CONSCIOUSNESS AND COGNITION **7,** 54–66 (1998)
ARTICLE NO. CC980329

An Electrophysiological Measure of Priming of Visual Word-Form

Ken A. Paller

Department of Psychology, Northwestern University, Evanston, Illinois 60208-2710

Marta Kutas

Department of Cognitive Science, University of California at San Diego, La Jolla, California

and

Heather K. McIsaac

Department of Psychology, University of British Columbia, Vancouver, B.C., Canada

Priming and recollection are expressions of human memory mediated by different brain events. These brain events were monitored while people discriminated words from nonwords. Mean response latencies were shorter for words that appeared in an earlier study phase than for new words. This priming effect was reduced when the letters of words in study-phase presentations were presented individually in succession as opposed to together as complete words. Based on this outcome, visual word-form priming was linked to a brain potential recorded from the scalp over the occipital lobe about 450 ms after word onset. This potential differed from another potential previously associated with recollection, suggesting that distinct operations associated with these two types of memory can be monitored at the precise time that they occur in the human brain. © 1998 Academic Press

Despite the long history of the distinction between memory that does and does not entail the conscious awareness of remembering (Schacter, 1987), only in recent years has it been feasible to map this distinction onto brain physiology. The primary source of evidence linking brain structures to particular memory functions has traditionally been neuropsychological studies of brain-damaged patients. In intact individuals, various functional neuroimaging techniques can now be used to determine which brain areas might be engaged in the service of these memory functions. The relevant brain events can also be monitored more directly via scalp recordings of brain electrical activity, or *neuromonitoring.* Here we present electrophysiological findings in accord with the distinction between aware and unaware forms of memory.

This distinction has been fostered by contrasting standard memory tests, such as recall and recognition, with *implicit memory tests,* which make no reference to prior learning episodes. In the lexical decision test, for example, the subject decides whether letter strings do or do not constitute bona fide words, and *priming* can be demonstrated by a facilitation of lexical decision time for words also presented in advance. Priming relies primarily on representations of semantic information in some circumstances and on presemantic, perceptual representations in others; hence the distinction between conceptual and perceptual priming. Perceptual priming is presumed to be relatively insensitive to the degree of semantic elaboration of studied items, whereas it is generally diminished when perceptual factors are altered from

1053-8100/98 $25.00

study to test (for reviews, see Richardson-Klavehn & Bjork, 1988; Schacter, Chiu, & Ochsner, 1993).

Several types of priming have been dissociated from recognition memory in studies of amnesic patients, who can show normal-magnitude priming effects for material that they fail to recollect (e.g., Graf, Squire, & Mandler, 1984; Paller, Mayes, McDermott, Pickering, & Meudell, 1991). Such neuropsychological dissociations suggest that different brain events underlie priming and recollection (e.g., Mayes & Downes, 1997; Schacter & Tulving, 1994; Shimamura, 1986; Torres & Raz, 1994). Tulving and Schacter (1990) have termed the system responsible for perceptual priming the *perceptual representation system.* For priming effects involving visually presented words, one of the most relevant portions of the perceptual representation system is the *visual word-form system.* Priming is usually thought to be independent of recollection, as only the latter depends on the retrieval of contextual information.

Some attempts to monitor human memory processes as they occur have used the electrical activity of the brain in the form of event-related potentials (ERPs) recorded noninvasively from the scalp (see reviews by Johnson, 1995; Kutas, 1988; Paller, 1993; Rugg, 1995). Prior studies, however, have not demonstrated that perceptual priming produces an ERP. To demonstrate that such a brain potential exists, the critical step is to isolate an ERP correlate of priming from other ERPs that occur concurrently. Comparisons between studied and unstudied items in standard recognition paradigms or in implicit memory tests are insufficient because the two types of memory are confounded.

The present experiment overcomes this problem through the use of a study-phase manipulation that differentially influences priming and recollection. We hypothesized that if an ERP correlate of priming exists distinct from ERP correlates of recognition and related processes, it would systematically vary with a manipulation that (a) enhances the magnitude of priming and (b) does not influence recognition accuracy for the same material. During the study phase, the letters of each word were presented either disjoined in time in a ‘‘letter-by-letter’’ format or connected in a ‘‘whole-word’’ format. Based on related experimental results (Graf & Ryan, 1990; Jacoby, 1991; Jacoby & Hayman, 1987; Marsolek, Kosslyn, & Squire, 1992; McAndrews & Moscovitch, 1990; Roediger, Weldon, & Challis, 1989), we predicted that we would be able to isolate an ERP correlate of perceptual priming corresponding to the influence of this manipulation on priming but not recognition (even though the tests themselves may not be process-pure). Of course, this ERP effect is not necessarily the only possible ERP correlate of perceptual priming. Given that priming may reflect the sum of a multitude of experience-induced changes, the present results concern only the subset specific to the processing of a whole written word as a distinct perceptual unit—that is, the processing of visual word-form.

METHOD

Subjects were 15 right-handed, native English-speaking men and women, aged 19–25 years, who gave informed consent. Recordings were made from 13 scalp electrodes embedded in an elastic cap, each referred to an off-line average from left and right mastoids. In addition, two channels were used for monitoring horizontal and vertical eye movements, and trials contaminated by electroocular artifacts were excluded from ERP analyses (an average of 26% of the test-phase trials). The band pass was 0.01–100 Hz.

Words and nonwords were presented within a rectangular frame in the center of a monitor, using uppercase letters that each subtended a vertical visual angle of 0.6°. The primary set of 450 words varied in length from five to eight letters and had an average frequency of written occurrence of 27 according to Kucera and Francis (1967) norms.

In the study phase, word presentation alternated trial-by-trial between two formats. In the whole-word format, each word was presented for 133 ms followed by a 3350-ms blank interval. In the letter-by-letter format, each word was presented by showing the first two letters followed by each subsequent letter presented individually. To avoid pattern-masking effects, letters were shown in their normal spatial location with an underscore in place of each missing letter. For example, the word ‘‘apple’’ would be presented in four frames (117 ms each) separated by blank intervals (100 ms each) as follows: AP___, __P__, ___L_, ____E. The final frame was followed by a 3350-ms blank interval.

Instructions during the study phase were to form a visual image of each word’s referent and to indicate with a left or right button-press whether the actual object would be smaller or larger than the video monitor on which the words were displayed. Accordingly, the cue ‘‘small large’’ appeared continuously above the frame as a reminder of the response requirements. Subjects were also instructed to press a third button whenever they were unable to read a word, and responses to those words were excluded from all analyses.

In the test phase, letter strings were flashed for 300 ms each at a rate of one every 1500 ms, always in the whole-word format. Subjects were asked to indicate as quickly as possible whether each letter string was or was not an English word. Accordingly, the cue ‘‘nonword word’’ above the rectangular frame reminded subjects which hand to use for which response. Test items included an equal proportion of (a) nonword letter strings that were orthographically and phonologically word-like (e.g., glone, drice); (b) words from the letter-by-letter condition; (c) words from the whole-word condition; and (d) words that had not appeared in the study phase. In this way, 30 words were presented in each study phase (half in each format) and 45 words were presented in each test phase (two-thirds of which were from the prior study phase).

There were 10 study–test blocks with different words and nonwords in each block. Words assigned to letter-by-letter, whole-word, and unstudied conditions were counterbalanced across subjects. Recognition was tested at the end of the 10th block by asking subjects to circle study words appearing on a list of 239 words not previously used in the experiment intermixed with the 300 study words. All study words had previously appeared once in the study phase and once in the test phase.

RESULTS

Mean reaction times in the lexical decision test were 626 ms for unstudied words, 585 ms for words studied in the letter-by-letter format, and 565 ms for words studied in the whole-word format. A priming effect was evident in that decisions were made more quickly for studied words than for unstudied words [$t(14) = 8.7$, $MSe = 254$, $p = .0001$, both study conditions together]. Furthermore, the facilitation was greater for the whole-word condition than for the letter-by-letter condition [$t(14) = 4.0$, $MSe = 189$, $p = .0014$]. Importantly, although the magnitude of the effect of study format was small, this pattern of reaction time results held for each individual subject.

In contrast, recognition did not differ significantly as a function of study format [$t(14) = 1.9$, $MSe = 11$, $p = .075$]. Recognition accuracy tended to be slightly higher for words from the letter-by-letter condition (85% correct) than from the whole-word condition (82% correct), but this trend was not reliable. Recognition was superior in the letter-by-letter condition for nine subjects and in the whole-word condition for six subjects. The mean false alarm rate was quite low (5%). Although word presentations during the intervening priming test may have influenced recognition performance, we believe that this influence was equivalent for whole-word and letter-by-letter conditions given that both cases involved an additional study opportunity with the identical, whole-word presentation format. Moreover, the trend in recognition accuracy (letter-by-letter $>$ whole-word) was in the opposite direction of the effect on priming magnitude (whole-word $>$ letter-by-letter). In sum, memory tested implicitly via lexical decision times was reliably influenced by the study-phase manipulation, whereas memory tested explicitly via measures of recognition accuracy at a longer delay was not.

Analysis of brain potentials will focus on recordings made during the lexical decision test. ERPs from the scalp location over the left occipital region are shown in Fig. 1. At this location, ERPs followed the pattern of effects on lexical response times, in that there were differences between studied and unstudied words as well as between studied words as a function of study format.

Another way to visualize these ERP effects is as difference waves computed by subtracting ERPs to unstudied words from ERPs to studied words. The resulting wave forms represent the pure effects of word repetition, because effects not sensitive to repetition are subtracted out. Figure 2 shows such difference waves plotted for each scalp location. At most locations there was a positive difference from about 300 to 600 ms, followed at some locations by a negative difference. The positive difference wave from 300 to 600 ms was largest at posterior locations over the occipital lobes (O1 and O2), and it was at these locations that the two difference waves diverged such that the difference wave from the whole-word condition was larger than that from the letter-by-letter condition.

Initial statistical analyses compared ERPs to studied versus unstudied words at all scalp locations using mean amplitude measurements over consecutive 50-ms intervals. Measurements for each interval were submitted to a two-way analysis of variance (ANOVA) with studied/unstudied and electrode location as factors, using the Geisser–Greenhouse correction. The main effect of repetition was significant from 300 to 550 ms ($p = .0169$, .0004, .0001, .0001, and .01, respectively). In addition, significant repetition by location interactions from 350 to 700 ms ($p = .0487$, .0118, .0012, .0089, .0458, .0226, and .0226, respectively) indicated that the magnitude of the ERP repetition effect differed across recording sites. A mean amplitude measure-

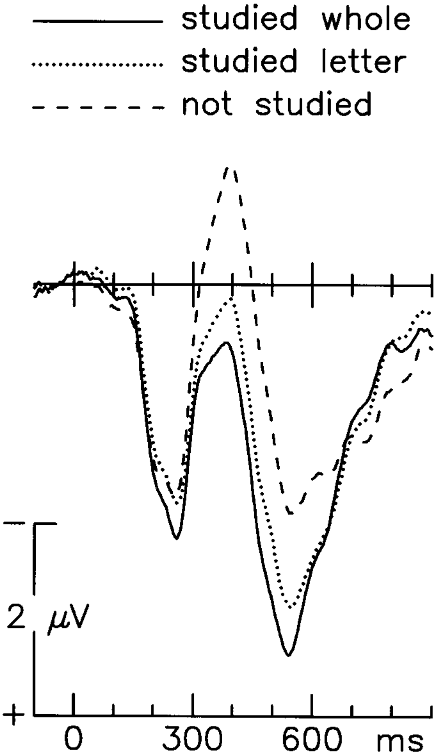

FIG. 1. Event-related potentials (ERPs) recorded during the test phase from the scalp electrode positioned over the left occipital lobe. Beginning at about 300 ms after word onset, ERPs to words studied previously in either format were more positive than ERPs to unstudied words. Furthermore, ERPs were more positive for words studied in the whole-word format than for words studied in the letter-by-letter format.

ment over this latency range revealed that the ERP repetition effect was significant (p's $< .0233$) at all locations except two, Fz and F4.

A second analysis was conducted to examine effects of the manipulation of presentation format during the study phase. Measurements over consecutive 50-ms intervals from occipital recordings were submitted to two-way ANOVAs with study condition (whole-word/letter-by-letter) and side (left/right) as factors. The main effect of study condition was statistically reliable only in the interval from 450 to 500 ms after word onset [$F(1, 14) = 5.31$, $MSe = 1.95$, $p = .037$]. This enhanced positivity for the whole-word relative to the letter-by-letter condition was bilaterally symmetric [0.82 μV at O1, 0.84 μV at O2, nonsignificant study condition by side interaction $F(1, 14) = 0.01$, $MSe = 0.11$]. Moreover, ERP differences from 450 to 500 ms as a function of study condition were nonsignificant at all other electrode locations.

An effect of study condition was also observed slightly later at some anterior locations, where ERPs from the letter-by-letter condition were more positive than ERPs from the whole-word condition. An analysis of differences between the two condi-

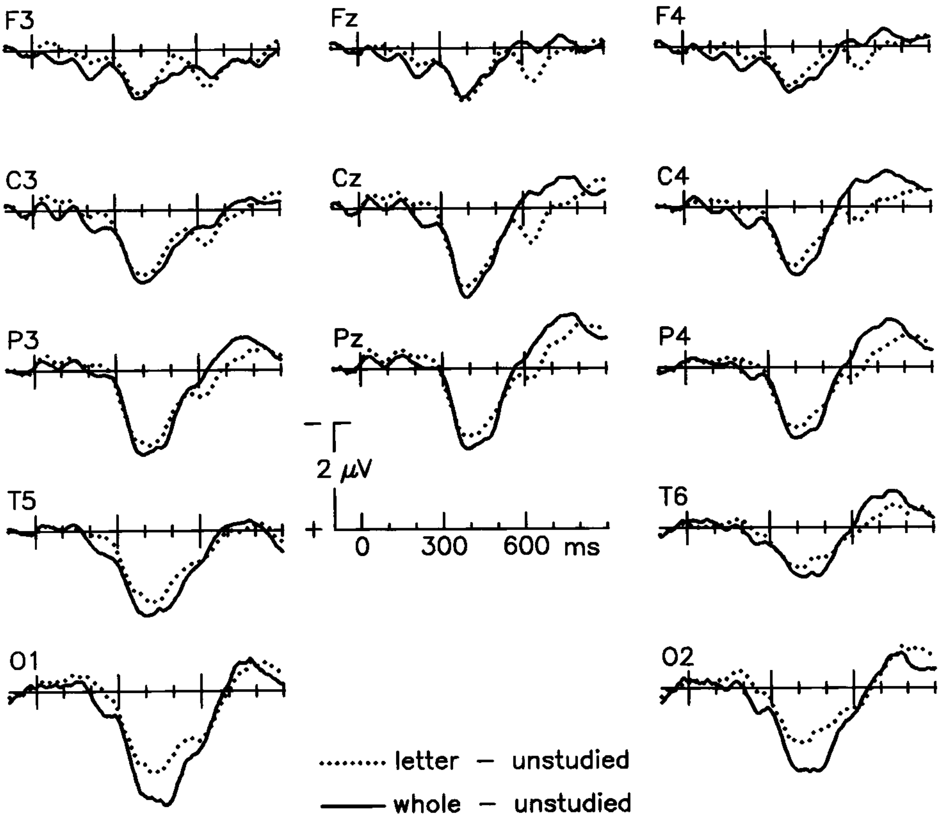

FIG. 2. Difference waves computed by subtracting ERPs to unstudied words from ERPs to studied words. ERPs are arranged topographically as viewed from the top of the head, with recordings over the left hemisphere in the left column, recordings from the midline in the center column, and recordings over the right hemisphere in the right column, moving from anterior to posterior regions from top to bottom of each column. Significant differences were observed at occipital locations labeled ''O1'' (left occipital) and ''O2'' (right occipital).

tions taking into account data from all electrodes revealed a significant main effect of condition from 600 to 650 ms [$F(1, 14) = 5.84$, $MSe = 3.81$, $p = .0299$], but for none of the other 50-ms intervals. A marginal condition by electrode interaction for this interval [$F(12, 168) = 2.52$, $MSe = 0.27$, $p = .0721$] reflected the fact that ERPs differed significantly between the two conditions only at frontal, central, and parietal electrodes on the right side (F4, C4, P4) and on the midline (Fz, Cz, Pz). These effects may be associated with the slight tendency for recognition to be better for words studied in the letter-by-letter condition and as such may correspond to ERP correlates of recollection recorded in prior studies (Paller & Kutas, 1992; Paller, Kutas, & McIsaac, 1995). A related possibility is that the enhanced positivity for the letter-by-letter condition reflects retrieval of contextual information in the form of memory for the unusual study presentation format.

DISCUSSION

The format of word presentation in the study phase influenced both subsequent lexical decision performance and brain potentials elicited during the lexical decision test. Study presentations gave rise to a decrease in lexical decision times for corresponding words presented in the test phase, and this decrease was reliably larger when the initial exposure was with the whole-word study format compared to the letter-by-letter study format. Given that the whole-word format was used in test presentations, transfer-appropriate processing can be said to differ across conditions. For study presentations with the letter-by-letter format, encoding of visual word-form was presumably less effective and/or less complete.

Recognition memory, in contrast, was determined in large part by elaborative processing and not presentation format. The trend for a recognition advantage for the letter-by-letter condition may relate to the distinctiveness of the presentation format or to the potentially increased effort and subvocalization that may have been invoked to decipher words presented in this way (perhaps as in the ‘‘generation effect,’’ Slamecka & Graf, 1978). In any event, this trend was not consistent across participants in this study.

Because the study-phase manipulation reliably influenced priming but not recognition, we interpret the corresponding ERP differences at 450 ms in the test phase (prior whole-word study vs. prior letter-by-letter study) as an indication of differential activation of the visual word-form system. This effect was robust only at occipital scalp locations. The amplitude of a negative deflection that began 200–300 ms after word onset (see Fig. 1) was largest for words that did not appear in the study phase and it declined with word repetition, especially for words that were presented again in the same, whole-word format. This evidence pertains not only to the time course of priming mechanisms, but also to anatomical substrates. Although detailed modeling and additional topographic evidence may be required for precise localization, the present topography is consistent with an origin in posterior neocortex. The timing and cognitive correlates of the effect suggest that it does not arise from primary visual cortex. However, occipitotemporal regions can be associated with processing of visual word-form on the basis of evidence from neuropsychology and neuroimaging.

Of particular relevance is the syndrome of pure alexia (also referred to as pure word blindness, alexia without agraphia, word-form dyslexia, and letter-by-letter reading). The hallmark of this syndrome is a loss of the normal ability to read, together with the preservation of other linguistic abilities such as writing. Patients with pure alexia typically attempt to decipher words by spelling out the individual letters, but both letter identification and letter-by-letter reading are abnormally slow and laborious (Warrington & Langdon, 1994). The hypothesis that pure alexia results from a fundamental dysfunction of the visual word-form system was originally made by Warrington and Shallice (1980). Various alternative accounts ascribe the deficits to: (1) abnormal, serial transmittal of letter information to the visual word-form system (Patterson & Kay, 1982); (2) a general inability to rapidly encode sets of objects, including but not specific to words (Farah, 1990); or (3) disrupted selection processing required for the automatic identification of familiar characters and character strings (Arguin & Bub, 1994). Although pathological results vary substantially from patient to patient, the damage generally involves posterior regions of the left hemisphere near the occipitotemporal or occipitoparietal border and in some patients the splenium of the corpus callosum. Other neuropsychological evidence that also implicates posterior neocortical regions in visual word-form priming includes the case study of a patient with bilateral damage to occipitotemporal regions who exhibited a memory impairment that encompassed perceptual priming but excluded conceptual priming and recognition for visual words (Keane, Gabrieli, Mapstone, Johnson, & Corkin, 1995).

Evidence from positron emission tomography (PET) has also been used to argue that priming reflects an increased efficiency of perceptual processing in the occipitotemporal region (Buckner, Petersen, Ojemann, Miezin, Squire, & Raichle, 1995; Squire, Ojemann, Miezin, Petersen, Videen, & Raichle, 1992). In this region, blood flow measures averaged over 40-s periods were found to decrease in a priming condition relative to a baseline condition. The notion that this region is specialized for the processing of visual word-form is consistent with some prior PET findings, although there are discrepancies across studies concerning localization within the occipitotemporal area (Howard, Patterson, Wise, Brown, Friston, Weiller, & Frackowiak, 1992; Petersen, Fox, Posner, Mintun, & Raichle, 1989). Indeed, there may be a large number of cortical areas that are specifically responsive to words and that are activated differentially as a function of word repetition (e.g., Halgren, Buckner, Marinkovic, Rosen, & Dale, 1997). Future studies using neuroimaging based on hemodynamics may succeed in clearing up this controversy and precisely identifying the areas involved in processing visual word-form, but these methods lack the temporal resolution necessary to monitor the course of perceptual and memory processes that transpire on a subsecond timescale.

Electrophysiological recordings from electrodes implanted in epileptic patients have also revealed areas in extrastriate visual cortex that may be specifically responsive to words (Allison, McCarthy, Nobre, Puce, & Belger, 1994; Nobre, Allison, & McCarthy, 1994). Visual letter strings elicited N200 potentials from fusiform and inferior temporal gyri. From these locations as well as from more anterior portions of the inferior temporal lobe, N200 potentials were followed by other potentials also apparently word-specific. Brain activity generating intracranial N200 potentials may be evident in recordings from scalp electrodes (Schendan, Ganis, & Kutas, in press), although these potentials occur at shorter latencies than that of the ERP correlate of priming of visual word-form reported here.

In an ERP study of three patients with cortical damage in the right inferior occipitotemporal and adjacent regions, Swick and Knight (1995) reported that ERPs related to stimulus repetition were eliminated. Priming of lexical decision times was also reduced relative to that in control subjects. These results are thus consistent with a link between this brain region and perceptual priming of visual word-form. However, two of the three patients had additional damage to the right posterior hippocampus. In addition, the ERP results were not necessarily specific to priming, given that differences in priming may have been confounded with differences in incidental recollection, as in many prior ERP studies of memory. In contrast, the design of the present experiment minimized the confound between priming and recollection.

The ERP correlate of priming observed here can also be validated by juxtaposing

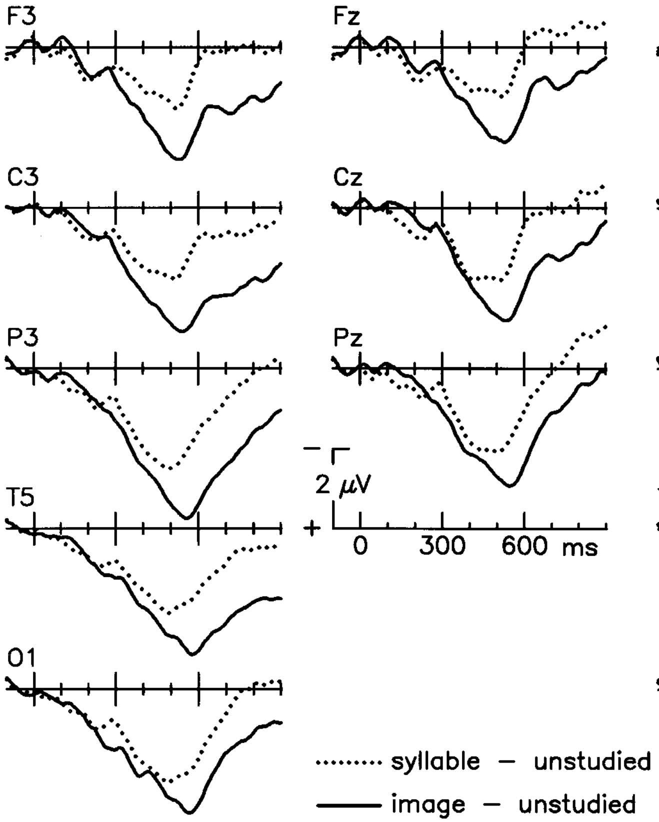

FIG. 3. Difference waves computed from a prior study (Paller et al., 1995, Experiment 2). The experimental design was similar in many respects to that in the present experiment, but these difference waves allowed a comparison between two conditions that differed in recognition but were matched in lexical decision priming, thus isolating an ERP correlate of recollection. ERPs are arranged as in Fig. 2.

it with ERP correlates of recollection from prior experiments (Paller & Kutas, 1992; Paller et al., 1995). Figure 3 shows difference waves from the test phase in one such experiment—many features, including stimuli, procedural details of lexical decision testing, and EEG recording methods, were comparable to those in the present experiment. Based on a manipulation of task requirements during the study phase that influenced later recognition but not priming, the divergence between ERPs from two conditions was interpreted as an index of differential recollection. This ERP correlate of recollection was evident at all 13 scalp locations, especially in the interval from 500 to 900 ms. Figure 4 contrasts topographic differences directly. Whereas the ERP correlate of priming was observed principally at posterior locations, the ERP correlate of recollection was smallest at posterior locations and was larger over the left hemisphere than over the right hemisphere. In addition, the ERP correlate of priming occurred over a narrow time interval (Fig. 2), whereas the ERP correlate of recollection continued for hundreds of milliseconds (Fig. 3).

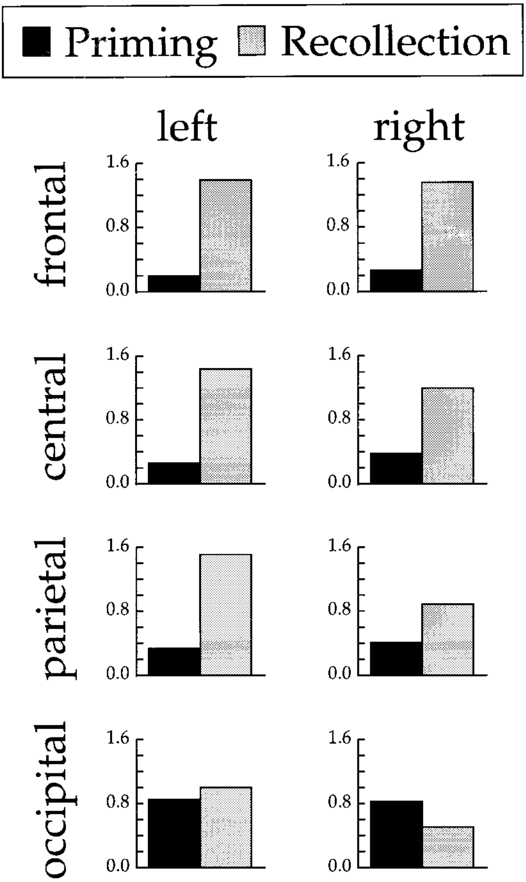

FIG. 4. Bar graphs showing the spatial distribution of the ERP correlate of word-form priming measured from 450 to 500 ms (dark bars) and the ERP correlate of recollection measured from 500 to 900 ms (light bars, data from Paller et al., 1995, Experiment 2). The scale ranges from 0 to 1.6 μV.

In conclusion, the findings that ERP correlates of recollection and priming differed in latency and topography suggest that these two electrophysiological phenomena reflect different ways in which the brain makes use of information it stores. The ERP correlate of priming reported here was not identified in previous experiments because manipulations with a specific impact on priming were not used. The manipulation between whole-word and letter-by-letter conditions reliably influenced measures of priming but not recognition, enabling us to tease apart ERP effects related specifically to priming of visual word-form. Further research will be needed to determine whether other manipulations that specifically influence priming yield similar results (see Paller & Gross, 1998). We hypothesize that the ERP correlate of priming observed here is related to aspects of visual word-form processing that take place in occipito-temporal regions of the brain. It is our hope that the ability to monitor the distinct neural transactions responsible for memory with and without the conscious awareness of remembering will provide information useful for further characterizing the neural substrates of this distinction (Paller, 1997).

ACKNOWLEDGMENTS

We thank R. Ohst and N. Herold for technical and programming assistance. This research was supported by grants from NIA (AG08313), NICHD (HD22614), NIMH (MH52893), and NINDS (NS34639).

Address correspondence to Ken A. Paller, Department of Psychology, Northwestern University, 2029 Sheridan Road, Evanston, IL 60208-2710. E-mail: kap@nwu.edu. Fax: 847/491-7859.

REFERENCES

Allison, T., McCarthy, G., Nobre, A., Puce, A., & Belger, A. (1994). Human extrastriate cortex and the perception of faces, words, numbers, and colors. *Cerebral Cortex,* **5,** 544–554.

Arguin, M., & Bub, D. N. (1994). Functional mechanisms in pure alexia: Evidence from letter processing. In M. J. Farah & G. Ratcliff (Eds.), *The neuropsychology of high-level vision* (pp. 149–171). Hillsdale, NJ: Erlbaum.

Buckner, R. L., Petersen, S. E., Ojemann, J. G., Miezin, F. M., Squire, L. R., & Raichle, M. E. (1995). Functional anatomical studies of explicit and implicit memory retrieval tasks. *Journal of Neuroscience,* **15,** 12–29.

Farah, M. J. (1990). *Visual agnosia: Disorders of object recognition and what they tell us about normal vision.* Cambridge, MA: MIT Press.

Graf, P., & Ryan, L. (1990). Transfer-appropriate processing for implicit and explicit memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **16,** 978–992.

Graf, P., Squire, L. R., & Mandler, G. (1984). The information that amnesic patients do not forget. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **10,** 164–178.

Halgren, E., Buckner, R. L., Marinkovic, K., Rosen, B., & Dale, A. M. (1997). *Cortical localization of word-repetition effects.* Paper presented at the 4th annual meeting of the Cognitive Neuroscience Society, Boston, MA.

Howard, D., Patterson, K., Wise, R., Brown, W. D., Friston, K., Weiller, C., & Frackowiak, R. (1992). The cortical localization of the lexicons: Positron emission tomography evidence. *Brain,* **115,** 1769–1782.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language,* **30,** 513–541.

Jacoby, L. L., & Hayman, C. A. G. (1987). Specific visual transfer in word identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **13,** 456–463.

Johnson, R., Jr. (1995). Event-related potential insights into the neurobiology of memory systems. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology* (Vol. 10, pp. 135–163). Amsterdam: Elsevier.

Keane, M. M., Gabrieli, J. D. E., Mapstone, M., Johnson, K. A., & Corkin, S. (1995). Double dissociation of memory capacities after bilateral occipital-lobe or medial temporal-lobe lesions. *Brain,* **118,** 1129–1148.

Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English.* Providence RI: Brown Univ. Press.

Kutas, M. (1988). Review of event-related potential studies of memory. In M. S. Gazzaniga (Ed.), *Perspectives in memory research* (pp. 181–218). Cambridge MA: MIT Press.

Marsolek, C. J., Kosslyn, S. M., & Squire, L. R. (1992). Form-specific visual priming in the right cerebral hemisphere. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **18,** 492–508.

Mayes, A. R., & Downes, J. J. (Eds.). (1997). *Theories of organic amnesia.* East Sussex: Psychology Press.

McAndrews, M. P., & Moscovitch, M. (1990). Transfer effects in implicit tests of memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **16,** 772–788.

Nobre, A. C., Allison, T., & McCarthy, G. (1994). Word recognition in the human inferior temporal lobe. *Nature,* **372,** 260–263.

Paller, K. A. (1993). Elektrophysiologische Studien zum Menschlichen Gedächtnis [Electrophysiological studies of human memory]. *Zeitschrift für Elektroenzephalographie, Elektromyographie und verwandte Gebiete,* **24,** 24–33.

Paller, K. A. (1997). Consolidating dispersed neocortical memories: The missing link in amnesia. *Memory,* **5,** 73–88.

Paller, K. A., & Gross, M. Brain potentials associated with perceptual priming versus explicit remembering during the repetition of visual word-form. *Neuropsychologia,* in press.

Paller, K. A., & Kutas, M. (1992). Brain potentials during memory retrieval provide neurophysiological support for the distinction between conscious recollection and priming. *Journal of Cognitive Neuroscience,* **4,** 376–391.

Paller, K. A., Kutas, M., & McIsaac, H. K. (1995). Monitoring conscious recollection via the electrical activity of the brain. *Psychological Science,* **6,** 107–111.

Paller, K. A., Mayes, A. R., McDermott, M., Pickering, A. D., & Meudell, P. R. (1991). Indirect measures of memory in a duration-judgement task are normal in amnesic patients. *Neuropsychologia,* **29,** 1007–1018.

Patterson, K., & Kay, J. (1982). Letter-by-letter reading: Psychological descriptions of a neurological syndrome. *Quarterly Journal of Experimental Psychology,* **34A,** 411–441.

Petersen, S. E., Fox, P. T., Posner, M. I., Mintun, M., & Raichle, M. E. (1989). Positron emission tomographic studies of the processing of single words. *Journal of Cognitive Neuroscience,* **1,** 153–170.

Richardson-Klavehn, A., & Bjork, R. A. (1988). Measures of memory. *Annual Review of Psychology,* **39,** 475–543.

Roediger, H. L., Weldon, M. S., & Challis, B. H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 3–41). Hillsdale, NJ: Erlbaum.

Rugg, M. D. (1995). Event-related potential studies of human memory. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 789–801). Cambridge, MA: MIT Press.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **13,** 501–518.

Schacter, D. L., Chiu, C. Y. P., & Ochsner, K. N. (1993). Implicit memory: A selective review. *Annual Review of Neuroscience,* **16,** 159–182.

Schacter, D. L., & Tulving, E. (Eds.). (1994). *Memory systems 1994.* Cambridge, UK: MIT Press.

Schendan, H., Ganis, G., & Kutas, M. Neurophysiological evidence for visual perceptual organization of words and faces by 150 ms. *Psychophysiology,* in press.

Shimamura, A. P. (1986). Priming effects in amnesia: Evidence for a dissociable memory function. *Quarterly Journal of Experimental Psychology,* **38A,** 619–644.

Slamecka, N. J., & Graf, P. (1978). The generation effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Human Learning and Memory,* **4,** 592–604.

Squire, L. R., Ojemann, J. G., Miezin, F. M., Petersen, S. E., Videen, T. O., & Raichle, M. E. (1992). Activation of the hippocampus in normal humans: A functional anatomical study of memory. *Proceedings of the National Academy of Sciences, USA,* **89,** 1837–1841.

Swick, D., & Knight, R. T. (1995). Contributions of right inferior temporal-occipital cortex to visual word and non-word priming. *Neuroreport,* **7,** 11–16.

Torres, I. J., & Raz, N. (1994). Toward the neural basis of verbal priming: A cognitive-neuropsychological synthesis. *Neuropsychology Review,* **4,** 1–30.

Tulving, E., & Schacter, D. L. (1990). Priming and human memory systems. *Science*, **247,** 301–306.

Warrington, E. K., & Langdon, D. (1994). Spelling dyslexia: A deficit of the visual word-form. *Journal of Neurology, Neurosurgery, and Psychiatry*, **57,** 211–216.

Warrington, E. K., & Shallice, T. (1980). Word-form dyslexia. *Brain*, **103,** 99–112.

Received April 22, 1997