Memory Retrieval: An Electrophysiological Perspective

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ABSTRACT Event-related potential (ERP) studies of indirect and direct memory tasks have identified retrieval-related neural activity that onsets at approximately 200 to 250 ms post-stimulus. This activity is sensitive to variables that selectively influence item-specific implicit (unaware) memory and differs in its scalp distribution from neural activity engaged during the retrieval of explicit (aware) memories. These findings support the view that implicit memory and explicit memory engage distinct retrieval processes and give insights into their relative timing. Other studies, contrasting ERPs elicited by items that were explicitly recognized on the basis of "recollection" or "familiarity," have failed to find evidence in favor of the idea that these two kinds of memory are supported by qualitatively different processes. The findings from these studies indicate, however, that multiple processes support recollection. Whereas some of these processes support the retrieval of information from episodic memory, other, "postretrieval" processes are required to make the products of retrieval available to current behavioral goals.

In this chapter, studies employing event-related brain potentials to investigate the neural correlates of human memory are reviewed. Because event-related potential (ERP) studies of memory published before 1995 are already the subject of comprehensive reviews (Johnson, 1995; Rugg, 1995a, b), these studies are not discussed in any detail in this chapter. We focus on the area—item-specific long-term memory retrieval—in which progress since 1994 has been both substantial and cumulative, leaving aside topics such as encoding, working memory, and semantic memory, where, at the time of writing, there is little to be added to the content of the reviews just cited.

Event-related potentials and memory

Event-related potentials represent scalp-recorded changes in brain electrical activity (electroencephalogram [EEG]) time-locked to some definable event. The magnitude of these changes is small compared with the amplitude of the "background" EEG. ERP waveforms with satisfactory signal-to-noise ratios are obtained by averaging the EEG samples obtained on a number of trials (typically, 20–50) belonging to the same experimental condition. ERP waveforms thus represent estimates of time-locked neural activity elicited by stimuli belonging to different experimental conditions (see Kutas and Dale, 1998, and Rugg and Coles, 1995a, for introductions to the ERP technique).

ERPs are useful for studying memory for a number of reasons. First, neural activity associated with stimulus processing can be measured with a temporal resolution in the millisecond range. Thus, upper-bound estimates of the time required by the nervous system to discriminate between different classes of item (e.g., old and new words in a recognition memory test) can be made directly. This level of temporal resolution is presently unattainable with functional neuroimaging techniques such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). A second benefit of the ERP technique, central to the research reviewed subsequently, is that ERP waveforms can be formed "off-line," after the experimental trials have been sorted into different conditions according to the subject's behavior. Thus, it is easy to compare records of brain activity associated with different classes of response to the same experimental items (e.g., hits vs. misses, or false alarms vs. correct rejections).

Finally, ERPs can be used to investigate whether different experimental conditions engage functionally dissociable cognitive processes. This application of ERPs rests on the assumption that if two experimental conditions are associated with qualitatively different patterns of scalp electrical activity, this usually signifies the engagement of at least partially nonoverlapping neural and, thus, functional processes (Rugg and Coles, 1995b). In the following research, the analysis of the spatial distribution (the "scalp topography") of ERP effects occupies a central place; when two topographies differ, we take this to mean that the cognitive processes engaged in the respective experimental conditions are not identical.

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Event-related potentials and memory retrieval

Studies employing ERPs to investigate memory retrieval have shared a common logic. Event-related potential waveforms are obtained during memory tests for two or more classes of test item. Items may be defined a priori (e.g., previously studied vs. unstudied) or classified according to behavior (e.g., recognition hit vs. false alarm). Differences between the ERPs elicited by different classes of test items are taken to represent the neural correlates of the memory processes engaged to a greater extent by one class of item than another.

Theoretical background

There have been numerous proposals about how memory for specific events is fractionated. Perhaps the most widely accepted fractionation is between explicit (aware) and implicit (unaware) memory. This distinction is supported by findings (see Moscovitch, Vriezen, and Gottstein, 1993, for review) demonstrating that implicit memory, as assessed by performance on “indirect” memory tests (when memory for study items is incidental to task performance and expressed through “priming” effects such as facilitation of reaction time or identification accuracy), can be normal or near normal in amnesic patients exhibiting severe impairments on the “direct” memory tests of recognition and recall. The distinction receives further support from the many studies with healthy participants in which dissociations between direct and indirect test performance have been reported (see Roediger and McDermott, 1993, for review). Findings from neuropsychological and normal studies suggest that implicit memory may further fractionate into “data-driven” and “conceptually-driven” components (Roediger and McDermott, 1993). Data-driven implicit memory reflects processing overlap at early, presemantic processing stages, as evidenced by its relative insensitivity to the degree of semantic processing accorded study items and its sensitivity to the perceptual similarity of study and test items. Conceptually-driven implicit memory is a consequence of processing overlap at the semantic level and shows the reverse pattern of sensitivity to semantic and perceptual variables.

A second and more controversial memory fractionation is between two different forms of explicit memory—familiarity and recollection (episodic retrieval). According to the proponents of “dual process” models (Jacoby and Dallas, 1981; Jacoby and Kelley, 1992; Mandler, 1980; Richardson-Klavehn, Gardiner, and JAVA, 1996), these two forms of memory represent qualitatively different ways in which a retrieval cue can access information about a past episode. In the case of recollection, the information includes contextual details of the learning episode and is accompanied by the phenomenological experience of having brought back to mind (“remembering”) a specific past event. When memory is based on familiarity, information about the context in which the test item was encoded, and the phenomenological experience of remembering (in the sense defined previously) are both absent.

Event-related potentials and implicit memory

As has been noted previously (Rugg 1995a, b), the identification of an electrophysiological correlate of implicit memory requires more than the mere demonstration that ERPs vary in an indirect memory test according to the study status of the items (e.g., old vs. new). It also is necessary to show that the ERP effect does not reflect “incidental” or “involuntary” explicit memory (Bowers and Schacter, 1990). Because of the difficulty of satisfying this requirement, one of us (Rugg, 1995a, b) argued that despite the large number of studies demonstrating the sensitivity of ERPs to item repetition in indirect memory tests, it was not possible to conclude that any aspect of these “ERP repetition effects” reflected implicit memory. One way around this impasse is to employ experimental manipulations known to have dissociative effects on implicit and explicit memory. The demonstration that an ERP memory effect is modulated by the same variables that selectively influence behavioral manifestations of implicit memory makes it unlikely that the effect is a reflection of explicit memory for the test items.

One such variable is presentation modality. As assessed on a variety of indirect tasks, implicit memory is weaker when study and test items are presented in different sensory modalities than when the modality is held constant (Roediger and McDermott, 1993). Therefore, it is noteworthy that the effects of repetition within modality (visual–visual) and across modality (auditory–visual) on ERPs elicited by visually presented words differ markedly (Rugg and Nieto-Vegas, unpublished data; figure 56.1). Although visual–visual repetition gave rise to the “standard” ERP repetition effect—a widespread, positive-going shift that onsets approximately 250 ms poststimulus—auditory–visual repetition resulted in the absence of the early part of this effect. As illustrated in figures 56.1 and 56.2 (see color plate 37) even when repetition was immediate, within- and across-modality repetition effects differed in their magnitudes and scalp topographies.

These findings point to the existence of neural activity occupying a latency region of approximately 200 to
400 ms poststimulus that is both repetition and modality sensitive. This effect seems likely to reflect the modulation of perceptual processes contributing to data-driven implicit memory for words and word-like stimuli. This proposal receives support from the finding (Doyle, Rugg, and Wells, 1997) that “formal” priming (e.g., SCAN-SCANDAL), nonword repetition (e.g., BLINT-BLINT), and word repetition all have similar effects on ERPs in the latency range occupied by the modality-sensitive effects illustrated in figure 56.1. Event-related potential findings analogous to those of Rugg and Nieto-Vegas (unpublished data) were also described by Paller and associates (Paller, Kutas, and McIsaac, 1998; Paller and Gross, 1998), who employed manipulations of item presentation format, rather than modality, to identify ERP correlates of data-driven implicit memory. In sum, these observations suggest that ERP repetition effects may reflect the functioning of the domain-specific “perceptual representation systems” proposed by Tulving and Schacter (Tulving and Schacter, 1990; Schacter, 1994) to underlie data-driven priming.

The neural correlates of implicit memory can also be investigated in direct memory tests by contrasting ERPs elicited by studied items that are misclassified as new (misses) with those elicited by correctly classified new items. On the assumption that studied items are “missed” when they fail to elicit explicit memory, differences between these two classes of ERPs represent neural correlates of implicit memory retrieval. This approach has two advantages over studies that investigate implicit memory with indirect memory tests. First, the problem of “contamination” by explicit memory is minimal; the critical items are those that were not remembered explicitly at the time the ERPs were recorded. Second, the approach allows the neural correlates of implicit and explicit memory to be contrasted in one and the same test. This is important because almost all studies that have sought to dissociate brain activity associated with implicit and explicit memory have contrasted findings from direct and indirect tests. Because memory retrieval is intentional on direct tests but unintentional on indirect tests, such
Within Modality (200-400 msec)

Across Modality (400-600 msec)

**Figure 56.2** Topographic maps illustrating the scalp distribution of the repetition effects illustrated in figure 56.1. Left panel: distribution of the early (200–400 ms) within-modality effects. Right panel: distribution of the late (400–600 ms) across modality effects. The latter effects have the more posterior distribution.

**Figure 56.3** Event-related potentials (ERPs) from Rugg and associates (1998b), shown for lateral frontal (F3, F4) and parietal (P3, P4) sites. (A) Waveforms elicited by correctly rejected new items (NEW), by recognized (REC) and unrecognized (UNREC) old items. Note the similarity at the parietal sites of the early differences between the ERPs to new items and those to each class of old item. (B) Waveforms elicited by correctly rejected new items, and recognized items accorded either deep or shallow study.

Studies confound retrieval intentionality with type of memory.

Event-related potentials elicited by recognition "misses" were investigated by Rugg, Mark, and colleagues (1998). Participants studied a series of words under either "deep" (sentence generation) or "shallow" (alphanumeric judgment) conditions and subsequently were tested for their recognition memory of these words. Although more than 90% of the deeply studied words were recognized, this was true for only 50% of the shallowly studied items, permitting ERPs of equivalent signal quality to be formed for shallow "hits" and shallow "misses." At central and parietal electrode locations, the ERPs to hits and misses were both more positive-going than were those to correct rejections. At frontal sites, by contrast, only the ERPs to hits differed from those to new items (figure 56.3A). Furthermore, as shown in figure 56.3B, up to approximately 500 ms poststimulus, a very similar ERP modulation was found in the ERPs from parietal electrodes that were elicited by deeply studied test items. Thus, "shallow misses," "shallow hits," and "deep hits" were all associated with a posteriorly distributed positive-going memory effect between approximately 300 to 500 ms poststimulus.

These findings suggest that ERPs detect neural activity associated with implicit memory for recently experi-

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808 MEMORY
enced words and that this activity is neuroanatomically dissociable from that associated with explicit memory (figure 56.4; see color plate 38). Thus, when task factors are held constant, these two forms of memory nonetheless can be dissociated neurophysiologically.

In summary, the view (Rugg, 1995a, b) that there are no convincing examples of ERP correlates of implicit memory no longer seems tenable. Event-related potential repetition effects in indirect tasks are sensitive to the degree of perceptual match between study and test items, mimicking the sensitivity of data-driven implicit memory to this variable. Furthermore, there is evidence that ERPs detect neural activity that is sensitive to the repetition of items for which recognition failed. An important remaining question is whether these different putative neural correlates of implicit memory reflect the activity of a common neural population.

**Recollective versus familiarity**

As already noted, the proposal that two functionally distinct forms of memory—recollection and familiarity—support recognition memory is controversial. Although support for this view has been claimed on the basis of behavioral findings from studies of both healthy (Jacoby, 1991; Jacoby and Dallas, 1981; Yonelinas, 1994) and amnesic (Verfaillie and Treadwell, 1993) participants, the claims have been challenged on the grounds that the findings can be accommodated within models of recognition memory that posit only a single process (Knowlton and Squire, 1995; Mulligan and Hirshman, 1997).

The question of whether recognition memory is supported by one or two processes has been addressed in a number of ERP studies, employing a variety of operational definitions of familiarity and recollection. In all
basis for recognition. This conclusion is tempered by the possibility that these negative findings reflect the insensitivity of ERPs to the neural activity supporting familiarity, rather than the inadequacy of dual-process models.

The foregoing conclusion also should be qualified in light of the findings from two studies in which a dissociation between the neural correlates of recollection and familiarity may have been obtained. Düzel and colleagues (1997) employed the "Remember/Know" procedure (Tulving, 1985) to distinguish between trials on which recognition was associated with the presence or absence of a "recollective experience." Düzel and associates (1997) reported that ERPs elicited by recognized words endorsed as remembered or known differed in their scalp distributions from approximately 300 to 1000 ms poststimulus. These findings suggest that recollection and familiarity indeed may be electrophysiologically dissociable. For two reasons, however, this conclusion should be considered tentative. First, the number of trials forming the ERPs to old words assigned a "know" judgment was very low in some participants, raising concerns about signal quality. Second, the claim of differing scalp topographies for the ERPs associated with remember and know judgments was made in the absence of appropriate statistical analysis (McCarthy and Wood, 1985).

The second study to suggest that familiarity and recollection can be dissociated electrophysiologically is that of Rugg, Mark, and coworkers (1998) described in the previous section. As shown in figure 56.3, between approximately 300 and 500 ms poststimulus, ERPs from frontal electrodes were more positive-going for recognized old words than they were for correctly rejected and missed items. Unlike the prominent memory effects arising after approximately 500 ms, this frontal effect was insensitive to depth of study processing. These findings therefore provide evidence for two qualitatively distinct patterns of neural activity associated with successful recognition, only one of which is sensitive to depth of study processing. If depth of processing exerts its effects exclusively through recollection (Gardiner, Java, and Richardson-Klavehn, 1996), the ERP findings suggest that familiarity and recollection have distinct neural correlates. Unfortunately, it is unlikely that depth of processing does dissociate recollection and familiarity (Toth, 1996; Yonelinas et al., 1998), leaving the interpretation of these ERP findings uncertain.

In summary, recent ERP findings provide, at best, only weak support for dual-process models of recognition memory. It appears, however, that although ERP memory effects may not dissociate two bases for recognition memory, the effects are sensitive to more than just whether a test item is old or new and index instead the amount of information that can be retrieved about the context in which an old item was experienced. Thus, ERP memory effects appear to reflect cognitive operations associated with the recollection of recently experienced episodes (episodic memory). In the next section, we assess this proposal in more detail, and address the question of whether the cognitive operations supporting recollection can be dissociated neurally and functionally.

**Event-related potentials and recollection**

As is evident from figures 56.5 and 56.7 (see color plate 39), the ERP memory effects associated with successful recollection are manifest as at least two positive-going
studies, test items were segregated according to whether they were recollected or recognized on the basis of familiarity alone. If ERP memory effects (i.e., the differences between ERPs to recognized and to new items) elicited by the two classes of item are topographically distinct, this would lend support to the view that recollection and familiarity are supported by functionally distinct cognitive operations. By contrast, single-process models would receive support from the finding that differences between the memory effects are quantitative only.

One way to operationalize the distinction between recollection and familiarity is with a test of source memory. In such tests, participants study a series of items in one context or another. At test, they discriminate studied from unstudied items (yes/no recognition), and in addition, they categorize recognized items according to their study context. According to proponents of the dual-process framework (Jacoby, 1991), trials on which source memory is successful involve recollection of the study episode, whereas trials on which recognition is accurate but memory for source is not are likely to be based solely on familiarity. Thus, the relative proportions of trials associated with each form of memory should vary according to whether source memory is successful or unsuccessful. If recollection and familiarity have distinct neural correlates, the scalp distributions of ERPs elicited by recognized items should vary according to the accuracy of the source judgment.

Wilding and colleagues reported two studies in which ERPs associated with accurate and inaccurate source memory were contrasted. In their first study (Wilding, Doyle, and Rugg, 1995), the source attribute was sensory modality; in the second study (Wilding and Rugg, 1996), it was speaker voice. In both cases, memory effects were larger for recognized items that were assigned correctly to their study context, but in neither case was there evidence that the effects differed qualitatively (figure 56.5).

Similar findings were reported by Donaldson and Rugg (1998), who investigated the ERP correlates of associative recognition. Participants performed recognition judgments on word pairs that were new, representations of pairs studied in a preceding study task, or re-pairings of study items. Donaldson and Rugg assumed that words that maintained their pairing between study and test (same pairs) would be more likely to elicit recollection than rearranged pairs, a high proportion of which would be recognized exclusively on the basis of familiarity (Yonelinas, 1997). As illustrated in figure 56.6, ERP memory effects were markedly larger when elicited by same versus rearranged pairs. However, there was no evidence that the effects elicited by the rearranged pairs differed qualitatively from those elicited by the same pairs.

The findings reviewed previously (see also Wilding and Rugg, 1997) offer little support for dual process models of recognition memory. Rather, the findings support the view (Johnson, Hashtroudi, and Lindsay, 1993; Mulligan and Hirshman, 1997) that recognition based on "familiarity" depends on the same processes as those that support recollection and is better conceived of as impoverished recollection rather than an independent
modulations of the waveform, dissociable on both temporal and neuroanatomical criteria (see also Allan, Wilding, and Rugg, 1998). One of these modulations (the “left parietal effect”) onsets at approximately 400 to 500 ms, is maximal over the left parietal scalp, and typically has a duration of approximately 500 ms. The other modulation (the “right frontal effect”) onsets at about the same time or a little later, is maximal over the right frontal scalp, and is considerably more sustained over time.

The proposal that the left parietal effect is an electrophysiological correlate of recollection fits well with the findings of previous research investigating the ERP correlates of recognition memory (Rugg, 1995a,b; Allan, Wilding, and Rugg, 1998). The proposal receives additional support from studies (Ditzel et al., 1997; Johnson et al., 1997) in which the ERP correlates of “false recollection” (Roediger and McDermott, 1995) were investigated. This term refers to the tendency of participants to make a “false alarm” response to unstudied associates of study items and to endorse such responses as “remembered.” This tendency is believed to depend on the same processes that support “true” recollection (Schacter et al., 1996). Ditzel and associates (1997) and Johnson and colleagues (1997) found that in contrast to the ERPs elicited by false alarms to items that are not associates of study words, the ERPs to falsely recollected items elicited prominent left parietal effects, comparable in magnitude to the effects elicited by items correctly endorsed as old.

The right frontal effect appears to be most prominent in tasks that require more than simple old/new recognition judgments and first came to light in the study of source memory by Wilding and Rugg (1996; see figure 56.5). The effect was also found in the associative recognition task of Donaldson and Rugg (1998; see figure 56.6), in the Remember/Know task (Rugg, Scleroch, and Mark, 1998; Ditzel et al., 1997) and, in a much attenuated form, in a study of old/new recognition (Allan and Rugg, 1997a).

The differing spatiotemporal characteristics of the left parietal and right frontal effects suggest that they reflect distinct cognitive operations. Wilding and Rugg (1996) proposed that these operations involve the retrieval of item and contextual information from memory—operations supported by the “medial temporal lobe memory system” (Squire, 1992)—and processing the products of retrieval to generate an episodic representation capable of supporting accurate source discrimination—operations held to be dependent on the prefrontal cortex (Squire, Knowlton, and Musen, 1993). Wilding and Rugg (1996) linked the left parietal effect to the first of these operations and the right frontal effect with the second, “postretrieval,” operation.

By linking the left parietal effect to retrieval operations supported by the medial temporal lobe, Wilding and Rugg (1996) did not mean to imply that the effect directly reflected neural activity in these regions. Indeed, current evidence suggests that hippocampal activity makes, at best, a very modest contribution to scalp-recorded potentials (Rugg, 1995c). A more likely possibility is that the left parietal effect reflects changes in cortical activity resulting from the corticohippocampal interactions that have been proposed to underlie episodic memory retrieval (McClelland, McNaughton, and O’Reilly, 1995). This hypothesis about the neural origins of the left parietal effect is consistent with the findings of a PET study of depth of processing effects on recognition memory (Rugg et al., 1997; Rugg, Walla, et al., 1998). Relative to the recognition of shallowly studied items, recognition of deeply studied items was associated with activation not only in the left hippocampal formation, but also in an extensive region of the cortex of the left hemisphere, including frontal, temporal, and parietal areas.

The proposal that the right frontal effect reflects cognitive operations associated with “post-retrieval” processing receives support from both functional and neuroanatomical evidence. The idea that the products of memory retrieval are subjected to such operations as “monitoring” or “evaluation,” and that the need for such operations varies with task demands, is central to some models of memory retrieval (Koriat and Goldsmith, 1996). The nature of the memory impairments that follow lesions of the prefrontal cortex suggests that these impairments reflect, in part, the disruption of post-retrieval processing (Shallice, 1988).

The scalp distribution (figure 56.7) of the right frontal effect suggests that its generator is located within right prefrontal cortex. This hypothesis receives support from the findings of studies of memory retrieval using PET and fMRI, which have demonstrated consistently that episodic memory retrieval is associated with activation of right dorsolateral and anterior prefrontal cortex (Fletcher, Frith, and Rugg, 1997). The hypothesis receives further support from functional neuroimaging studies showing that the activity of this region is greater when recognition memory test items eliciting successful retrieval than when they do not (Buckner et al., 1998a; Rugg et al., 1996; Rugg, Fletcher, et al., 1998; but see also Buckner et al., 1998b; Kapur et al., 1995; Nyberg et al., 1995).

Thus far, the experiments described in this section have all investigated the ERP correlates of recollection by employing “copy” cues to elicit the retrieval of episodic memories. It is, of course, also possible to elicit memory retrieval with cues that provide only an incomplete specification of study items. One such task is word stem cued recall, in the simplest version of which partic
Participants are required to retrieve study words in response to three letter (stem) cues (e.g., MOTEL > MOT). The ERP correlates of recollection engendered by such cues differ from those found with copy cues (Allan, Doyle, and Rugg, 1996; Allan and Rugg, 1997a, b). These studies all employed the same basic test procedure: A series of stems were presented, only a proportion of which corresponded to study items. Participants attempted to retrieve a study word in response to each stem and, following a response cue, provided a study word if they could or gave the first word to come to mind. Crucially, participants also judged whether each completion belonged to the study list, making it possible to separate recalled study items according to whether recall was implicit (associated with the judgment that the item had not appeared at study) or accompanied by explicit memory for the study presentation (associated with a positive judgment; see Jacoby, Toth, and Yonelinas, 1993, and Jacoby, 1998, for discussion of the explicit/implicit distinction in cued recall).

The basic finding from these studies is illustrated in figure 56.8, which contrasts waveforms elicited by stems completed with explicitly retrieved study words and unstudied items. The ERPs to the stems corresponding to the studied items show a positive-going ERP modulation that onsets at approximately 300 ms and continues until the end of the recording epoch. Figure 56.9 (see color plate 40) shows that the scalp distribution of these memory effects evolves from an initial anterior midline focus to include a left temporoparietal maximum, before shifting back to a (right) anterior focus. These effects seem likely to be a relatively pure reflection of episodic memory because they are absent in ERPs elicited by stems completed with falsely recognized unstudied items and in ERPs elicited by correct completions wrongly judged to be unstudied (Allan, Doyle, and Rugg, 1996). This proposal is strengthened by the findings of Allan and Rugg (1997b). Employing a source procedure, they reported that the scalp distribution of the memory effects for correctly completed stems assigned to their correct encoding context was indistinguishable from the distribution of the effects elicited by stems attracting an incorrect source judgment. This finding suggests that, as far as can be detected from the scalp, the same memory processes supported retrieval of the study item and its encoding context.

The findings from the cued recall studies described previously are important for two reasons. First, they

**FIGURE 56.8** Event-related potentials (ERPs) from lateral frontal and parietal electrodes elicited by word stems in the study of Allan and Rugg (1997b). ERPs are shown for stems correctly completed with items judged to have been shown at study, collapsed across a subsequent source (study list) judgment [recalled], and for stems completed with unstudied items correctly endorsed as “new” (new completion).

**FIGURE 56.9** Topographic maps illustrating the scalp distribution of the memory effects shown in figure 56.8. Each map depicts the differences between ERPs evoked by stems correctly completed with studied items, collapsed across the subsequent source judgment, and ERPs evoked by stems completed with unstudied items correctly endorsed as “new.” Maps are shown for three latency regions, 400-700 ms, 800-1100 ms, and 1200-1500 ms.
indicate that recollection is associated with more than one pattern of ERP memory effects. Although the effects from cued recall appear to include contributions from the generators of the left parietal and right frontal effects discussed previously, the cued recall effects are distributed more diffusely over the scalp than are the effects elicited by copy cues (Allan and Rugg, 1997a). Second, the findings show that the left parietal effect is not necessarily the earliest electrophysiological sign of successful memory retrieval. In cued recall, the earliest such sign takes the form of a bilaterally distributed effect over the frontal scalp (figure 56.9). Similar findings have been reported in other studies (figure 56.4; Rugg, Mark, et al., 1998; Tendolkar, Doyle, and Rugg, 1997; Schloerscheidt and Rugg, 1997).

Together, the findings reviewed in this section indicate that recollection—the bringing to mind of aspects of a prior episode—is associated with a pattern of neural activity that varies in its scalp distribution over the first two seconds or so following the presentation of a retrieval cue. Although part of this activity (e.g., that reflected by the left parietal effect) appears to be engaged in an obligatory fashion when a test item engenders recollection, other activity appears to be more task dependent.

By identifying the structures responsible for generating recollection-related ERP effects and specifying their functional significance, it will be possible to shed further light on the mechanisms by which retrieval cues engender recollection and the means by which representations of prior experiences can be used to guide behavior.

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