

Shared Space, Separate Processes: Neural Activation Patterns for Auditory Description and Visual Object Naming in Healthy Adults

Marla J. Hamberger,^{1*} Christian G. Habeck,¹ Spiro P. Pantazatos,^{2,3}
Alicia C. Williams,¹ and Joy Hirsch^{3,4,5}

¹Department of Neurology, Columbia University Medical Center, New York

²Department of Physiology and Cellular Biophysics, Columbia University Medical Center,
New York

³fMRI Research Center, Columbia University Medical Center, New York

⁴Department of Neuroscience, Columbia University Medical Center, New York

⁵Department of Radiology, Columbia University Medical Center, New York

ABSTRACT: Historically, both clinicians and cognitive scientists have used visual object naming measures to study naming, and lesion-type studies have implicated the left posterior, temporo-parietal region as a critical component of naming circuitry. However, recent results from behavioral and cortical stimulation studies using auditory description naming as well as visual object naming in left temporal lobe epilepsy patients suggest that discrete sites in anterior temporal cortex are critical for description naming, whereas posterior temporal regions mediate both visual object naming and description naming. To determine whether this task specificity reflects normal cerebral organization and processing, 13 healthy adults performed description naming and visual naming during functional neuroimaging. In addition to standard univariate analysis, multivariate, ordinal trend analysis examined the network character of the regions involved in task-specific naming. Univariate analysis indicated posterior temporal activation for both visual naming and description naming, whereas multivariate analysis revealed broader networks for both tasks, with both overlapping and task-specific regions, as well as task-related differences in the way the tasks utilized common regions. Additionally, multivariate analysis revealed unique, task-specific, regionally covarying activation patterns that were strikingly consistent in all 13 subjects for visual naming and 12/13 subjects for description naming. Results suggest a common neural substrate, yet differentiable neural processes underlying visual naming and description naming in neurologically intact individuals. These findings support the use of both types of tasks for clinical assessment and may have application in the treatment of neurologically based naming deficits. *Hum Brain Mapp* 00:000–000, 2013. © 2013 Wiley Periodicals, Inc.

Additional Supporting Information may be found in the online version of this article.

Contract grant sponsor: National Institutes of Health and National Institute of Neurological Disorders and Stroke; Contract grant number: R01 NS35140 (MJH); Contract grant sponsor: National Institute of Biomedical Imaging and Bioengineering; Contract grant number: NIBIB 5R01EB006204-03 (CGH); Contract grant sponsor: NRSAs; Contract grant number: F31MH088104-01A1 (SPP); Contract grant sponsor: U.S. Army; Contract grant number: RDECOM-TARDEC W56H2V-04-P-L (JH)

*Correspondence to: Marla J. Hamberger, Ph.D., Department of Neurology, 710 West 168th Street New York, NY 10032, USA. E-mail: mh61@columbia.edu

Received for publication 21 August 2012; Revised 2 May 2013; Accepted 27 May 2013.

DOI 10.1002/hbm.22345

Published online in Wiley Online Library (wileyonlinelibrary.com).

Key words: visual object naming; auditory description naming; fMRI

INTRODUCTION

Naming is considered a left (dominant) hemisphere function and results from both lesion studies and cortical stimulation mapping suggest the mid-posterior temporo-parietal region as critical for normal naming function (Geschwind, 1965; Haglund et al., 1994; Joseph, 1996; Ojemann et al., 1989). This inference is based on decades of clinical assessment and clinical research using visual object naming, which represents the most widely used technique for naming assessment. However, it is important to consider that naming difficulty occurs not only during attempts to name visually available objects but also in the context of linguistically based, everyday discourse. Accordingly, more recent use of auditory description naming (“DN” e.g., “What a king wears on his head”) has demonstrated a stronger association between naming performance and subjective word finding ability in everyday conversation (Hamberger and Seidel, 2003), and DN appears to be more sensitive than visual object naming (VN) to left temporal dysfunction associated with dominant temporal lobe epilepsy (Bell et al., 2003; Hamberger and Seidel, 2003). Additionally, patients with anterior temporal abnormalities (i.e., lesion or region of seizure onset) have demonstrated significantly poorer DN than VN scores, whereas patients with posterior temporal abnormalities have shown significantly weaker VN than DN scores (Hamberger and Seidel, 2009). In fact, these naming performance asymmetries accurately classified temporal lobe lesion location in individual patients.

In addition to these behavioral findings, electrical stimulation mapping (ESM) studies in dominant left TLE patients and patients with dominant left temporal lobe lesions have shown neuroanatomical differences between VN and DN (Hamberger et al., 2001; Malow et al., 1996). ESM evokes dysfunction of restricted cortical areas (beneath stimulating electrodes) via the application of several seconds of stimulation to electrode pairs on the cortical surface. Stimulation essentially produces a discrete, reversible cortical lesion, and thus, testing during stimulation provides information regarding the function of the “deactivated” site (Hamberger, 2007). Accordingly, ESM simulates the lesion method; however, the areas affected are much smaller than naturally occurring lesions and the investigator has control over site location, within the limits of clinical circumstances. Although multiple sites are tested with stimulation, most patients typically exhibit only a few positive sites (Ojemann et al., 1989). ESM studies have found that stimulation at identified positive sites in posterior temporal cortex disrupts both DN and VN, whereas stimulation at identified

positive sites in the anterior temporal region tends to disrupt DN, with no impairment to VN. Of note, some patients exhibit posterior sites where stimulation impairs VN but not DN, representing a double dissociation rather than the more common single dissociation (Hamberger et al., 2001). That stimulation can impair DN at sites found across lateral temporal cortex does not appear to reflect impaired comprehension of the description, as comprehension is demonstrated to be intact during stimulation at these sites (Hamberger et al., 2003a). Specifically, patients typically provide the item-name immediately following cessation of stimulation, indicating that the description was heard and understood. Also of note, inability to provide target words during stimulation does not reflect speech difficulty, as patients articulate normally during stimulation at these sites, despite the inability to name the target item.

Although the particulars remain controversial, research involving patients with semantic dementia as well as healthy adults suggests that the anterior temporal region serves as a core substrate for the semantic system (Lambon Ralph et al., 2010; Rogers et al., 2004). According to these theories, the anterior temporal lobe is considered an amodal semantic hub, with modality specificity referring to the representational format of the information (e.g., visual versus auditory features of a musical instrument) (Binder and Desai, 2011). In the current study, modality refers only to the form of incoming information, unrelated to the concept itself, and ESM findings suggest that the type of processing that precedes naming of a target word (i.e., pictured object versus verbal description) influences the neural substrate needed to mediate word retrieval from the semantic system. Another neurocognitive perspective parses the language system into a dorsal network that mediates phonology based motor articulation, and a ventral network that mediates access to conceptual information (Hickok and Poeppel, 2004). Although ESM findings are scientifically intriguing and clinically useful in neurosurgical patients, ESM techniques allow only for analysis of discrete cortical sites, one at a time, whereas the complexity of language warrants analysis at a more macroscopic level, investigating networks comprised of multiple brain regions that contribute to a given language function. Further, the ESM data described above are based on patients with left temporal lobe abnormalities, which, theoretically, may have altered normal brain organization and processing. Although clinical populations such as these provide unique information that cannot be obtained with noninvasive techniques, it remains unknown whether their results are relevant to healthy individuals.

We sought to determine whether, using fMRI (1) healthy adults would show different activation patterns associated with VN and DN, and if so, (2) whether task-related activation patterns would be similar to the task-related disruption patterns observed using ESM in left temporal patients. To address the above questions, we utilized fMRI in healthy adults to compare neural activation patterns during VN and DN. In addition to standard univariate (GLM) analyses to identify discrete areas of activation, we performed multivariate, Ordinal Trend Analysis (detailed below), as multivariate analyses tend to be more sensitive to the network character of the neural substrates involved in task performance.

Based on previous cortical stimulation and behavioral results, we hypothesized that (1) healthy adults would show task related differences in activation patterns for VN and DN, and that (2) DN would elicit activation across anterior and posterior temporal cortex, whereas VN activation would be limited to the posterior temporal region. Such findings would suggest that behavioral and anatomic differences observed in temporal lobe patients could be generalized to healthy adults, which would carry clinical implications for the assessment of naming in acquired brain injury or disease involving the temporal region.

METHODS

Participants

Thirteen healthy adults (nine women) participated in this study. All participants were native English speakers and were educated in English. Subjects were screened before testing to exclude those with a history of neurological disorder, head injury with loss of consciousness, or major psychiatric illness. Individuals with a history of special education or diagnosed learning disability were excluded. Twelve subjects were self-reported right-handed, one was left-handed. All subjects reported normal hearing and vision or corrected-to-normal vision. Demographic data and test scores are shown in Table I. This study was approved by the Institutional Review Board at Columbia University Medical Center, and all subjects gave informed written consent.

Stimuli

DN stimuli consisted of 63 aurally presented descriptions of concrete items (e.g. "What a king wears on his head") that required less than 4.5 seconds for presentation. Forty descriptions from Hamberger and Seidel (2003) met this criterion, and therefore 23 additional descriptions were developed and pilot tested with 10 healthy adults (all descriptions elicited the same target word in all 10 subjects). DN control (DC) stimuli consisted of 63 sentences (e.g., "The elevator was not working") matched to DN stimuli based on number of words per description.

Additionally, word frequency of the sentence subject was matched to the DN target word. Sixty-one word frequencies were obtained from Francis and Kucera (1982); two-word frequency values (i.e., hourglass, spatula) were obtained from the CELEX database (<http://www.ru.nl/celex/>). The duration of DN stimuli ranged from 2.0 to 4.4 seconds. DN stimuli were presented aurally via headphones, during which subjects viewed a fixation cross.

VN stimuli were line-drawn objects (e.g. ruler, leaf). Forty-six pictures selected from Hamberger and Seidel (2003) had item names that matched DN target word frequency; 17 additional pictures were selected from Snodgrass and Vanderwordtt (1980). Visual control (VC) stimuli were 63 "non-objects" selected from Magnie et al. (2003). These stimuli were modified slightly to better match the shading and black/white contrast features of the VN stimuli. Visual stimuli were presented for two seconds each, displayed on an LCD projection screen which allowed subjects to view the stimuli from a mirror attached to the head coil.

Selection of Control Tasks

Unlike ESM, in which it is clear from both the anatomical region and the behavioral response that the site of stimulation is not involved in sensory processing, control tasks were necessary in this fMRI study. Therefore, other language and visual tasks were developed to factor out perceptual processing before examining differences in activation elicited by DN and VN tasks.

Sentence listening served as the DN control task to subtract auditory verbal processing, as this would render the DN contrast more similar to the stimulation mapping data. Specifically, this aims to distinguish between the restricted region of electrical stimulation-identified DN sites that reflect auditory verbal comprehension (primarily, mid- to posterior superior temporal gyrus), and the vast majority of DN sites at which stimulation leaves comprehension intact yet disrupts naming (Hamberger et al., 2003b). We would also note that this very specific, targeted word retrieval task is quite different from more commonly used word-generation tasks in which multiple words could accurately complete the task. A theoretically ideal VN control task would have utilized line-drawn real objects, similar to those in the VN task, and instructed subjects to perform a non-naming task. However, given the automaticity of object recognition, automatic, mental naming could not be ruled out, and therefore, nonnamable visual stimuli similar in visual complexity to the VN line-drawn objects were employed, similar to that used by others (Bookheimer et al., 1998). Although the tasks cannot be perfectly equated, they enable subtraction of both primary sensory and some additional processing, with the goal of revealing activation related to word retrieval associated with DN and VN stimuli in the temporal lobe region. Due to inherent

TABLE I. Demographic data and test results

Age (years)	26.2 (3.6)
Education (years)	16.9 (1.0)
Estimated IQ ^a	111.1 (6.2)
ANT RT (sec)	.63 (.10)
ANT Number Correct	49.7 (.48)
ANT TOT	.90 (.73)
VNT RT (sec)	.93 (.12)
VNT Number Correct	49.9 (.32)
VNT TOT	.90 (.87)
GSI	44.7 (14.48)

Mean (SD); Abbreviations: Estimated IQ, North American Adult Reading Test estimated Full Scale IQ; ANT, Auditory Naming Test; VNT, Visual Naming Test; Number Correct, Number of correct responses within 20 seconds (range 0–50); RT, response time; TOT, Tip-of-the-tongue responses: number of correct responses following phonemic cue, plus number of correct responses provided ≥ 2 seconds post stimulus presentation; GSI, Global Severity Index from Symptom Checklist 90-Revised (T score, mean = 50, >65 = clinical cut-off).

^aAvailable for 10 subjects.

differences in description naming and visual naming, it is not possible to fully equate the experimental-control task pairings, and this should be kept in mind when considering the results. Nevertheless, the control tasks for DN and VN were both post-perceptual baseline tasks, which are important for comparisons of task-related activation (Price et al., 2005). Most relevant, the combination of activation and control tasks render the fMRI task comparison as closely matched as possible to DN and VN tasks used in stimulation mapping.

Procedure

For both DN and VN, subjects were instructed to covertly name the orally described target words and the pictured objects as quickly as possible. Covert naming was utilized to avoid excessive head movement and other susceptibility artifacts (van Turenout et al., 2003).

During the control conditions (i.e., DC and VC), subjects were instructed to listen to the sentences or view the abstract stimuli without attempting to name them. This instruction was simple to follow, as neither the control sentences nor the control visual stimuli elicit naming. The control stimuli contrasted markedly with both the DN and VN stimuli for which one is essentially unable to inhibit the item-name coming to mind—either from a pictured or described object. Further, even an attempt to name during the control conditions would differ from the immediate and automatic targeted word retrieval that has been shown to occur in healthy adults upon presentation of these DN and VN stimuli (Hamberger and Seidel, 2003). Moreover, normative data for these two naming tasks, as well as subject performance on these two tasks outside the

scanner (Table I) show ceiling level performances. Subjects were instructed to attend closely to all stimuli and were permitted a short break between each run. Subjects were debriefed immediately following the experiment and asked if they attended to stimuli and followed instructions throughout the scanning session. All participants reported good attention compliance.

Stimuli were presented using Presentation® software (Neurobehavioral Systems, <http://nbs.neuro-bs.com>) in a 15-epoch (21–28 seconds per epoch) block design paradigm. During each of three, 6-minute functional scanning runs, subjects were presented with a 10-second baseline fixation cross and four conditions: DN, DC, VN, and VC. The four conditions and fixation cross were presented three times each per run. Blocks were counterbalanced and selectively randomized to ensure that the same condition would not be presented consecutively. Each language block contained seven stimuli with a one-second interstimulus interval. Each functional run began with a 13-second fixation cross and ended with a 16-second fixation cross.

Before entering the scanner, subjects completed a practice session with items that were not used in the experiment. Following the scanning session, 10/13 subjects were administered three brief measures: North American Adult Reading Test to obtain an estimate of general intelligence, Description naming and Visual naming Tests to obtain an objective measure of naming ability, and Symptom Checklist 90-Revised (SCL90-R) to obtain an estimate of current psychological functioning.

Image Acquisition

Subjects were scanned in a GE 1.5-T scanner located at the fMRI Research Center at Columbia University Medical Center, using a T2*-weighted echo-planar imaging sequence. Images were acquired in parallel to the anterior-posterior commissure line. The following functional scan parameters were used: 28 contiguous axial slices (time repetition [TR] = 2000 ms, echo time [TE] = 42 ms, flip angle = 60°, field of view [FoV] = 200 mm \times 200 mm, array size = 64 \times 64) of 3.5 mm thickness. After functional imaging, anatomical reference images were acquired with a T1-weighted spoiled gradient echo (SPGR) sequence (TR = 19 ms, TE = 5 ms, flip angle = 20°, FoV = 256 mm, matrix = 256 \times 256), recording 180 slices at a slice thickness of 1 mm. Foam padding and surgical tape were used to limit head motion within the scanner.

Image Preprocessing

SPM5 (<http://www.fil.ion.ucl.ac.uk/spm/software/spm5/>) was used for all preprocessing and statistical analyses. The first six functional images from each run were discarded to ensure signal stability. The following steps were carried out sequentially during pre-processing: slice time correction, spatial realignment, normalization of

functional images onto the Montreal Neurologic Institute (MNI) template, and spatial smoothing (Gaussian kernel, FWHM = 8 mm). A 128-second high-pass filter was used to remove low frequency confounds. Global effects remained and an autoregression model (AR-1) was used for temporal correction.

Image Analysis: Mass-Univariate GLM

Each epoch was convolved with the canonical hemodynamic response function (HRF) and regression coefficients for each condition (i.e. DN, DC, VN, and VC) were estimated in a General Linear Model (GLM). These beta maps were then used in the ordinal trends analysis (detailed below). SPM maps for each condition were visually examined in each subject for expected visual and auditory activations. Three subjects displayed minimal activation. However, models for these subjects were re-estimated after including additional global signal and spike regressors using the `scn_session_spike_id.m` diagnostic tool (<http://wagerlab.colorado.edu/>). Following re-estimation these individual maps displayed the expected auditory and visual activations. For all subjects, contrasts of interest were generated (i.e., DN>DC and VN> VC) and were then submitted to a random effects analysis (one sample *t*-test). Whole brain maps were thresholded at $P < 0.001$, uncorrected, with a cluster extent threshold of 64. An ROI analysis (Marsbar) (Brett et al., 2002) of these same contrasts employed a mask of the left temporal lobe defined by the WFU Pickatlas (Maldjian et al. 2003). These maps were thresholded at $P < 0.01$ uncorrected, with cluster extent threshold of 118. These cluster thresholds were determined by 2000 Monte Carlo simulations of whole brain and ROI fMRI data with respective data parameters of the present study using the AlphaSim program as implemented in AFNI (version 2009) (Cox, 1996), and were used to control the overall probability of type 1 error at $P < 0.05$.

Image analysis: Ordinal Trend Analysis

Ordinal trend canonical variates analysis (OrT CVA) (Habeck et al., 2004, 2005) is a spatial covariance analysis technique that applies principal components analysis (PCA) to the data matrix that is transformed to increase the saliency of ordinal trend effects (McIntosh et al., 1996; Worsley et al., 1997). The design matrix of OrT CVA is optimized to increase the variance contribution (and subsequent detection in the PCA) of effects that show consistency in their behavior across conditions and subjects (Habeck et al., 2004, 2005). A subsequent linear regression is employed to identify a covariance pattern in the fMR signal with increasing mean subject expression from control to naming condition from a linear combination involving a small set of principal components. The property of a consistent monotonic within-subject change of pattern expression from the control to the experimental condition (beyond mere mean change)

is the “ordinal trend.” Individual subject’s expression of this activation pattern is quantified with a network score, i.e., a scalar value that quantifies the extent to which a participant manifests the covariance pattern. The network score is obtained by the operation of an inner product (i.e., covariance across brain regions) between the covariance pattern in question and a subject’s task scan. The activation attributable to the covariance pattern can then be written as:

$$\text{Activation} = \text{network score} \times \text{covariance pattern} \quad (1)$$

Once a network score has been computed for any pattern, it can be used for subsequent analysis, for instance, correlation with subject variables such as behavioral performance or demographics.

We performed ordinal trend analysis in tandem with voxel-wise univariate analysis to exploit the complementary nature of the two techniques: while mass-univariate analysis is well suited to identify strong focal effects in the data, ordinal trend analysis is geared toward the converse scenario of widely distributed effects in the activation data. If, additionally, these distributed changes *within* subject but *between* task conditions are small compared to the variability *within* task condition *across* subjects, ordinal trend analysis has a better chance of identifying these small, but statistically robust and task-related, neural changes than mass-univariate analysis. An illustration for didactic purposes is provided in the supplementary file (Supporting Information).

Permutation Test

To ascertain whether an activation pattern exhibits a statistically significant ordinal trend, a permutation test is conducted. To generate null data, the task data are re-sampled and the condition assignment (naming vs. control) is randomized, while leaving the subject assignment intact. The analysis procedure described before is then run on the re-sampled data, and a covariance pattern is derived for every iteration of the permutation test. The ordinal-trend statistic (Habeck et al., 2005), which corresponds to the number of subjects who fail to show a consistent increase from VC to VN condition, is computed for the covariance pattern. Executing these steps for 1,000 iterations generates a null-hypothesis histogram for the ordinal-trend statistic. The p-level is computed as the fraction of the iterations that produced a statistic (i.e., the number of subjects violating the rule of change) smaller than or equal to our point estimate value. A *P*-level of 0.05 thus implies that at most 5% of data sets with random task-condition assignment give rise to activation patterns whose expression increases for a greater number of participants than for our point estimate.

Bootstrap Resampling to Assess Stability of Voxel Loadings

To render an inferential judgment about the stability of the voxel loadings in the covariance pattern and establish

a thresholded map for visualization purposes similar to a univariate SPM {T} map, we conducted a nonparametric bootstrap test. Contrary to the permutation test outlined above, the condition assignment is left intact and the data are re-sampled with replacement, i.e. some subjects are left out of the sample, while others are included more than once, but naming and control are not swapped to create null-hypothesis conditions. This procedure approximates the natural variation incurred when sampling from the underlying distribution. The complete pattern derivation is applied to the re-sampled data. For a given voxel, a Z-value is computed as the point estimate value of the voxel loading divided by the variability (STD) of the bootstrap samples around this point estimate value as:

$$Z = \text{point estimate}/\text{STD} \quad (2)$$

We thresholded the resulting Z-map at $|Z| > 3.09$, i.e., imposing a one-tailed P -level of $P < 0.001$. The topographic composition of the Z-map is shown in Figure 2.

Topographic Overlap Analysis

The degree of overlap of thresholded statistical maps (i.e., visual and auditory description naming maps obtained with GLM) was assessed using the `cluster_overlap_npm.m` script available from the laboratory of Tor Wager, Ph.D. (<http://wagerlab.colorado.edu>). Description naming and visual naming T/Z-maps (i.e., $DN > DC$ and $VN > VC$) were thresholded at $P < 0.001$ uncorrected (one-tailed) and binarized. The number of overlapping voxels between the two maps was then calculated, and the probability of this amount of overlap occurring by chance was calculated by comparing its observed value to a null distribution, which was derived by randomizing the locations of the centers of the clusters of each map 2,000 times.

Statistical Analyses

Two-way, repeated measures ANOVAs (Task [description vs. visual] by Condition [naming vs. control]) were used to determine whether any regions exhibited task-dependent effects of naming. Pearson correlations were used to determine whether the level of activation in one task predicted the level of activation in the other. Pearson correlations that did not rely on parametric statistics, but used permutation tests, were employed to assess the relation between covariance patterns associated with visual and description naming.

RESULTS

Whole-Brain GLM Analyses

Visual naming (i.e., the visual naming contrast $VN > VC$) was associated with activation in bilateral pre- and

postcentral gyri, bilateral inferior frontal gyri, left insula, bilateral posterior and inferior temporal cortex, middle occipital cortex, parahippocampal gyri and cerebellum, and left claustrum ($VN > VC$, $P < 0.05$ corrected, see methods; Fig. 1, yellow). Description naming (i.e., description naming contrast ($DN > DC$)) was associated with activation in left posterior inferior temporal cortex and inferior frontal cortex ($DN > DC$, $P < 0.05$ corrected, see methods; Fig. 1, red). Thus, both DN and VN had clusters of activation in the left posterior temporal region.

Results of two-way ANOVA (task by condition) revealed a significant interaction between task and condition. Specifically, significant activation was associated with visual but not description naming, in left temporal-occipital cortex, right putamen, left middle temporal gyrus, left and right postcentral gyrus, and left middle cingulate gyrus. There were no significant negative interaction effects.

Topographical Overlap and Task-Related Activation for Visual and Description Naming

The topographical overlap in the above thresholded GLM statistical maps for description and visual naming was formally quantified (see Methods). Significant overlap was found in the left posterior temporal region and in the left precentral gyrus (56 overlapping voxels, $P = 0.0005$, see Methods). To further explore this spatial overlap, we investigated the relation in activity levels associated with description and visual naming (contrast values $DN > DC$ and $VN > VC$) in these overlapping areas. Results showed no correlation across subjects in the overlapping posterior temporal region (Fig. 1, $Z = 16$, first slice, circled) ($r = -0.20$, $P = 0.51$) or in the precentral gyrus (Fig. 1, $Z = 48$, first slice, $r = -0.16$, $P = 0.60$). Thus, level of activation in description naming did not predict level of activation in visual naming, or vice versa, suggesting independent naming processes despite shared topography.

Temporal Lobe ROI Analyses

Within the left temporal lobe, visual naming showed significant activation in both anterior and posterior sections of the superior, middle, and inferior temporal gyri ($VN > VC$, $P < 0.05$, corrected). Description naming showed significant activation in the middle and inferior gyri of the left temporal lobe but only in the posterior section ($DN > DC$, $P < 0.05$, corrected).

Within the right temporal lobe, visual naming was associated with activation in the superior and middle temporal gyri and the fusiform gyrus ($P < 0.05$, corrected). On the other hand, no significant activation was found for description naming in the right temporal lobe ($P < 0.05$, corrected).

Results of GLM analyses suggested that description naming and visual naming are supported by overlapping cortical areas, but that overlapping regions are not used to a

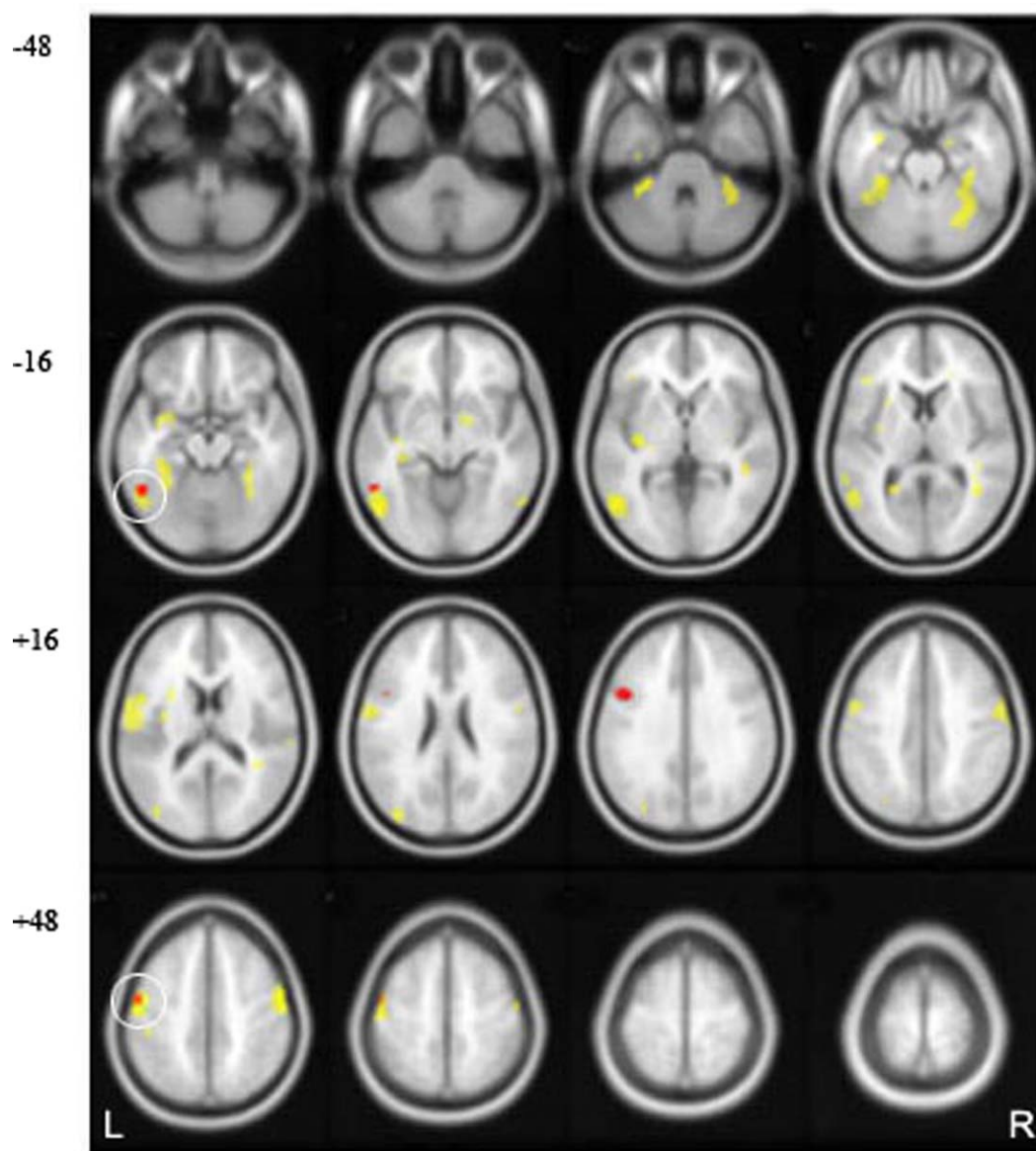


Figure 1.

GLM results for visual and description naming. There was visual naming activation (yellow, VN>VC) in the bilateral parahippocampal gyrus and fusiform gyrus (row 1, fourth panel), temporo-occipital cortex (row 2, bottom clusters), and bilateral pre/post-central and inferior frontal gyrus (row 3 and 4). There was description naming activation (red, DN>DC) in left temporo-

occipital cortex (row 2, left two panels), left inferior frontal gyrus (row 3, third panel), and left precentral gyrus (row 4, first panel). Regions of overlap for description and visual naming are indicated with circles (temporo-occipital cortex, second row, and pre/post central gyrus, fourth row).

similar extent across modalities. One limitation of univariate analyses, however, is the identification of focal areas of activation without regard to how these areas interact with one another, whereas naming more likely involves an interaction of brain regions. Therefore, we subjected the data to ordinal trend analyses in an attempt to characterize the neural networks that mediate description and visual naming.

Ordinal Trend Analysis

Description naming

A pattern with a significant ordinal trend ($P < 0.001$) was identified, with 12 of 13 subjects showing increased expression of this pattern from the DC to DN condition

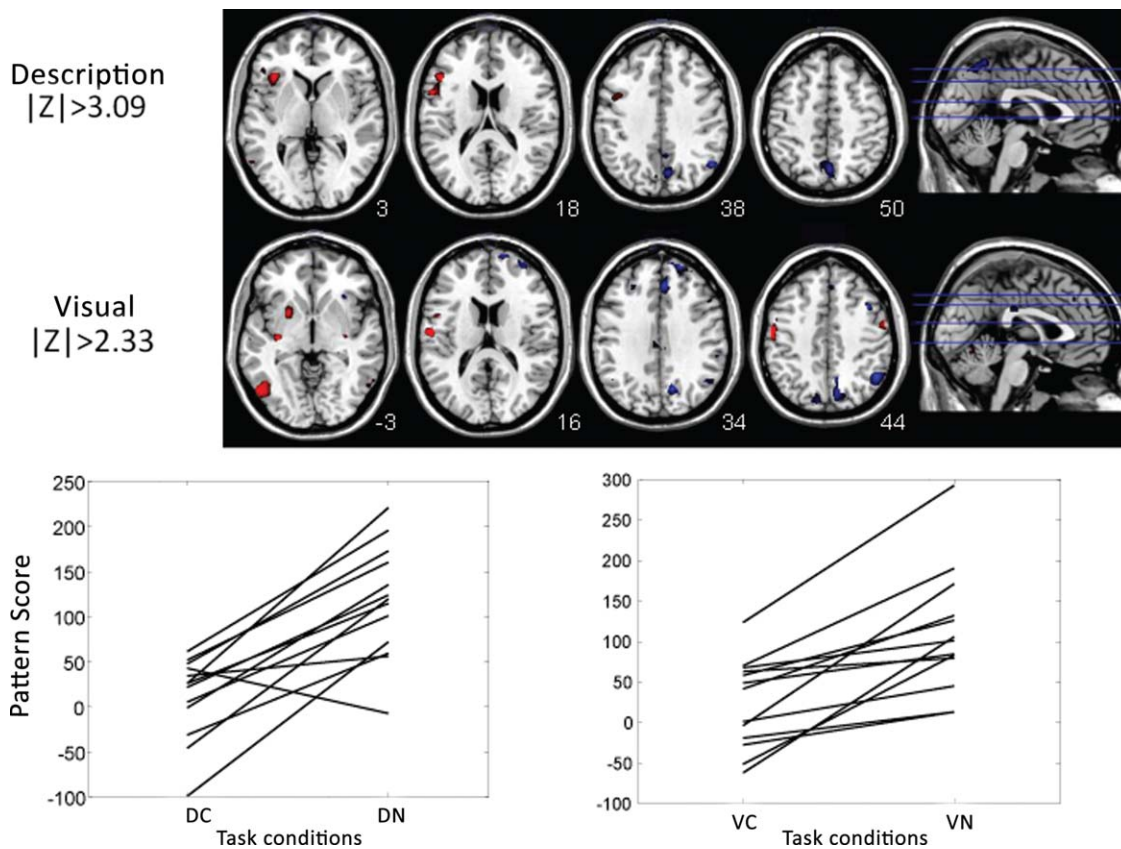


Figure 2.

Description and visual naming pattern expression based on ordinal trend analyses. **(A)** Group data: Bootstrap Z-map for the covariance pattern found for description (top row) and visual naming (bottom row). **(B)** Network expression scores of the derived activation pattern for individual subjects: Left: Description naming pattern, 12 of 13 participants increased the

network pattern expression from the control condition (DC) to the naming condition (DN) ($P < 0.001$). Right: Visual naming pattern; every subject increased the network pattern expression from control condition (VC) to naming condition (VN), $P < 0.001$.

(Fig. 2A top and 2B left). The single subject who did not show this pattern was left handed. For the sake of completeness, Table II lists the regions that increased (Table IIA) and decreased (Table IIB) in activation from the DC to DN condition. Areas with significant loadings in the pattern that showed increased activation from the DC to DN condition were found in left inferior frontal cortex as well as left mid-temporal and fusiform regions, while areas showing decreased activation as a function of naming were found in left and right parietal and right occipital cortex.

Visual naming

Ordinal trend covariance analysis was similarly performed for the VN task and a covariance pattern was identified for which all 13 subjects showed increased expression of this same activation pattern from the VC to

the VN condition ($P < 0.001$, Fig. 2A bottom and 2B right). The bootstrap Z-map for the visual pattern achieved lower absolute values than the one for the auditory pattern: instead of the customary threshold of $|Z| > 3.09$, $P < 0.001$, it was necessary to lower the value to $|Z| > 2.33$, $P < 0.01$. However, despite the low robustness achieved for the visual task in the bootstrap maps, we emphasize that the analyses overall remained highly significant, i.e., activation patterns showed strong task-related behavior on a subject-by-subject basis. The bootstrap result only indicates that the pattern cannot be localized to a few key areas.

For the sake of completeness, Table III lists the regions that increased (Table IIIA) and decreased (Table IIIB) in activation from the VC to VN condition. Areas with significant loadings in the pattern that showed increased activation from the VC to VN condition included the left parietal region, middle temporal gyrus and parahippocampal gyrus and right precentral gyrus and middle and

◆ Description and Visual Naming Activation Patterns ◆

TABLE II. Topography of description naming pattern: Positive (A) and negative (B) loadings with Talairach coordinates in descending order of Z value

X	Y	Z	Laterality	Lobe	Structure	Z
(A) Positive loadings						
-36	23	-1	Left	Frontal	Inferior Frontal Gyrus	4.7031
-55	10	14	Left	Frontal	Inferior Frontal Gyrus	4.532
-50	-6	41	Left	Frontal	Precentral Gyrus	3.8925
-55	-51	-13	Left	Temporal	Fusiform Gyrus	3.7091
-46	6	37	Left	Frontal	Middle Frontal Gyrus	3.7089
-59	-58	5	Left	Temporal	Middle Temporal Gyrus	3.6403
(B) Negative loadings						
50	-58	38	Right	Parietal	Inferior Parietal Lobule	-4.4242
10	-57	27	Right	Occipital	Precuneus	-4.3938
-10	-63	23	Left	Parietal	Precuneus	-4.0678
-4	-46	56	Left	Parietal	Precuneus	-3.8925
8	53	3	Right	Frontal	Medial Frontal Gyrus	-3.5767

(A) Positive weights (increasing activation from DC to DN condition), $Z > -3.09$ ($P < 0.001$), cluster size >10 voxels.

(B) Negative weights (decreasing activation from DC to DN condition), $Z < -3.09$ ($P < 0.001$), cluster size >10 voxels.

TABLE III. Topography of visual naming pattern: Positive (A) and negative (B) loadings with Talairach coordinates in descending order of Z value

X	Y	Z	Laterality	Lobe	Structure	Z
(A) Positive loadings						
-59	-9	15	Left	Parietal	Postcentral Gyrus	3.1904
30	-63	-20	Right Cerebellum	Posterior	Declive	3.1681
-32	-38	-18	Left	Temporal	Fusiform Gyrus	3.1597
-53	-59	-9	Left	Temporal	Middle Temporal Gyrus	3.1546
-51	-13	47	Left	Parietal	Postcentral Gyrus	3.0936
-34	-18	-2	Left	Sub-lobar	Lentiform Nucleus	3.0626
55	0	42	Right	Frontal	Precentral Gyrus	2.9657
-34	-3	-20	Left	Limbic	Parahippocampal Gyrus	2.8669
30	-14	-3	Right	Sub-lobar	Lentiform Nucleus	2.8598
-24	8	-2	Left	Sub-lobar	Lentiform Nucleus	2.8552
38	-6	-35	Right	Temporal	Inferior Temporal Gyrus	2.6890
55	-62	0	Right	Temporal	Middle Temporal Gyrus	2.6376
24	-7	-20	Right	Limbic	Uncus	2.5851
-6	-44	-18	Left Cerebellum	Anterior	Culmen	2.5731
(B) Negative loadings						
10	64	6	Right	Frontal	Medial Frontal Gyrus	-3.2146
65	-30	-9	Right	Temporal	Middle Temporal Gyrus	-3.1261
48	-48	48	Right	Parietal	Inferior Parietal Lobule	-3.0536
40	17	38	Right	Frontal	Precentral Gyrus	-2.9738
20	-68	38	Right	Parietal	Precuneus	-2.9728
20	54	30	Right	Frontal	Superior Frontal Gyrus	-2.9621
18	26	50	Right	Frontal	Superior Frontal Gyrus	-2.8894
4	34	28	Right	Limbic	Cingulate Gyrus	-2.8473
30	23	-3	Right	Frontal	Inferior Frontal Gyrus	-2.7475
55	-31	35	Right	Parietal	Inferior Parietal Lobule	-2.7457
34	55	10	Right	Frontal	Middle Frontal Gyrus	-2.6281
-22	6	49	Left	Frontal	Medial Frontal Gyrus	-2.6201
-24	39	33	Left	Frontal	Superior Frontal Gyrus	-2.5452
8	-32	51	Right	Frontal	Paracentral Lobule	-2.5231

(A) Positive weights (increasing in activation from VC to VN), $Z > 2.33$ ($P < 0.01$), cluster size >10 voxels.

(B) Negative weights (decreasing activation from VC to VN), $Z < -2.33$ ($P < 0.01$), cluster size >10 voxels.

inferior temporal gyri, whereas reductions in activation involved a different portion of the right middle temporal gyrus, as well as right parietal regions and portions of right frontal cortex.

Relation Between Visual and Description Naming Covariance Patterns

We conducted an additional analysis to investigate whether the covariance pattern obtained from VN and DN tasks might share some characteristics in subject pattern expression (i.e., degree of conformity between the subject's scan and the covariance pattern). We correlated the increase in pattern expression from control to naming for both tasks across subjects. This yielded a nonsignificant correlation ($R = 0.32$, $P = 0.28$), suggesting that the manner in which both covariance patterns are deployed during task performance bears little relationship between tasks.

We found no topographic overlap in the areas that surpassed the significance thresholds of the bootstrap Z-maps. However, this result is not definitive, as focusing on the super-threshold areas in the bootstrap map neglects the fact that multivariate patterns consist of brain-wide voxel assignments of loadings, and that topographic similarity ideally, must be assessed for the patterns as a whole. Correlating the voxel loadings between the two patterns, we obtained a correlation coefficient of $R = 0.30$. Assignment of a parametric P -level for this regression problem is difficult because the actual number of degrees of freedom is not known: due to the smoothing pre-process and resulting spatial correlation between voxels, the true number of degrees of freedom is less than the number of voxels in the image ($\sim 100,000$) and more in the range of 100–200 regional resolution elements. This would make the topographic correlation of $R = 0.30$ still highly significant, hinting at substantial similarity of the topographic composition of the task-related covariance patterns.

A further test of plausibility confirms this: sampling 100 voxels randomly and computing the correlation between pattern loadings at these voxels yields significant correlations at $P < 0.05$ in 87% of 10,000 iterations. We are thus confident to claim that the description naming and visual naming activation patterns have topographical overlap.

The relation between the substrates of both description naming and visual naming are summarized: both description naming and visual naming involve neural substrates that overlap topographically, although the utilization of these substrates in their respective tasks is different. Concretely this means, subjects who show a large increase in description naming-pattern utilization in the DN task do not necessarily show a large increase in visual naming pattern utilization in the VN task, and vice versa.

DISCUSSION

Results from previous cortical stimulation studies in patients with left temporal lobe abnormalities suggest that

naming based on verbal descriptions and pictured objects can be differentially disrupted, depending on the region stimulated. Specifically, description naming is compromised by stimulation at individual sites across anterior and posterior lateral temporal cortex, whereas visual naming is disrupted by stimulation primarily in the posterior temporal region. We hypothesized that description naming and visual naming are mediated by partially dissociable neural substrates in healthy adults as well, and that these task-related differences, observed using “disruption” techniques (i.e., lesions, electrical stimulation) in temporal lobe (TL) patients, would also be observed using fMRI, an activation method, in healthy individuals. Additionally, we sought to exploit fMRI methodology and analysis to explore the network structure underlying these naming processes, as ESM allows only for examination of discrete cortical sites.

Relation Between VN and DN

The current univariate results demonstrated topographical overlap between tasks in the left posterior temporal region, as observed with ESM, yet did not replicate ESM findings of a region unique to DN. Specifically, DN was associated with activation in the left posterior, middle, and inferior temporal gyri, whereas VN activation was found in both anterior and posterior sections of the left superior, middle, and inferior temporal gyri, as well as right superior and middle temporal gyri and the fusiform gyrus. On the other hand, OrT analyses revealed different covariance patterns associated with DN and VN, characterized by overlapping areas, yet also by task-specific regions of activation for each task. Specifically, regions that showed increased expression with DN (i.e., DC to DN) included the left middle temporal gyrus, fusiform gyrus, precentral gyrus, and middle and inferior frontal gyri. VN (i.e., VC to VN) was similarly associated with increased expression in the left middle temporal and fusiform gyri, but not in frontal regions, yet uniquely in the left inferior temporal gyrus, post central gyrus, and parahippocampal gyrus, as well as the right postcentral, middle temporal, and inferior temporal gyri.

Regions of Overlap

Further analysis of regions common to covariance patterns for both DN and VN provided novel, dynamic information that could not be obtained from the discrete topographical data afforded by cortical stimulation. Within the region of overlap, there was no correlation between activation levels associated with DN and VN. That is, the level of activation in one task had little bearing on the level of activation in the other, suggesting that despite utilization of the same brain region, the manner in which the DN and VN tasks utilized this region differed between tasks. Further, multivariate analyses, which explore whole

patterns of activation rather than individual regions, revealed unique covariance patterns for DN and VN that were strikingly consistent across subjects, with all 13 subjects showing increased expression from VC to VN, and 12/13 subjects (i.e., all right-handed subjects) showing increased expression from DC to DN.

In contemplating the covariance patterns of DN and VN, it is worth considering recent neurocognitive models of language processing. Similar to the dual stream model of visual processing (Goodale and Milner, 1992), findings from lesion, neuroimaging and electrophysiological investigations suggest that the language system is organized via independent dorsal and ventral processing streams as well (Hickok and Poeppel, 2004; Saur et al., 2008). Within this organization, speech perception begins in the auditory fields of the superior temporal gyrus and then diverges into (1) a ventral stream, which serves as an interface between sound-based representations of speech in the superior temporal region and widely distributed conceptual representations, encompassing primarily, the superior temporal sulcus, and middle and inferior posterior temporal cortex (Damasio, 1989), and (2) a dorsal stream, which maps sound onto articulatory based motor representations, comprised of the parietal-temporal boundary, and projects to frontal regions.

As put forth by Hickok and Poeppel (2004), the extent of dorsal or ventral stream involvement in a given language task depends on the extent to which that task involves mapping between auditory and motor systems (dorsal) or between auditory and conceptual systems (ventral). Both description naming and visual naming require access to conceptual representations; thus, it is not surprising that both tasks activated middle and inferior temporal cortex. On the other hand, although neither task required a speech response, DN (but not VN) engaged frontal regions of the dorsal network. One might postulate that this reflects articulatory motor activation due to covert articulation of the target words (Schwartz et al., 2012); however, it is unclear why this would occur for description naming and not visual naming, especially when, as described, the DN and DC tasks are more closely matched than the VN and VC tasks. Further, it is unlikely that frontal activation reflects covert articulation of the descriptions given that the DC control task involves listening to normal speech, similar to that of the verbal descriptions. Given that the primary difference between DN and DC is the honing in and retrieval of the single target word, this result might raise the interesting possibility that these frontal regions play an important role in these processes for description naming, but not visual naming. Specifically, inferior frontal activity has been associated with competition in word selection during semantic tasks (Moss et al., 2005). Although the descriptions are highly constrained, reflected in high name agreement and accuracy (Hamberger and Seidel, 2003), they nonetheless, proffer less constraint than the pictured objects. For example, presented with, “what a king wears on his head,” the subject must

select among plausible responses such as “hat” and “crown,” whereas a picture of a crown would likely elicit less competition. Thus, the frontal activation associated with DN might reflect a higher level of response competition and resolution relative to that elicited by VN.

Another notable task difference in covariance patterns was the presence of right hemisphere activation for VN. This is consistent with other studies that have compared activation elicited by pictures versus verbal stimuli (Lambon Ralph et al., 2010). Visual naming was associated with bilateral activation whereas the covariance pattern for description naming was restricted to the left hemisphere. Bi-hemispheric activity for visual naming might reflect, in part, its demands on both language and visuoperceptual processing, whereas the component processes of description naming might be more language specific, and therefore, more focused within the left, dominant hemisphere. These interhemispheric differences might also explain why description naming appears to be more sensitive than visual naming to left temporal damage (Bell et al., 2003; Hamberger and Seidel, 2003). That is, left TLE patients perform disproportionately worse on auditory description naming than visual naming, possibly because description naming is more dependent on left hemisphere processing, whereas visual naming receives contribution from both the left and right hemispheres. The established decline in visual naming following left temporal surgery (Bell and Davies, 1998; Hamberger and Drake, 2006) would appear to counter this explanation, although, perhaps, bilateral integrity of these regions is necessary for adequate visual naming. Finally, another possibility to consider might be that the greater difference between VC and VN relative to that of DC and DN resulted, at least in part, in more extensive activation associated with visual naming. Whereas the DC–DN pairing factored out a considerable amount of semantic processing, the difference between the cognitive processes required for visual perception of non-objects (VC) and covert naming of meaningful objects (VN) would not factor out semantic processing to the same extent. Therefore, relative to DN–DC, the VC–VN pairing likely yielded broader activation due to inclusion of areas involved in semantic processing.

Taken together, the results suggest that in healthy adults, visual naming and description naming are mediated by different cortical networks, with some unique and some common brain regions, and that within the regions common to both, the processes involved in these two tasks are different. This is consistent with both ESM and behavioral findings in temporal lobe patients demonstrating that DN and VN can be differentially affected. Moreover, these results support the clinical practice of using both DN and VN measures for a thorough assessment of naming (i.e., in populations without primarily visual or auditory impairment), as limiting the assessment to one task risks failure to detect a genuine naming deficit that might be revealed by the other. For instance, inconsistencies in DN and VN have been useful in temporal lobe epilepsy patients (Bell

et al., 2003; Hamberger and Seidel, 2003) and preliminary work suggests potential utility in differentiating among dementia subtypes (Miller et al., 2010). We speculate that these findings might also carry implications for treatment of naming deficits, such that in the presence of a function-specific deficit, the unaffected, or less affected function might be utilized or trained to compensate for the naming process that is compromised. For example, an individual with subjective word finding difficulty in everyday discourse and poor description naming yet stronger visual naming performance might utilize visual imagery to assist word retrieval.

fMRI Versus Cortical Mapping

Both univariate and ordinal trend results for visual naming were generally complementary and compatible with regions implicated by cortical mapping and natural lesion studies, at least with respect to left hemisphere findings. Specifically, visual naming deficits have been documented with insult to most aspects of the left temporal region. The left ITG is classically associated with object naming and a component of the basal temporal language areas identified by cortical stimulation, and the left MTG, traditionally considered visual association cortex (Mesalun, 1985) together with the ITG, is considered a primary component of the ventral language processing stream. The current results for visual naming were more widespread than the region implicated by cortical stimulation, with activation found in left hemisphere regions including the left anterior temporal cortex, as well as right hemisphere regions. Similarly, relative to cortical stimulation results, the covariance pattern elucidated by ordinal trend analysis for description naming revealed a broader, more anterior topography across left frontal and mid-posterior temporal cortex. Although this might be related to differences in experimental-control task pairings, it is not uncommon for fMRI to implicate broader regions than cortical stimulation. In fact, differences in topographic findings between cortical stimulation and fMRI are commonly attributed to inherent differences between “disruptive” and “activation” techniques. It is generally held that disruptive methods (e.g., cortical stimulation, lesions) identify brain regions that are essential to a given function, whereas activation techniques (e.g., fMRI, EEG) reveal areas that participate but are not necessarily critical (Binder, 2009; Bookheimer, 2007). This is compatible with visual naming results as fMRI results included regions implicated by ESM within a broader network of activation. Although both ESM and fMRI implicated posterior temporal involvement in description naming, unlike ESM, fMRI did not implicate the anterior temporal region, yet revealed activation in left frontal cortex. Whether frontal involvement is “critical” for description naming is unclear, as DN is rarely tested in frontal cortex during ESM; future ESM work can address this question.

The absence of anterior temporal activation for DN in the current study might appear at odds with our

hypothesis, potentially implying that the anterior temporal region does not mediate description naming. However, lesion-type studies suggest otherwise, at least in select neurological populations (Hamberger et al., 2001; Hamberger and Seidel, 2009). One possibility is that this absence, together with the presence of anterior temporal activation for VN, could be related to the different task-control pairings between the two tasks. Nevertheless, it should be kept in mind that functional imaging studies provide correlational evidence of function. Certainly, confluence of *both* lesion-associated impairment and activation in a functional imaging study would strongly argue for the functional involvement of a brain region; however, it is worth noting that lesion-associated impairment does not necessarily imply activation of that region in an imaging paradigm, and vice versa.

In addition to the methodological differences between ESM and fMRI studies, another obvious difference is the populations under investigation. Irritative effects of seizures and interictal discharges might alter the “normal” distribution of cortical sites that underlie language processes. However, ESM studies in patients both with space-occupying lesions and structurally normal MRI have shown relatively similar topographical patterns of DN and VN sites. Although the population difference is an important variable, it might not represent a significant factor in this regard.

Comparison with Previous Work

We are aware of only one other fMRI study that compared activation patterns associated with auditory description naming versus visual object naming in healthy adults. This study (Tomaszewski-Farias et al., 2005) which reported more widespread temporal lobe activation for description naming relative to visual naming, and relative to our observed description naming region, differed from the current study in two important respects. First, in the earlier study, only two of the 20 participants completed both description naming and visual naming, while nine participants completed only description naming (“responsive naming”) and nine completed only visual naming (“confrontation naming”). In contrast, all 13 participants in the current study completed both tasks, raising the possibility that the different results might be related to the within-subject versus across-subject design. The second, and arguably, more critical difference concerns differences in control tasks. In the earlier study, the VN control task required subjects to view sets of vertical, horizontal, diagonal, and crossing lines, which is fairly similar to our visual naming contrast task, though not as closely matched to VN stimuli for visual contrast and shading. More relevant, the description naming control task in the earlier study required participants to listen to backward speech, thereby controlling only for low-level auditory perception. As a result, brain regions supporting auditory verbal

comprehension, in addition to targeted word retrieval, were included in the “activation area” reported for description naming. In contrast, by utilizing sentence-listening in the current study, we aimed to factor out auditory verbal comprehension, with the goal of honing in specifically on auditory based, targeted word retrieval. Given this fundamental difference in DN contrast conditions between the two studies, it is not surprising that the earlier study found more widespread “activation” associated with description naming relative to our more circumscribed description naming region, or that their “responsive naming” region was broader than that revealed by their VN contrasts. In light of our intention to exclude auditory comprehension, our more discrete area of description naming would appear a more precise representation of the region involved specifically in description-based naming.

Although most in vivo studies of normal processing are limited to functional neuroimaging methods, some investigators have studied naming in healthy controls during repetitive transcranial magnetic stimulation (rTMS) of the anterior temporal region (Pobric et al., 2007). Effects are subtle (i.e., mildly reduced response times) relative to the dramatic effects of ESM; yet both temporal pole and middle temporal rTMS have been shown to compromise visual object naming in neurologically intact participants. Perhaps rTMS might be used to explore potentially differential disruptions to description naming and visual naming in healthy adults.

Limitations

As described, a limitation of this study was the inability to fully equate the experimental-control task pairings due to the inherent differences between description naming and visual naming. This may have resulted in more widespread activation associated with visual naming and should be considered with respect to the activation patterns associated with each task. Another potential limitation was the use of covert responses during scanning; thus, it was not possible to fully ensure that participants performed the task correctly. Nevertheless, as described, participants reported good attention to tasks immediately post scan, and as shown in Table I, participants were near ceiling performance for accuracy, with rapid responses on both DN and VN tasks. Further, as stated above, it is actually difficult *not* to perform the naming tasks; that is, when presented with a picture or a description of a meaningful object, it is virtually automatic for the object name to come to mind. Additionally, mean estimated IQ for our subject sample was in the high average range. There is some indication from cortical mapping in epilepsy patients that cortical regions mediating language might differ between individuals with high versus low IQ scores (Devinsky et al., 2000). Thus, this might limit the generalizability of our results. Finally, our GE-EPI sequence was

susceptible to signal drop-out in the anterior temporal lobes and orbital frontal cortex. Although stringent false positive controls were adopted, false negatives in these candidate areas are a possible weakness of our study and should be addressed in future studies with non-EPI acquisition sequences.

Closing Comments

Historically, both clinical assessment and research investigations of naming have been limited to visual object naming. However, more recent work involving ESM, lesion, and behavioral studies in temporal lobe patients using both visual naming and description naming have demonstrated differential effects on these naming processes. The current fMRI results build upon these more static sources of data, providing a network perspective of distributed brain regions that mediate these naming processes. Additionally, results suggest that visual naming and description naming differences are present in neurologically intact adults and further imply that these task-specific differences might be characterized by different patterns of intra- and interhemispheric activity and by processing differences within a common neural substrate. As such, assessment of description naming and visual naming together would likely yield a more thorough assessment of naming in the clinical setting, and a richer, more complex appreciation of naming processes in neuroscientific investigations of brain and language.

ACKNOWLEDGMENTS

We thank Aviva Olsavsky for her help with project development, Stephen Dashnaw for his scanner expertise, Kristen Geraci for assistance with Presentation® programming and the technical staff at the fMRI Research Center. We also thank the reviewers for their thoughtful comments and suggestions. The authors have no conflicts of interest to disclose.

REFERENCES

- Bell B, Seidenberg M, Hermann B, Douville K (2003): Visual and auditory naming in patients with left or bilateral temporal lobe epilepsy. *Epilep Res* 55:29–37.
- Bell BD, Davies KG (1998): Anterior temporal lobectomy, hippocampal sclerosis, and memory: recent neuropsychological findings. *Neuropsychol Rev* 8:25–41.
- Binder JR, Desai RH (2011): The neurobiology of semantic memory. *Trend Cogn Neurosci* 15:527–536.
- Binder JR, Desai RH, Graves WW, Conant LL (2009): Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cerebral Cortex* 19.
- Bookheimer S (2007): Pre-surgical language mapping with functional magnetic resonance imaging. *Neuropsychol Rev* 17:145–155.

- Bookheimer SY, Zeffiro TA, Blaxton TA, Gaillard WD, Malow B, Theodore WH (1998): Regional cerebral blood flow during auditory responsive naming: Evidence for cross-modality neural activation. *Neuroreport* 9:2409–2413.
- Brett M, Anton J, Valabregue R, Poline J (2002): Region of interest analysis using an SPM toolbox. Japan. *NeuroImage*.
- Cox RW (1996): AFNI: software for analysis and visualization of functional magnetic resonance neuroimages. *Comp Biomed Res Int J* 29:162–173.
- Damasio AR (1989): The brain binds entities and events by multi-regional activation from convergence zones. *Neural Comput* 1: 123–132.
- Devinsky O, Perrine K, Hirsch J, McMullen W, Pacia S, Doyle W (2000): Relation of cortical language distribution and cognitive function in surgical epilepsy patients. *Epilepsia* 41:400–404.
- Francis WN, Kucera H (1982): *Frequency Analysis of English Usage: Lexicon and Grammar*. Boston. Houghton Mifflin.
- Geschwind N (1965): Disconnexion syndromes in animals and man, Part I. *Brain* 88:237–294.
- Goodale MA, Milner AD (1992): Separate pathways for perception and action. *Trend Neurosci* 15: 20–25.
- Habeck C, Rakin BC, Moeller J, Scarneas N, Zarahn E, Brown T, Stern Y (2004): An event-related fMRI study of the neurobehavioral impact of sleep deprivation on performance of a delayed-match-to-sample task. *Cogn Brain Res* 18:306–321.
- Habeck C, Krakauer JW, Ghez C, Sackeim HA, Eidelberg D, Stern Y, Moeller JR (2005): A new approach to spatial covariance modeling of functional brain imaging data: Ordinal trend analysis. *Neural Comput* 17:1602–1645.
- Haglund M, Berger M, Shamseldin M, Lettich E, Ojemann GA (1994): Cortical localization of temporal lobe language sites in patients with gliomas. *Neurosurgery* 34:567–576.
- Hamberger M, Goodman RR, Seidel WT, McKhann GM (2003a): Anatomical dissociation of temporal lobe auditory naming processes: Impaired comprehension versus disrupted word retrieval. *Epilepsia* 42 (supplement).
- Hamberger MJ (2007): Cortical language mapping in epilepsy: A critical review. *Neuropsychol Rev* 4:477–489.
- Hamberger MJ, Drake E (2006): Cognitive functioning following epilepsy surgery. *Curr Neurol Neurosci Rep* 6:319–326.
- Hamberger MJ, Seidel WT (2003): Auditory and visual naming tests: Normative and patient data for accuracy, response time and tip-of-the-tongue. *J Int Neuropsychol Soc* 9:479–489.
- Hamberger MJ, Seidel WT (2009): Localization of cortical dysfunction based on auditory and visual naming performance. *J Int Neuropsychol Soc* 15:529–535.
- Hamberger MJ, Goodman RR, Perrine K, Tammy T (2001): Anatomical dissociation of auditory and visual naming in the lateral temporal cortex. *Neurology* 56:56–61.
- Hamberger MJ, Seidel WT, Goodman RR, Perrine K, McKhann GM (2003b): Temporal lobe stimulation reveals anatomical distinction between temporal lobe auditory naming processes. *Neurology* 60:1478–1483.
- Hickok G, Poeppel D (2004): Dorsal and ventral streams: A framework for understanding aspects of the functional anatomy of language. *Cognition* 92:67–99.
- Joseph R (1996): *The Left Cerebral Hemisphere: Language, Aphasia, Apraxia, Alexia, Agraphia, Psychosis, the Evolution of Reading and Writing, and the Origin of Thought*. Neuropsychiatry, Neuropsychology, and Clinical Neuroscience, 2nd ed. Baltimore: Williams & Wilkins. pp 118–158.
- Lambon Ralph MA, Cipolotti L, Manes F, Patterson K (2010): Taking both sides: Do unilateral anterior temporal lobe lesions disrupt semantic memory? *Brain* 133:3243–3255.
- Magnie MN, Besson M, Ponset M, Dolisi C (2003): The Snodgrass and Vanderwart set revisited: Norms for object manipulability and for pictorial ambiguity of objects, chimeric objects and nonobjects. *J Clin Exp Neuropsychol* 25:521–560.
- Malow BA, Blaxton TA, Susumu S, Bookheimer S, Kufta CV, Figlozzi CM, Theodore WH (1996): Cortical stimulation elicits regional distinctions in auditory and visual naming. *Epilepsia* 37:245–252.
- McIntosh AR, Bookstein FL, Haxby JV, Grady CL (1996): Spatial pattern analysis of functional brain images using partial least squares. *NeuroImage* 3:143–157.
- Mesalun M (1985): Patterns in behavioral neuroanatomy: Association areas, the limbic system, and hemispheric specialization. In: Mesalun M, editor. *Principles of Behavioral Neurology*. Philadelphia, PA: F.A. Davis. pp 1–71.
- Miller KM, Finney GR, Meader KJ, Loring DW (2010): Auditory responsive naming versus visual confrontation naming in dementia. *Clin Neuropsychol* 24:103–118.
- Moss HE, Abdallah S, Fletcher P, Bright P, Pilgrim L, Acres K, Tyler LK (2005): Selecting among competing alternatives: selection and retrieval in the left inferior frontal gyrus. *Cereb Cort* 15:1723–1735.
- Ojemann GA, Ojemann J, Lettich E, Berger M (1989): Cortical language localization in left-dominant hemisphere: An electrical stimulation mapping investigation in 117 patients. *J Neurosurg* 71:316–326.
- Pobric G, Jefferies E, Ralph MAL (2007): Anterior temporal lobes mediate semantic representation: mimicking semantic dementia by using rTMS in normal participants. *Proc Natl Acad Sci USA* 104:20137–20141.
- Price CJ, Devlin JT, Moore CJ, Morton C, Laird AR (2005): Meta-analyses of object naming: Effect of baseline. *Hum Brain Mapp* 25:70–82.
- Rogers TT, Lambon Ralph MA, Garrard P, Bozeat S, McClelland JL, Hodges JR, Patterson K (2004): Structure and deterioration of semantic memory: A neuropsychological and computational investigation. *Psychol Rev* 111:205–235.
- Saur D, Kreher BW, Schnell B, Kümmerer D, Kellmeyer P, Vrya M, Umarovaa R, Mussoa M, Glauchea V, Abeld S, Huber W, Rijntjesa MJH, Weillera C (2008): Ventral and dorsal pathways for language. *Proc Natl Acad Sci USA* 105:18035–18040.
- Schwartz MF, Faseyitan O, Kim J, Coslett HB (2012): The dorsal stream contribution to phonological retrieval in object naming. *Brain* 135:3799–3814.
- Snodgrass JG, Vanderwordt M (1980): A standardized set of 260 pictures: Norms for name agreement, familiarity, and visual complexity. *J Exp Psychol: Learn Mem Cogn* 6:174–215.
- Tomaszewski-Farias S, Harrington G, Broomand C, Seyal M (2005): Differences in functional MR imaging activation patterns associated with confrontation naming and responsive naming. *Am J Neuroradiol* 26:2492–2499.
- van Turennout M, Bielamowicz L, Martin A (2003): Modulation of neural activity during object naming: Effects of time and practice. *Cereb Cort* 13:381–391.
- Worsley KJ, Poline JB, Friston KJ, Evans AC (1997): Characterizing the response of PET and fMRI data using multivariate linear models. *NeuroImage* 6:305–319.