contributed to overall performance on both trained and untrained items.

Effects of Presurgical Language Treatment on Postsurgical Proper-Name Retrieval

Our second hypothesis, that presurgical language treatment would confer an advantage to trained items postsurgery, yielded mixed results. P3 did not show a mitigation effect, likely because of the low number of treatment hours he received (6) compared to the other two individuals (32 h for P1, 13 h for P2). That the participant with the lowest number of treatment hours did not show a mitigation effect is important information for this phase I study and likely suggests that a higher number of treatment hours are needed if the goal is to mitigate the expected postsurgical proper-naming deficits. Of interest, P1 showed a preservation effect for FF and FP, but not for PRF. The PRF stimuli employed may not have been carefully selected: the trained PRF stimuli were a combination of healthcare professionals from his epilepsy team (*n* = 6 items) and family/friends (*n* = 4 items). Retrospective analysis showed that the medium treatment effect of PRF (4.36) was because of his ability to learn names of his family members only and not his healthcare team. The family names likely represented semantic knowledge that was more richly represented and more strongly instantiated compared to the medical professionals who, while personally relevant, constituted more recently acquired conceptual knowledge. Finally, the ES for P2's trained items was approaching significance for the preservation hypothesis. As it turns out, compared to P1 and P3, P2 pretreatment baseline scores were 28 percent accurate, where P1 and P3 baseline scores were 0 percent accurate. Therefore, P2 was not able to make as large an improvement as a result of treatment as were P1 and P3. This relatively preserved baseline may be related to his atypical (bilateral, right > left) language dominance. Compared to those with typical (left) dominance, patients with atypical dominance may be expected to have similar language organization within the temporal lobe [32–33] but lateralization of proper names could be altered wholly or in part [34]. Finally, it is interesting to note that P2 did not show much self-reported decline in activities of daily living and memory testing following surgery, which provides evidence that his presurgical reliance on ATL function was lower than it was for P1 and P3.

Limitations and Future Directions

The data presented here are preliminary, given the small number of participants and the diversity across training protocols that was necessitated by differences in the participants' neurological and neurosurgical treatment plans. There are a number of issues that remain to be resolved in future studies. First, as is typical in treatment development research, systematic refinement of the methodology should occur. This includes the addition of standardized measures to capture familiarity data used for stimuli selection. Second, standardizing the number of treatment hours would allow further exploration of the dose-response relationship that is suggested by our data. Third, while our data demonstrate that the participants were better off naming trained items after surgery than would have been expected had they not received the language treatment, we cannot be certain at this time whether it was solely the treatment that mitigated the negative effects of surgery on naming or it was merely that participants went into surgery with those trained items being more familiar prior to training. This issue can be resolved in future studies by comparing the effects of surgery on trained items that are returned to high levels of accuracy before surgery with the effects on items that were highly accurate presurgery without training. A fourth issue to consider in future studies is whether positive treatment effects rely on the entire multimodality treatment approach that we used here or on specific elements of that approach. Future studies should explore both participant and stimulus variables that may predict the response to treatment as well as neural mechanisms responsible for reorganization. Regardless of these limitations, however, we believe that the data presented here support the idea that providing a linguistically distributed treatment for proper-name retrieval can have a positive effect on people with left temporal lobe epilepsy, whether or not they undergo surgical resection of the left temporal lobe. Finally, in considering this treatment program approach from a broader perspective related to the timing of treatment delivery and the type of treatment administered, the concept employed here (presurgical delivery) is consistent with rehabilitation efforts applied to prevent or diminish effects of cognitive decline, such as those in mild cognitive impairment [35].

CONCLUSIONS

It has long been observed that individuals with left temporal lobe epilepsy typically show impaired proper-name retrieval and that this impairment can be expected to become worse following left temporal lobe resection for seizure control. This study demonstrates two conclusions relevant to these phenomena: first, we have demonstrated that proper-name retrieval can be improved with a linguistically distributed treatment in people who have not had surgery, despite diseased temporal lobe function. Preoperatively, deficits were present but essentially resolved for most trained items (given adequate time for treatment), indicating that the areas damaged by ongoing epilepsy do not prevent the occurrence of processes that allow such naming to be rehabilitated. Second, we have shown that providing this intervention prior to surgery can result in postsurgical proper-name retrieval that is better than it had been prior to treatment; this is in contrast to the expected decline from baseline function that would be expected if there were no language treatment provided (which is typical of current standard care). This study, then, supports treatment of deficits prior to their full realization rather than in reaction to them.

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REFERENCES

1. Centers for Disease Control and Prevention. Epilepsy fast facts [Internet]. Atlanta (GA): U.S. Department of Health and Human Services [updated 2016 Feb 2; cited 216 Oct 4]. Available from: http://www.cdc.gov/epilepsy/basics/fast-facts.htm
2. Pugh MJ, Orman JA, Jaramillo CA, Salinsky MC, Eapen BC, Towne AR, Amuan ME, Roman G, McNamee SD, Kent TA, McMillan KK, Hamid H, Grafman JH. The prevalence of epilepsy and association with traumatic brain injury in veterans of the Afghanistan and Iraq wars. J Head

Trauma Rehabil. 2015;30(1):29–37. [PMID:24695268] http://dx.doi.org/10.1097/HTR.0000000000000045

3. Wiebe S, Blume WT, Girvin JP, Eliasziw M; Effectiveness and Efficiency of Surgery for Temporal Lobe Epilepsy Study Group. A randomized, controlled trial of surgery for temporal-lobe epilepsy. N Engl J Med. 2001;345(5):311–18. [PMID:11484687] http://dx.doi.org/10.1056/NEJM200108023450501
4. Tranel D, Feinstein J, Manzel K. Further lesion evidence for the neural basis of conceptual knowledge for persons and other concrete entities. J Neuropsychol. 2008;2(Pt 1): 301–20. [PMID:19334316] http://dx.doi.org/10.1348/174866407X227033
5. Drane DL, Ojemann GA, Aylward E, Ojemann JG, Johnson LC, Silbergeld DL, Miller JW, Tranel D. Category-specific naming and recognition deficits in temporal lobe epilepsy surgical patients. Neuropsychologia. 2008;46(5):1242–55. [PMID:18206185] http://dx.doi.org/10.1016/j.neuropsychologia.2007.11.034
6. Damasio AR. The brain binds entities and events by multiregional activation from convergence zones. Neural Comput. 1989;1:123–32. http://dx.doi.org/10.1162/neco.1989.1.1.123
7. Damasio H, Tranel D, Grabowski T, Adolphs R, Damasio A. Neural systems behind word and concept retrieval. Cognition. 2004;92(1–2):179–229. [PMID:15037130] http://dx.doi.org/10.1016/j.cognition.2002.07.001
8. Damasio H, Grabowski TJ, Tranel D, Hichwa RD, Damasio AR. A neural basis for lexical retrieval. Nature. 1996; 380(6574):499–505. [PMID:8606767] http://dx.doi.org/10.1038/380499a0
9. Grabowski TJ, Damasio H, Tranel D, Ponto LL, Hichwa RD, Damasio AR. A role for left temporal pole in the retrieval of words for unique entities. Hum Brain Mapp. 2001;13(4):199–212. [PMID:11410949] http://dx.doi.org/10.1002/hbm.1033
10. Grabowski TJ, Damasio H, Tranel D, Cooper GE, Ponto LL, Watkins GL, Hichwa RD. Residual naming after damage to the left temporal pole: A PET activation study. Neuroimage. 2003;19(3):846–60. [PMID:12880813] http://dx.doi.org/10.1016/S1053-8119(03)00109-5
11. Simmons WK, Reddish M, Bellgowan PS, Martin A. The selectivity and functional connectivity of the anterior temporal lobes. Cereb Cortex. 2010;20(4):813–25. [PMID:19620621] http://dx.doi.org/10.1093/cercor/bhp149
12. Bozeat S, Gregory CA, Ralph MA, Hodges JR. Which neuropsychiatric and behavioural features distinguish frontal and temporal variants of frontotemporal dementia from Alzheimer’s disease? J Neurol Neurosurg Psychiatry. 2000; 69(2):178–86. [PMID:10896690] http://dx.doi.org/10.1136/jnnp.69.2.178
13. Binney RJ, Embleton KV, Jefferies E, Parker GJ, Ralph MA. The ventral and inferolateral aspects of the anterior temporal lobe are crucial in semantic memory: Evidence from a novel direct comparison of distortion-corrected fMRI, rTMS, and semantic dementia. Cereb Cortex. 2010;20(11):2728–38. [PMID:20190005] http://dx.doi.org/10.1093/cercor/bhq019
14. Binder JR, Desai RH, Graves WW, Conant LL. Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. Cereb Cortex. 2009; 19(12):2767–96. [PMID:19329570] http://dx.doi.org/10.1093/cercor/bhp055
15. Kleim JA, Jones TA. Principles of experience-dependent neural plasticity: Implications for rehabilitation after brain damage. J Speech Lang Hear Res. 2008;51(1):S225–39. [PMID:18230848] http://dx.doi.org/10.1044/1092-4388(2008/018)
16. Hebb DO. The organization of behavior. New York (NY): John Wiley and Sons; 1949. 335 p.
17. Raymer AM, Beeson P, Holland A, Kendall D, Maher LM, Martin N, Murray L, Rose M, Thompson CK, Turkstra L, Altmann L, Boyle M, Conway T, Hula W, Kearns K, Rapp B, Simmons-Mackie N, Gonzalez Rothi LJ. Translational research in aphasia: From neuroscience to neurorehabilitation. J Speech Lang Hear Res. 2008;51(1):S259–75. [PMID:18230850] http://dx.doi.org/10.1044/1092-4388(2008/020)
18. Nadeau SE. Phonology: A review and proposals from a connectionist perspective. Brain Lang. 2001;79(3):511–79. [PMID:11781057] http://dx.doi.org/10.1006/brln.2001.2566
19. Kendall DL, Rosenbek JC, Heilman KM, Conway T, Klenberg K, Gonzalez Rothi LJ, Nadeau SE. Phoneme-based rehabilitation of anomia in aphasia. Brain Lang. 2008;105(1):1–17. [PMID:18237773] http://dx.doi.org/10.1016/j.bandl.2007.11.007
20. Wechsler D. WMS-III administration and scoring manual. San Antonio (TX): The Psychological Corporation; 1997.
21. Wechsler D. Wechsler Memory Scale-Fourth edition (WMS-IV). San Antonio (TX): Pearson; 2009.
22. Kertesz A. Western Aphasia Battery test manual. New York (NY): Grune & Stratton; 1982. 7 p.
23. Kaplan E, Goodglass H, Weintraub S, Segal O. Boston Naming Test. Philadelphia (PA): Lea and Febiger; 1983.
24. Tranel D. Impaired naming of unique landmarks is associated with left temporal polar damage. Neuropsychology. 2006;20(1):1–10. [PMID:16460217] http://dx.doi.org/10.1037/0894-4105.20.1.1
25. Tranel D, Damasio H, Damasio AR. A neural basis for the retrieval of conceptual knowledge. Neuropsychologia. 1997;35(10):1319–27. [PMID:9347478] http://dx.doi.org/10.1016/S0028-3932(97)00085-7
26. Minkina I, Ojemann JG, Grabowski TJ, Silkes JP, Phatak V, Kendall DL. Treatment of proper name retrieval deficits in an individual with temporal lobe epilepsy. Am J Speech

Lang Pathol. 2013;22(2):S250–55. [PMID:23695901] http://dx.doi.org/10.1044/1058-0360(2012/12-0048)
27. Kromrey JD, Foster-Johnson L. Determining the efficacy of intervention: The use of effect sizes for data analysis in single-subject research. J Exp Educ. 1996;65:73–93. http://dx.doi.org/10.1080/00220973.1996.9943464
28. Beeson PM, Robey RR. Evaluating single-subject treatment research: Lessons learned from the aphasia literature. Neuropsychol Rev. 2006;16(4):161–69. [PMID:17151940] http://dx.doi.org/10.1007/s11065-006-9013-7
29. Ojemann G, Ojemann J, Lettich E, Berger M. Cortical language localization in left, dominant hemisphere. An electrical stimulation mapping investigation in 117 patients. J Neurosurg. 1989;71(3):316–26. [PMID:2769383] http://dx.doi.org/10.3171/jns.1989.71.3.0316
30. McKhann GM 2nd, Schoenfeld-McNeill J, Born DE, Haglund MM, Ojemann GA. Intraoperative hippocampal electrocorticography to predict the extent of hippocampal resection in temporal lobe epilepsy surgery. J Neurosurg. 2000;93(1):44–52. [PMID:10883904] http://dx.doi.org/10.3171/jns.2000.93.1.0044
31. Vigneau M, Beaucousin V, Hervé PY, Duffau H, Crivello F, Houdé O, Mazoyer B, Tzourio-Mazoyer N. Meta-analyzing left hemisphere language areas: Phonology, semantics, and sentence processing. Neuroimage. 2006;30(4):1414–32. [PMID:16413796] http://dx.doi.org/10.1016/j.neuroimage.2005.11.002
32. Chang EF, Wang DD, Perry DW, Barbaro NM, Berger MS. Homotopic organization of essential language sites in right and bilateral cerebral hemispheric dominance. J Neurosurg. 2011;114(4):893–902. [PMID:21235314] http://dx.doi.org/10.3171/2010.11.JNS10888
33. Drane DL, Roraback-Carson J, Hebb AO, Hersonskey T, Lucas T, Ojemann GA, Lettich E, Silbergeld DL, Miller JW, Ojemann JG. Cortical stimulation mapping and Wada results demonstrate a normal variant of right hemisphere language organization. Epilepsia. 2012;53(10):1790–98. [PMID:22780099] http://dx.doi.org/10.1111/j.1528-1167.2012.03573.x
34. Drane DL, Ojemann GA, Ojemann JG, Aylward E, Silbergeld DL, Miller JW, Tranel D. Category-specific recognition and naming deficits following resection of a right anterior temporal lobe tumor in a patient with atypical language lateralization. Cortex. 2009;45(5):630–40. [PMID:18632095] http://dx.doi.org/10.1016/j.cortex.2008.04.007
35. Baker LD, Frank LL, Foster-Schubert K, Green PS, Wilkinson CW, McTiernan A, Plymate SR, Fishel MA, Watson GS, Cholerton BA, Duncan GE, Mehta PD, Craft S. Effects of aerobic exercise on mild cognitive impairment: A controlled trial. Arch Neurol. 2010;67(1):71–79. [PMID:20065132] http://dx.doi.org/10.1001/archneurol.2009.307

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