BRAIN AND LANGUAGE **65,** 135–146 (1998)
ARTICLE NO. BL982008

2.5 SYMPOSIUM: ACTIVATING WORDS IN THE BRAIN: INTEGRATING NEUROPSYCHOLOGY AND PSYCHOLINGUISTICS

1. Activating Words in the Brain: Integrating Neuropsychology and Psycholinguistics

Kathleen Baynes*,† and Tamara Swaab* (Organizers)

with

Debra Long* (Discussant)

**University of California at Davis; and †VA Northern California Health Care System, Martinez*

Throughout the field of neuropsychology, evidence for complex implicit competence has been documented in patients with neurological damage and limited linguistic, attentional, or mnemonic performance. Such results suggest that systems are activated and carrying out their functions even though this information is no longer available for conscious planning and problem solving. One example of this sort of competence in the face of impaired behavior is lexical and semantic priming in neurological populations. Results of this sort have been widely reported but their neurological implications and relation to psycholinguistic models of processing have not been made clear.

The goal of this symposium is to examine the locus of both preserved and disturbed facilitation from the level of form represented by repetition priming to the level of conceptual knowledge represented by pictures. At the periphery, Dr. Swick's studies of patients with left and right temporal parietal lesions demonstrate intact repetition priming for words, but an impairment in repetition priming of nonwords in left lesioned patients. Prior work has shown that both word and nonword repetition priming were intact in patients with frontal lobe damage. She hypothesizes that this may be related to a defective phonological store in the left temporal parietal patients which is crucial to establishing a stable representation of the nonword stimuli. Drs. Baynes and Dronkers have examined the hemispheric organization and integration of lexical-semantic and conceptual knowledge by studying facilitation of words and pictures in normal controls, focal lesion patients and split-brain subjects. Facilitation effects indicate that both hemispheres support a

0093-934X/98 $25.00

semantic network with preferential processing of lexical information in the left hemisphere and conceptual information in the right hemisphere. These results are consistent with the idea that lexemes and concepts are represented by dual codes, a verbal based code and an image based code (Paivio, 1991). This idea finds further support in the ERP results of the third paper in this symposium presented by Dr. Swaab. Efficient integration of lexical-semantic and conceptual information requires an intact corpus callosum. Additionally, in this study, the role of the right hemisphere in the processing of associative and purely semantic relations between words was examined in patients that have a focal lesion in the right hemisphere. Results indicate that sensitivity to semantic relations is disrupted in right hemisphere lesioned patients, which indicates that the right hemisphere may be involved in processing more distant semantic relations between words, or coarse semantic coding (Beeman et al., 1994). Finally, Dr. Ober has exhaustively studied the semantic and associative priming of patients with Alzheimer's dementia (AD) under a variety of conditions to better characterize semantic memory in AD. She has concluded that the implicit knowledge of semantic relations is indeed intact in mild to moderate Alzheimer's disease and that task variables have a powerful influence on the performance of patients and controls. The robustness of semantic knowledge in this population argues for a distributed representation of conceptual knowledge that is maintained well into the dementing process.

How these results relate to models of psycholinguistic processing, including associative networks such as the HAL model (Burgess & Lund, 1997), and more traditional spreading activation models (e.g., Anderson, 1983) will be discussed by Dr. Debra Long, a cognitive psychologist whose own work in text comprehension and memory has looked at the contribution of individual differences to successful reading performance. Consideration will be given to the degree to which modular processes and distributed systems can be compatibly represented. She will integrate the common threads from these papers and suggest directions for neurolinguistic research that are of most interest to the cognitive psychologist.

REFERENCES

Anderson, J. R. 1983. *The architecture of cognition.* Cambridge, MA: Harvard University Press.

Beeman, M., Friedman, R. B., Grafman, J., Perez, E., Diamond, S., & Lindsay, M. B. 1994. Summation priming and coarse semantic coding in the right hemisphere. *Journal of Cognitive Neuroscience*, **6,** 26–45.

Burgess, C. and Lund, K. 1997. Modeling parsing constraints with high-dimensional context space. *Language and Cognitive Processes,* **12,** 177–210.

Paivio, A. 1991. Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology,* **45,** 255–287.

2. Facilitation of Word and Picture Recognition in Focal Lesion Patients

Kathleen Baynes,*,† Nina Dronkers,*,† Adam Greene,*
and Brenda Redfern*

**University of California at Davis; and †VA Northern California Health Care System, Martinez*

Semantic priming studies of aphasic patients have suggested that facilitation of lexical decisions by semantic and associative relations may be more disturbed in patients with Broca's aphasia than in patients with Wernicke's aphasia (i.e., Milberg & Blumstein, 1981). Other studies have found priming in Broca's aphasics either at short SOA's (Hagoort, 1997) or at long SOA's (Dronkers et al., 1997). Despite obvious areas of disagreement, the facilitations appear to be remarkably robust in the face of focal brain damage across a variety of aphasic syndromes. This observation leads to the question of what systems the intact facilitation depend upon and how those systems relate to models of language comprehension and production.

Work in our laboratory has examined what different roles the left and right cerebral hemispheres might play in our comprehension of the world around us and the words that are used to describe it. The superiority of the left hemisphere for language tasks has been well-documented but the possible contribution of the right hemisphere to language processes has been less obvious. In the 1970's, the right hemisphere was assumed to make a minimal contribution to formal language processes, being occupied with visual-spatial and manipulo-spatial processing, facial processing, and spatial attention. The right hemisphere was portrayed as mute with no phonology and limited syntax. However, multiple studies now suggest that the right hemisphere indeed contributes to aspects of language processing such as prosody, metaphor, discourse, and humor (Brownell et al., 1995). Some isolated right hemispheres can make grammaticality judgments (Baynes & Gazzaniga, 1988), develop speech output (Gazzaniga et al., 1984; Baynes et al., 1995; Zaidel & Seibert, 1997), and even maintain an independent writing system (Baynes et al., 1998). Such cases may be unusual, but a role for the right hemisphere in normal language processing has been incorporated into some models (Chiarello, 1998; Beeman, 1998).

The current studies were undertaken to investigate hemispheric contributions to semantic facilitation. Lexical and conceptual relations were examined in divided field studies using words and pictures in an effort to better understand the integration of semantic networks in the right and left hemispheres. A Purkinje eye-tracker with retinal stabilization was used to ensure lateralization of the stimuli in 14 normal subjects. Targets consisted of real words or line drawings of real objects. Foils were pseudowords or complex drawings of nonobjects presented in a lexical/object decision task. Two

SOA's of 250 and 1850 ms were used to differentiate automatic from controlled processing effects. Stimuli were blocked so that only word-word, picture-word, picture-picture, or word-picture pairs appeared together and short SOA data was always collected first. Primes and targets were presented centrally to focal lesion patients and were lateralized to normals and two callosotomy patients. Focal lesion subjects include 31 aphasics and eight right hemisphere lesioned patients. Six normal subjects participated in a within-field experiment and eight in a between-field experiment.

Taken together, results support faster, more consistent priming of words in the left hemisphere and pictures in the right. Strong conceptual-to-lexical effects were seen in cross format priming, but less consistent lexical-to-conceptual effects were found. However, split-brain subjects showed little cross-format facilitation suggesting it takes an intact callosum to permit the rapid integration of conceptual and semantic information. There is indication that there are individual differences in the degree to which the dominant and non-dominant hemispheres can support both lexical-semantic and conceptual processes.

One influential theory regarding the mental representation of words and pictures has been the dual coding hypothesis of Paivio (1991). Paivio has suggested that our mental encoding of pictures and words is dependent on two systems. One is a verbal symbolic system engaged most readily by words and the second is a nonverbal imaging system engaged most readily by pictures and objects. The superior recall of pictures over both concrete and abstract nouns results from the easier availability of both codes to picture representations. Under his view, these two codes must be independent to have separable effects and highly interconnected to show some additive properties. There has been considerable resistance to this view on theoretical and experimental grounds, but other recent studies have produced results compatible with the dual coding hypothesis as well (Kounios & Holcomb, 1994; Swaab, Baynes, & Knight, 1998). Generally, our results support a dual coding hypothesis such as that of Paivio and favor relative rather than absolute lateralization of these processes with an important role for the corpus callosum in inter-hemispheric integration.

REFERENCES

Baynes, K., Eliassen, J. C., Lutsep, H. L., & Gazzaniga, M. S. 1998. *Science,* **280,** 902–905.

Baynes, K. & Gazzaniga, M. S. 1988. In F. Plum (Ed.), *Language, communication and the brain* (pp. 117–126). New York: Raven Press.

Baynes, K., Wessinger, C. M., Fendrich, R., & Gazzaniga, M. S. 1995. *Neuropsychologia,* **31**, 1225–1242.

Beeman, M. 1998. In M. Beeman & C. Chiarello (Eds.) *Right hemisphere language comprehension.* (pp. 255–284). Mahweh, N.J.: Lawrence Erlbaum.

Brownell, H., Gardner, H., Prather, P., & Martino, G. 1995. In H. S. Kirshner, (Ed.) *Handbook*

of neurological speech and language disorders (pp. 309–328). New York: Marcel Dekker.

Chiarello, C. 1998. In M. Beeman & C. Chiarello (Eds.) *Right hemisphere language comprehension* (pp. 141–160). Mahweh, N.J.: Lawrence Erlbaum.

Dronkers, N. F., Baynes, K., Redfern, B. B., & Henik, A. 1997. *Brain and Language,* **60**(1), 29–32.

Gazzaniga, M. S., Smylie, C., Baynes, K., Hirst, W., & McCleary, C. 1997. *Brain and Language,* **22,** 206–220.

Hagoort, P. 1997. *Brain and Language,* **56,** 287–300.

Kounios, J. & Holcomb, P. 1994. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **20**(4), 804–823.

Milberg, W. & Blumstein, S. 1981. *Brain and Language,* **14**, 371–385.

Paivio, A. *Images in mind.* 1991. New York: Harvester Wheatsheaf.

Swaab, T., Baynes, K., & Knight, R. 1998. *Cognitive Neuroscience Society Abstracts,* **5,** 34.

Zaidel, E. & Seibert, L. *Brain and Language,* **60**(1), 188–192.

3. Semantic Priming in Alzheimer's Disease: Evidence for Preservation of Semantic Memory

Beth A. Ober and Gregory K. Shenaut

Human Development, University of California, Davis; and VA Northern California Health Care System, Martinez

Impaired performance on confrontation naming or verbal fluency tasks is often cited as evidence for degradation of the semantic-lexical memory network in Alzheimer's disease (AD) (Huff, Corkin, and Growdon, 1986). However, object/picture naming can be disrupted for reasons unrelated to the status of semantic memory (e.g., lack of access to phonological information). Likewise, the verbal fluency task requires more than an intact semantic network; normal performance on this task depends on attentional and working memory abilities, strategy implementation, inhibition of irrelevant material, and episodic memory ability.

What if semantic memory, that is, world knowledge, is intact in Alzheimer's disease? What if the impairments seen on confrontation naming and verbal fluency tasks are due to language and memory deficits unrelated to the semantic memory network, per se? First, it would mean that AD patients, their families, and the professionals who work with them, could call on the patient's memory database for use in day-to-day management, as well as in retraining exercises. Second, the preservation of semantic memory would bolster the view that semantic memory is a separate system in dependent of episodic memory. Third, preserved semantic memory in AD would be compatible with the view that conceptual knowledge in the neocortex has a

distributed and redundant representation and is therefore resistant to the loss of neurons which participate in these distributed representations.

Our general goal is to demonstrate that the notion of an intact semantic memory store in AD, at least in mild-to-moderate AD, is reasonable, and that this notion receives substantial support from the cognitive neuroscience research literature. Our more specific goals are to review four major issues that have been key in the debate over whether semantic memory is degraded or intact in Alzheimer's disease. These issues are: (1) intra-individual consistency versus inconsistency of responses, (2) disproportionate ''loss'' of lower-level features versus equivalent ''loss'' of lower-level and superordinate features, (3) intact versus abnormal semantic priming,and (4) intact versus abnormal organization of semantic representations within particular categories.

First, evidence will be presented that there is little intra-individual consistency in errors of AD patients (for example, on object naming tasks) across testing sessions, and that, in fact, task difficulty is a better predictor of the likelihood of error than is concept (object) specificity. Second, evidence will be presented that seems incompatible with the notion of ''bottom-up'' loss of semantic features in AD (e.g., Cox, Bayles, & Trosset, 1996; Nebes & Brady, 1988). Third, the overwhelming evidence for intact semantic priming effects in AD will be discussed (as reviewed by Ober & Shenaut, 1995). Semantic priming refers to the reduced reaction time to a stimulus from prior exposure to a semantically related as opposed to unrelated stimulus. Semantic priming paradigms can be used as tools for assessing the degree to which concepts and the connections among concepts in the semantic memory network are intact. The evidence for intact semantic priming in AD includes findings from a number of semantic priming studies conducted in our laboratory (e.g., Ober, Shenaut, Jagust, & Stillman, 1991; Ober, Shenaut, & Reed, 1995), with many different types of semantic relationships, several types of priming tasks (word pronunciation, single-choice lexical decision, dual-choice lexical decision), and a variety of paradigmatic variations (e.g., pairwise vs. continuous priming, short vs. long stimulus-onset-asynchronies). Several researchers have obtained greater-than-normal semantic priming in AD. This is sometimes interpreted as evidence for degradation of concepts in semantic memory (e.g., Chertkow, Bub, & Seidenberg, 1989; the logic is that degraded concepts have more to gain from the spread of activation within the semantic network than do intact concepts) and is sometimes interpreted as evidence for attentional abnormalities in AD (e.g., Hartman, 1991). However, an experiment from our laboratory has demonstrated both equal-to-normal and greater-than-normal priming in the *same* AD individuals, in the *same* testing session, depending on the stimulus-onset-asynchrony (Shenaut & Ober, 1996), with normal priming occurring at the short stimulus-onset-asynchrony and greater-than-normal priming occurring at the long stimulus-onset-asynchrony (when the attentionally-based process of expec-

tancy can occur). Thus, greater-than-normal priming does not provide evidence for semantic degradation in AD, but rather, provdes evidence for attentional abnormalities in AD.

Fourth, and finally, results from our current research project on semantic memory organization in AD will be presented. We are administering five different semantic memory tasks, both RT and non-RT tasks of varying difficulty, with stimuli from each of several semantic categories (e.g., animals, tools, fruit, clothing) to AD and elderly normal subjects. Each of these tasks yields similarity-based semantic networks for given semantic categories (using multi-dimensional scaling as well as Pathfinder analyses), demonstrating that the task with which the similarity data is obtained has a powerful influence on the semantic network ''solutions'' for AD as well as control subjects. AD subjects' semantic networks look more like those of control subjects with tasks that are relatively less demanding of attentional resources, strategic abilities, and decision-making skills, in comparison to tasks that are more difficult. These results demonstrate that task variables must be considered by clinicians and researchers who seek to determine whether a given patient or group of patients has deficits in semantic (world) knowledge.

REFERENCES

Chertkow, H., Bub, D., & Seidenberg, M. 1989. *Brain and Language,* **36,** 420–446.

Cox, D. M., Bayles, K. A., & Trosset, M. W. 1996. *Brain and Language,* **52,** 536–550.

Hartman, M. 1991. *Neuropsychologia,* **29,** 213–228.

Huff, F. J., Corkin, S., & Growdon, J. H. 1986. *Brain and Language,* **28,** 235–249.

Nebes, R. D. & Brady, C. B. 1988. *Cortex,* **24,** 291–299.

Ober, B. A. & Shenaut, G. K. 1995. In P. A. Allen & T. R. Bashore (Eds.) *Age differences in word and language processing* (Advances in Psychology Series, Vol. 110). Amsterdam: Elsevier Science Publishers.

Jagust, W. J. & Stillman, R.C. 1991. *Psychology and Aging,* **6,** 647–660.

Ober, B. A., Shenaut, G. K., & Reed, B. R. 1995. *Aging and Cognition,* **2,** 254–267.

Shenaut, G. K. & Ober, B.A. 1996. *Psychology and Aging,* **11,** 443–448.

4. Event-Related Potential Studies of the Role of the Right Hemisphere in Word Processing: Semantic Distance and Imageability

Tamara Y. Swaab,* Kathleen Baynes,*,† and Robert T. Knight*,†

**University of California at Davis; and †VA Northern California Health Care System, Martinez*

Although it is well established that for most people the left hemisphere is dominant for language, there are many studies that indicate that the right

hemisphere (RH) does play a role in some aspects of normal language comprehension. In particular it has been shown that lexical-semantic processing may involve the RH (e.g., Chiarello, 1998; Hagoort et al., 1996). In general, the current evidence suggests that the left and right hemisphere might be differentially sensitive to certain types of semantic relations. More specifically, Beeman et al. (1994) have proposed that the RH is involved in the processing of distant semantic relations or coarse semantic coding.

This idea is supported by an ERP priming study (Hagoort et al., 1996). In this study, RH lesioned patients showed relatively normal associative N400 priming effects (i.e., a reduction in amplitude of the N400 to related relative to unrelated target words), but failed to show a modulation of the N400 to non-associatively related words that were from the same semantic category (e.g., *church-villa*). This dissociation was not found for age-matched controls, nor for aphasic patients. These results suggest that the RH becomes more effective when the semantic distance between the words increases. However, in this study, the words that were used in the nonassociative semantic condition were all highly imageable (e.g., *''banana''*), whereas in the associative condition a larger proportion of the words was not imageable (e.g., *''justice''*). It has been argued that the RH is involved in the processing of imageability aspects of words (Deloche et al., 1987). Thus, the high imageability of the words in the nonassociative semantic condition might have mediated the results in the Hagoort et al. (1996) study.

In the present study, associative and purely semantic relations between words were tested, but in contrast to Hagoort et al. (1996), the imageability of the words was systematically varied. The ERP results of patients with focal lesions in the RH were compared to the results of normal age-matched control subjects (NC). The NC showed the expected N400 priming effects for the associative and the semantic conditions, and they also showed an ERP effect of imageability. The size of the N400 priming effects was comparable for both types of relations. In contrast to the NC, the RH patients only showed an N400 priming effect for the associative condition, but not for the semantic condition. Importantly, these patients did show an ERP imageability effect. These results therefore support Hagoort et al. (1996): Non-aphasic RH lesioned patients are impaired in the processing of semantically distant relations, and this cannot be explained in terms of the imageability of words.

However, these results cannot exclude the idea that the RH is involved in the processing of imageability aspects of words. It may be the case that coarse semantic coding and coding of imageability aspects of words are subserved by different areas of the RH. A large number of studies have shown that concrete or high imageable words are processed more easily than abstract or low imageable words. But it is still a matter of debate what causes this concreteness effect. Paivio (1991) has argued that there are two representational systems (*dual codes*): An image-based memory store and a verbal-based memory store. In this dual coding system, the processing advantage

for concrete words occurs because these words are represented by codes in image- and verbal based systems respectively, whereas abstract words are only represented with a verbal code. In the *context availability* theory (e.g., Schwanenflugel et al., 1988), on the other hand, it is proposed that the representations for concrete words contain more contextual information than those for abstract words, and this provides processing benefits for concrete relative to abstract words. These processing benefits should disappear when abstract words are embedded in a supportive context. In our study we found effects of imageability, independent of whether a target word was preceded by a related or an unrelated context word. The ERPs to the high imageable words were more negative than to the low imageable words, and this imageability effect had a strong right frontal focus. These results suggest that the processing of high imageable words may be supported by additional brain structures, and furthermore, that the imageablity effect is not dependent upon a supportive context, which is compatible with Paivio's (1991) dual coding theory.

Together these studies support the idea that the RH indeed plays a role in the processing of meaning aspects of words. In particular, the impairment in the processing of distant semantic relations in RH lesioned patients suggests that the RH becomes more involved in word processing when the meaning relations between words are distant. This effect is independent of whether words are imageable or not. However, the ERP topography of the imageability effect suggests that high imageable words are processed differently than low imageable words, and that the RH may support the processing of imageability aspects of words as well.

REFERENCES

Beeman, M., Friedman, R. B., Grafman, J., Perez, E., Diamond, S., & Lindsay, M. B. 1994. Summation priming and coarse semantic coding in the right hemisphere. *Journal of Cognitive Neuroscience,* **6,** 26–45.

Chiarello, C. 1998. In M. Beeman & C. Chiarello (Eds.), *Right hemisphere language comprehension.* Mahweh, NJ: Erlbaum.

Deloche, G., Seron, X., Scius, G., & Segui, J. Right hemisphere language processing: Lateral difference with imageable and nonimageable ambiguous words. *Brain & Language,* **30,** 197–205.

Hagoort, P., Brown, C., & Swaab, T.Y. 1996. Lexical-semantic event-related potential effects in patients with left hemisphere lesions and aphasia, and patients with right hemisphere lesions without aphasia. *Brain,* **119,** 627–649.

Paivio, A. 1991. Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology,* **45,** 255–287.

Schwanenflugel, P., Harnishfeger, K. K., & Stowe, R. W. 1988. Context availability and lexical decisions for abstract and concrete words. *Journal of Memory and Language,* **27,** 499–520.

5. Left Temporal-Parietal Lesions Impair Repetition Priming for Nonwords, But Not Words

Diane Swick

Department of Neurology, UC Davis; and VA Northern California Health Care System, Martinez

Repetition priming is the improved ability to identify a word after subsequent presentation. In the lexical decision task, priming is measured by a facilitation in reaction time (RT) following repeated exposure (Scarborough et al., 1977). Theories for interpreting repetition priming include abstractionist, episodic, and memory systems accounts. The logogen model (Morton, 1969) exemplifies abstractionist, or lexical, explanations. Presentation of a word transiently activates its abstract lexical representation (''logogen''), thereby lowering its threshold for subsequent activation. However, repetition effects are reduced with a change in modality, suggesting that nonmodal lexical units cannot entirely account for priming effects. Episodic theories, conversely, claim that priming effects are too long-lasting to be accommodated by the temporary activation of a logogen (Jacoby & Dallas, 1981). Instead, the initial presentation of a stimulus establishes an episodic memory trace that is accessed when the item is repeated. One objection, however, is that amnesics demonstrate dissociations between explicit and implicit versions of the same task. The memory systems view (Tulving & Schacter, 1990), which informs much neuropsychological work, hypothesizes that priming mechanisms are distinct from episodic memory, as in the specific perceptual representation system (PRS) for visual word forms.

Priming can also occur for novel material such as nonwords, which have no pre-existing representations in the lexicon. Certain characteristics of nonword priming present challenges for all three models. If based on episodic memory traces or similarity to visual word forms, repetition effects for orthographically legal nonwords should resemble those for words. Some experiments have observed nonword priming in lexical decision, while others have not. Typically, the effects are very short-lived, although longer duration effects have been found (McKone, 1995).

Little is known about the underlying brain mechanisms that mediate repetition priming at different temporal delays. Such information can inform and constrain theoretical models of priming. The current study examined the effects of damage to temporal-parietal cortex on word and nonword priming during lexical decision. These results will be compared to those from patients in other focal lesion groups.

Method: Subjects. Subjects were 6 patients with focal lesions in temporal-parietal junction (3L, 3R hemisphere, mean age 57.2 $\pm$ 6.0 yrs) and 6 con-

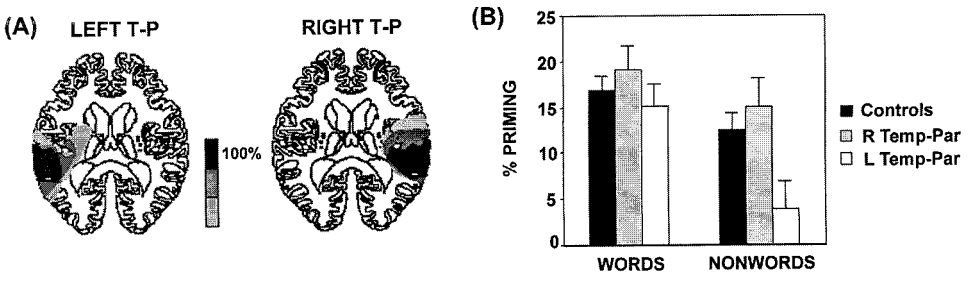

FIGURE 15

trols matched for age (mean 62.2 ± 5.0 yrs) and education. Lesions included posterior superior temporal and supramarginal gyri (Fig. 15A).

Procedure. Stimuli were words and pronounceable nonwords, 4 to 8 letters in length. Words were of moderate to low frequency (mean, 9.35 occurrences/million). Nonwords were created by altering 1–3 letters in real words or rearranging their sequence. Two sets of 360 stimuli (180 words and 180 nonwords) were constructed. Each stimulus set was divided into 8 blocks of 90 items each (22-23 words and 22-23 nonwords), with all stimuli repeating once within the block. Lags (delays) between first and second presentation were 3 s (0 intervening items), 6–12 s (1–3 intervening items), and 30–60 s (9–19 intervening items). Stimulus duration was 500 msec, ISI was 2500 msec. Subjects were instructed to press one button for words and the other button for nonwords.

Results. Statistical analysis of RT data utilized repeated measures ANOVAs with factors of stimulus type, lag, and group. Only correct responses were entered into these analyses. Main effects of stimulus type [$F(1, 10) = 23.35$, $p < .001$], lag [$F(3, 30) = 90.47$, $p < .0001$], and group [$F(1, 10) = 4.56$, $p < .06$] were observed. All participants were faster for words (732 ms) than nonwords (836 ms) and for repeated items compared to new stimuli. Temporal-parietal patients were marginally slower than controls (864 vs. 704 ms, $p < .06$). Therefore, priming was quantified as percent RT facilitation for the three delays, and hemisphere of lesion was examined. Priming was greater for immediately repeated stimuli than for lag 1–3 or lag 9–19 items [$F(2, 18) = 81.64$, $p < .0001$] and for words (17%) compared to nonwords [11%; $F(1, 9) = 22.23$, $p < .001$]. Furthermore, a stimulus type X group interaction was obtained [$F(2, 9) = 9.81$, $p < .006$; Fig. 15B]. For word priming, neither left nor right hemisphere patients differed from controls ($p > .2$). However, LTP patients showed significantly less nonword priming than controls and RTP patients. Nonword priming tended to show faster decay than word priming ($p < .09$), but no further interactions with lag approached significance.

Discussion. The major finding was that word repetition priming during lexical decision is intact in patients with LTP lesions, but nonword priming is reduced relative to controls. Patients with RTP lesions show intact priming for both words and nonwords. One possible framework for interpreting these results begins with the observation that nonwords (i.e., pronounceable pseudowords) have no preexisting representations, either orthographically or phonologically. Hence, nonword priming effects are smaller and more short-lived. The reduction of nonword priming by LTP lesions could be the result of a defective phonological store in this group (Baldo & Dronkers, unpublished observations), suggesting that nonword priming has a greater phonological basis than word priming. The finding of intact word priming indicates that preexisting lexical representations can be activated and maintained despite LTP damage. These results diverge from those of previous studies with frontal patients, in which priming for both stimulus types was unimpaired (Swick, in press), and patients with inferior temporal-occiptial lesions, who exhibited reduced word and nonword priming (Swick & Knight, 1995; Swick & Sadil, 1996), presumably due to damage in the PRS for visual word forms.

Lexical decision for written words requires analysis of orthography, implicit activation of phonology, access of lexical entries, and decision-making processes. Priming in this task can be based on facilitation in any or all of these processes, and neuropsychological studies can help determine the relative contributions of each.

REFERENCES

Jacoby L. L. & Dallas, M. 1981. *Journal of Experimental Psychology: General,* **110,** 306–340.

McKone, E. 1995. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **21,** 1108–1126.

Morton, J. 1969. *Psychological Review,* **76,** 165–178.

Scarborough, D. L., Cortese, C., & Scarborough, H. S. 1977. *Journal of Experimental Psychology: Human Perception & Performance,* **3,** 1–17.

Swick, D. in press. Cognitive Brain Research.

Swick, D. & Knight, R. T. 1995. *NeuroReport* **7,** 11–16.

Sadil, C. & Swick, D. 1996. Cognitive Neuroscience Society Abstract, **3,** 71.

Tulving, E. & Schacter, D. L. 1990. *Science,* **247,** 301–306.