Research Report

# THE SIMILARITY OF BRAIN ACTIVITY ASSOCIATED WITH TRUE AND FALSE RECOGNITION MEMORY DEPENDS ON TEST FORMAT

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**Abstract**—*Event-related potentials (ERPs) were compared for correct recognitions of previously presented words and false recognitions of associatively related, nonpresented words (lures). When the test items were presented blocked by test type (old, new, lure), waveforms for old and lure items were different, especially at frontal and left parietal electrode sites, consistent with previous positron emission tomography (PET) data (Schacter, Reiman, et al., 1996). When the test format randomly intermixed the types of items, waveforms for old and lure items were more similar. We suggest that test format affects the type of processing subjects engage in, consistent with expectations from the source-monitoring framework (Johnson, Hashtroudi, & Lindsay, 1993). These results also indicate that brain activity as assessed by neuroimaging designs requiring blocked presentation of trials (e.g., PET) do not necessarily reflect the brain activity that occurs in cognitive-behavioral paradigms, in which types of test trials are typically intermixed.*

One of the great promises of cognitive neuroscience is to couple the behavioral research methods developed by cognitive psychologists for the study of mental processes with innovative technologies that permit observation of the brain at work in order to further test and refine theoretical ideas about underlying cognitive processes. A case in point is the issue of the nature of true and false memories (Belli & Loftus, 1994; Johnson, Hashtroudi, & Lindsay, 1993; Lindsay & Read, 1994; Roediger, 1996; Schacter, 1995; Zaragoza & Lane, 1994). The present research illustrates how evidence from cognitive-behavioral and brain-imaging techniques can mutually contribute to current understanding in this domain.

Memory errors can reliably be induced experimentally using the *Deese paradigm*—a simple list-learning procedure in which participants are presented with sets of associates to nonpresented lure words (e.g., *thread, pin, eye, sewing, sharp, point, prick, thimble, haystack,* and *thorn* are all associates of *needle*). On a subsequent memory test, subjects are very likely to recall lures (Deese, 1959) or to falsely recognize lures among other new words (Roediger & McDermott, 1995). According to the source-monitoring framework (SMF, Johnson, 1988, 1997; Johnson et al., 1993), individuals make memory decisions based on a range of phenomenal attributes (e.g., perceptual detail or related memories called to mind), and the attributes used in the decision vary with factors such as task difficulty and accuracy requirements. In the Deese paradigm, *needle* is likely to have been activated at acquisition when study items were presented, or features of *needle* that overlap with features of list items (e.g., *sharp*) are likely to be activated at test. In either case, subjects may mistakenly attribute phenomenal experience from one source (prior thought or present feature familiarity) to another source (prior perceptual experience).

Although similarity between information from various sources (e.g., actual experience and imagined experience) produces false memories, nevertheless, false memories should differ, on average, from true memories because they have a somewhat different distribution of features (e.g., Johnson, 1985, Johnson & Raye, 1981). For example, what was associatively activated or imagined should have, on average, less auditory detail than what was actually heard. Evidence supporting this view has come from cognitive studies, including studies using the Deese paradigm. If subjects are asked to rate their memories on a number of qualitative characteristics, memories for falsely recognized lures tend to have less auditory detail and less remembered feelings and reactions that do memories for presented words (Mather, Henkel, & Johnson, in press; Norman & Schacter, in press).

Converging evidence has been obtained from a recent positron emission tomography (PET) study (Schacter, Reiman, et al., 1996). In general, brain activity during true and false recognition was quite similar. Nonetheless, Schacter, Reiman, et al. found that, compared with lures, old items produced greater blood flow in the left temporo-parietal region, an area that has been linked in other studies to phonological processing. This finding is consistent with the phenomenal ratings indicating greater auditory detail for old items (Mather et al., in press; Norman & Schacter, in press). Schacter, Reiman, et al. also found that lures tended to show somewhat more activation than old items in anterior prefrontal and orbitofrontal cortex. One interpretation is that this frontal activity reflects the greater evaluative effort required by the semantically familiar, but less perceptually detailed, lure items. This idea is consistent with evidence from brain-damaged patients suggesting that frontal regions are particularly important for monitoring the origins of memories (e.g., Baddeley & Wilson, 1986; Johnson, 1991; Milner, Petrides, & Smith, 1985; Moscovitch, 1995; Schacter, Curran, Galluccio Milberg, & Bates, 1996; Schacter, Harbluk, & McLachlan, 1984; Stuss, Alexander, Lieberman, & Levine, 1978). It is also consistent with findings from event-related potential (ERP) studies indicating that there are greater differences at frontal electrodes than at more posterior sites when subjects are required to identify the sources of memories compared with when they only make old-new recognition judgments (Johnson, Kounios, & Nolde, 1996; Wilding & Rugg, 1996).

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In their initial investigation of the brain activity associated with true and false recognition memory, Schacter, Reiman, et al (1996) used a typical PET design in which test trials are presented in blocks of similar items (e g , a scan in which subjects are presented with all old items, followed by a scan in which subjects are presented with all lure items) In contrast, cognitive-behavioral designs typically randomly intermix items from various conditions at test From the SMF, we would expect that this procedural difference at test might result in subjects considering different characteristics of memories to distinguish between items Indeed, Mather et al (in press) provided evidence of lower false recognition rates in the Deese paradigm when subjects were induced at test to examine their memories on several dimensions compared with when they were simply asked to distinguish whether they "remembered" or "knew" items (e g , Gardiner & Java, 1993, for the effects of test criteria on memory, see also Dodson & Johnson, 1993, Lindsay & Johnson, 1989, Multhaup, 1995) Blocking test items may also affect the phenomenal attributes and criteria subjects use In standard cognitive designs with randomly intermixed old and lure items, subjects may rely most heavily on familiarity or semantic features to discriminate between items However, in a block of similar items, familiarity or the likelihood of a semantic match will not vary much between successive items Thus, subjects should be more likely to consider more specific differentiating information (e g , perceptual details of the presentation) in an attempt to make distinctions among items within a block that are not easily discriminable

To explore this hypothesis, we used the Deese paradigm in combination with an electrophysiological technique in which ERPs were recorded from scalp electrodes while subjects made recognition judgments to old items, lures semantically related to old items, and new items Because ERPs can be recorded for each individual stimulus presentation, we could compare brain activity under two conditions blocked and random In the blocked test condition, the test items were presented blocked according to type—old, new, and lure, as in the Schacter, Reiman, et al (1996) PET study In the random test condition, the test items of various types were intermixed This variation in test format should have resulted in differences in the types of processing engaged in by subjects Assuming that lures were similar to old items in semantic familiarity, but less similar in terms of perceptual-contextual detail (Mather et al , in press, Norman & Schacter, in press), we expected the ERP waves for old and lure items recorded in the random condition (in which subjects should have been more likely to respond on the basis of familiarity) to be more similar than ERP waves for old and lure items recorded in the blocked condition (in which subjects should have been more likely to evaluate memories critically for perceptual-contextual detail)

This study also provides important evidence regarding the common practice of blocking test items by condition in PET studies Because PET has poor temporal resolution, activity across several successive trials of Condition A (one run) is subtracted from activity across several successive trials of Condition B (another run) for each brain region of interest In contrast, much of what is already known about cognition comes from behavioral designs in which test trials from various conditions are randomly intermixed If brain activity reflects only the interaction of what was stored with the physical test probe, then whether the test items are random or blocked should not matter in using PET to investigate memory If, however, as we hypothesize, brain activity is affected by the entire test context, including the subjective criteria individuals adopt in making attributions about memories, then blocked designs would not necessarily yield the same picture of brain activity as would random designs Such an outcome would suggest the need for caution in extrapolating from brain-imaging studies without taking into account potential cognitive processing consequences of the design restrictions of the particular neuroimaging technique used

## METHOD

### Subjects

Eighteen right-handed individuals (6 female, 12 male) recruited from the Princeton University community participated for payment and were randomly assigned to blocked and random conditions, except that each condition had equal numbers of male and female participants All had normal or corrected-to-normal visual acuity and were native speakers of English

### Stimuli

Thirty-six 10-word sets were used (drawn from items used by Schacter, Reiman, et al , 1996) All 10 words in each set were highly associated to a critical lure that was not presented during the study session Each participant heard a taped female speaker read the words from 24 of the sets during the study session (the words from the remaining 12 sets were used as new items, which words were not heard was counterbalanced across subjects) The words were grouped by sets and presented at a rate of 2 s per word After each set of 10 items, there was a tone followed by a 5-s pause, and then the next list began

The recognition test consisted of 72 old words, with 3 words from each set (in each case, the items that had been presented during acquisition in Positions 1, 6, and 10 in the list) In addition, there were 24 critical lures and 48 new words (12 were lures for the sets that had not been heard, and the others were taken from Positions 1, 6, and 10 in the sets not presented) In the blocked condition, the test words were grouped by type (i e , old, new, lure) in segments of 12 words Thus, subjects were presented with 12 old words, 12 lures, 12 new words, and so on There was a break between segments In the random condition, each segment of 12 words had old, new, and lure items The average position in the test list of old, new, and lure items was equivalent for the blocked and random conditions

### Procedure

Each participant was seated before a 17-in SVGA monitor on which the test stimuli were presented The monitor was positioned slightly below eye level Subjects responded by pressing one mouse button for new items (middle finger) and one for old items (index finger) The hand used to respond was counterbalanced across conditions

Subjects were told that they would be listening to a tape recording of lists of words and that later they would be asked to

recognize the words they heard During this study phase, electroencephalograms (EEGs) were not recorded For the test, recordings were made from 32 scalp electrodes mounted in an elastic cap (Electro-Cap International, Inc , Eaton, Ohio) These included one electrode placed below the left eye to monitor vertical eye movements and another placed just to the right of the right eye to monitor horizontal eye movements All electrodes were referenced to the left mastoid The sites were based on an extension of the International 10-20 system (Jasper, 1958)

The EEG was amplified 20,000 times by an SA Instrumentation (San Diego, California) bioamplifier system (3-dB cutoffs of 0 01 and 100 Hz) and digitized on-line at 250 Hz The individual subjects' ERPs were digitally filtered with a low-pass cutoff of 20 Hz (12 dB) Average ERPs were computed using a prestimulus baseline of 100 ms and an epoch length of 1,948 ms Average ERPs were computed off-line based on trials that were free of ocular or movement artifacts Analyses of variance were conducted on raw amplitudes averaged for the relevant intervals, interactions involving electrode site were confirmed with analyses of normalized amplitudes (McCarthy & Wood, 1985), and, when appropriate, the Greenhouse-Geisser correction was applied (Keselman & Rogan, 1980)

Data are reported here for 12 sites of interest based on prior findings and our initial hypotheses The first analysis included electrode sites to the left and right of the midline left (FP1) and right (FP2) prefrontal, left (F3) and right (F4) frontal, left (C3) and right (C4) central, left (P3) and right (P4) parietal, and left (O1) and right (O2) occipital The second analysis looked at more lateral left (P7) and right (P8) parietal electrode sites because these are nearer to the temporo-parietal region that showed differences between old items and lures in the PET study

The stimulus sequence for the test phase began with a plus sign as a fixation point Then a word was displayed in the center of the screen for 200 ms (succeeded by the fixation point) Subjects responded to the word during an interstimulus interval of 3,800 ms Next the message "OK to blink" was displayed on the screen for 3,000 ms This was followed by a blank screen (with fixation point) for 1,000 ms, and then the next word Each word was displayed in black against a white screen background

After a brief unrelated practice task to familiarize subjects with the general test procedure, they were told they would see words on the screen, and that if they had heard a word on the tape, they should press the index-finger button of the mouse, but if they had not heard it, they should press the middle button After each group of 12 words, the experimenter announced a short break (approximately 30 s) over an intercom

## RESULTS

The behavioral data are shown in Table 1 Both blocked and random groups showed more "old" responses to old items than to new items ($t[8] = 6\ 22$ and $4\ 79$, respectively, $p < 001$), and at least as many "old" responses to lure items as to old items ($ps > 11$), replicating earlier findings The blocked and random groups did not differ in the number of "old" responses to old items or "new" responses to new items ($ps > 53$) Neither corrected recognition (hits minus false positives to new items) nor false recognition of lures differed significantly between the blocked and random groups ($ps > 43$) Thus, the two groups were fairly well equated behaviorally, and differences in ERP waveforms are unlikely to be the result of differences in the number of observations contributing to waveforms in the two conditions[1] An analysis of the response times (RTs) for "old" responses to the three item types (old, lure, and new items) for the two conditions (blocked and random) yielded no significant effect for condition or Condition × Item Type interaction, $Fs < 1\ 00$ There was a significant effect for item type, $F(2, 32) = 9\ 51$, $MSE = 0\ 08$, $p < 001$ A Tukey post hoc test revealed that RTs for "old" responses were significantly greater for new items (1,825 ms) than for either old (1,450 ms) or Lure (1,509 ms) items, and that RTs for old and lure items were not statistically different

**Table 1** *Mean proportion of "old" responses and response times (in milliseconds) for old items, lures, and new items*

| | Condition | | | |
|---|---|---|---|---|
| | Blocked | | Random | |
| Item type | Proportion | Response time | Proportion | Response time |
| Old | 66 | 1,334 | 61 | 1,566 |
| Lure | 67 | 1,444 | 70 | 1,574 |
| New | 25 | 1,713 | 30 | 1,937 |

The ERP waveforms for selected electrode sites are shown in Figures 1a (blocked) and 1b (random), and the mean response amplitudes averaged over early (50- to 775-ms) and late (775- to 1,500-ms) poststimulus intervals are shown in Table 2 The first window was timed to start after the very earliest phases of stimulus processing, and the second window was timed to end approximately 300 ms before the overall average (collapsed across blocked and random conditions) RT to make "old" responses to old and lure items—that is, when decisions had been made but prior to response execution processes Although more detailed analysis of these ERPs is, of course, possible, these two broad time windows capture the major morphological differences in waveforms between the blocked and random groups that are of primary interest here

Separate Condition (blocked, random) × Item Type (old, lure) × Electrode Site (FP, F, C, P, O) × Hemisphere (left, right) analyses of variance were conducted on the data in Table 2 for the early and late poststimulus intervals Of primary interest was

1 The fact that extra effort at source monitoring pays off so little in this paradigm (see also Mather et al , in press) is probably a consequence of the generally impoverished memories yielded by the relatively rapid presentation of individual items In fact, when we reanalyzed the present data separately for the first and second halves of the test trials, we found no difference between random and blocked conditions in the first half of the trials but as expected, significantly lower performance in the random than the blocked condition in the second half of the trials Presumably it takes some experience with the task for the subjects in the random condition to adopt a fairly loose familiarity criterion Also, with somewhat richer materials, manipulations of subjects' source-monitoring criteria should produce corresponding changes in source accuracy (e.g., Dodson & Johnson, 1993, Lindsay & Johnson, 1989)

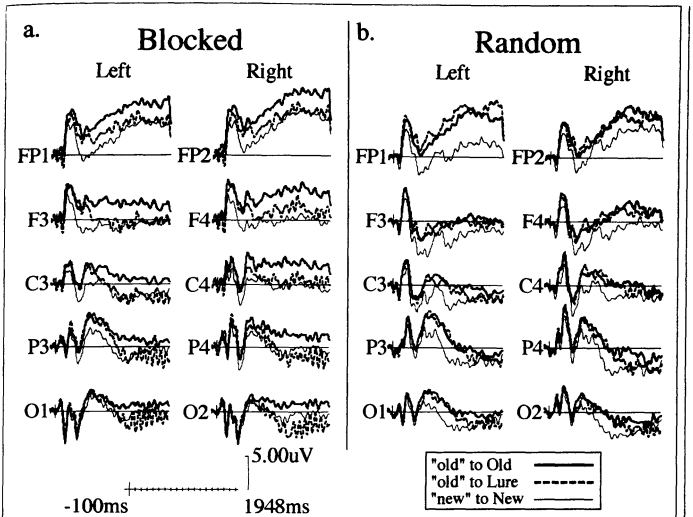


**Fig 1.** Event-related potentials recorded at selected prefrontal (FP), frontal (F), central (C), parietal (P), and occipital (O) sites for correct "old" responses to old items, incorrect "old" responses to lures (false recognitions), and correct "new" responses to new items Results for the blocked condition are shown in (a), and results for the random condition are shown in (b) The onset of the test stimulus is indicated with the largest vertical marker at the left, and subsequent 100-ms intervals are indicated with smaller vertical marks Positive voltages are plotted up, and negative voltages are plotted down

the comparison of ERP amplitudes for "old" responses to old items (correct recognitions, or hits) and lure items (false recognitions) (ERPs for "new" responses to new items are also shown in Fig 1 and Table 2 for reference, overall, ERPs differed significantly for old and new items, but these effects are not discussed here )

There were several main findings of interest In the early interval, there was a significant Condition × Item Type × Electrode Site interaction, $F(4, 64) = 3\,24$, $MSE = 1\,54$, $p < 05$ Subsequent separate analyses of the blocked and random conditions showed that in the blocked condition, there was an interaction between item type (old vs lure) and electrode site, $F(4, 32) = 4\,14$, $MSE = 1\,24$, $p < 05$ As can be seen in Table 2, the difference between old and lure items was greatest at more anterior sites (FP and F), and there was little difference at more posterior sites In marked contrast, in the random condition, there was no significant difference in the waveforms for "old" responses to old and lure items ($p > 56$) The overall brain activity accompanying "old" responses to lures was remarkably similar to the activity accompanying "old" responses to studied items (see Fig 1b) Similarly, in the late interval, in the blocked but not the random ($p > 80$) condition, the mean amplitude was significantly more positive for "old" responses to old items than for "old" responses to lure items, $F(1, 8) = 5\,77$, $MSE = 48\,22$, $p < 04$ [2]

2 In the late interval, there was also a significant Site × Hemisphere interaction $F(4, 64) = 8\,34$, $MSE = 0\,035$, $p < 001$ This replicates other ERP findings (Johnson et al , 1996, Wilding & Rugg, 1996) and is consistent with PET findings (e g , Buckner & Tulving, 1995) showing left-right asymmetries in activation (greater positivity on the right in ERP and greater blood flow on the right in PET), particularly in frontal regions of subjects engaged in episodic memory tasks

**Table 2** *Mean event-related potential amplitudes ("old" responses to old items "old" responses to lures, and "new" responses to new items)*

| Item type | Electrode site | Condition: Blocked — Left hemisphere | Blocked — Right hemisphere | Blocked — Average | Random — Left hemisphere | Random — Right hemisphere | Random — Average |
|---|---|---|---|---|---|---|---|
| | | Early (50- to 775-ms) poststimulus interval | | | | | |
| Old | FP1 and 2 | 4 28 | 5 18 | 4 73 | 2 17 | 2 12 | 2 15 |
| | F3 and 4 | 2 90 | 3 15 | 3 02 | −0 46 | −0 15 | −0 31 |
| | C3 and 4 | 1 76 | 2 19 | 1 98 | 0 43 | 1 05 | 0 74 |
| | P3 and 4 | 2 11 | 2 03 | 2 07 | 2 64 | 2 77 | 2 70 |
| | O1 and 2 | 0 29 | 0 09 | 0 19 | 1 57 | 1 71 | 1 64 |
| Lure | FP1 and 2 | 2 83 | 3 59 | 3 21 | 2 97 | 2 37 | 2 67 |
| | F3 and 4 | 1 59 | 1 73 | 1 66 | −0 44 | −0 34 | −0 39 |
| | C3 and 4 | 1 28 | 1 23 | 1 25 | 0 07 | 1 05 | 0 56 |
| | P3 and 4 | 2 49 | 1 80 | 2 15 | 2 45 | 2 68 | 2 57 |
| | O1 and 2 | 0 55 | −0 06 | 0 24 | 1 17 | 1 20 | 1 18 |
| New | FP1 and 2 | 1 17 | 2 27 | 1 72 | −0 10 | 0 36 | 0 13 |
| | F3 and 4 | −0 27 | 0 10 | −0 09 | −2 33 | −2 09 | −2 21 |
| | C3 and 4 | −0 12 | 0 16 | 0 02 | −1 37 | −0 78 | −1 07 |
| | P3 and 4 | 0 70 | 0 74 | 0 72 | 1 08 | 1 13 | 1 11 |
| | O1 and 2 | −0 34 | −0 50 | −0 42 | 0 32 | 0 49 | 0 41 |
| | | Late (775- to 1,500-ms) poststimulus interval | | | | | |
| Old | FP1 and 2 | 6 94 | 8 50 | 7 72 | 5 46 | 5 85 | 5 66 |
| | F3 and 4 | 2 64 | 4 38 | 3 51 | −0 01 | 1 53 | 0 76 |
| | C3 and 4 | 1 20 | 3 25 | 2 23 | 0 03 | 0 58 | 0 30 |
| | P3 and 4 | 1 83 | 2 21 | 2 02 | 1 01 | 0 16 | 0 58 |
| | O1 and 2 | 1 19 | 1 33 | 1 26 | 0 44 | −0 71 | −0 13 |
| Lure | FP1 and 2 | 4 73 | 6 13 | 5 43 | 6 40 | 5 25 | 5 83 |
| | F3 and 4 | −0 42 | 1 79 | 0 68 | −0 47 | 1 18 | 0 36 |
| | C3 and 4 | −1 32 | 0 67 | −0 32 | −1 00 | 0 33 | −0 33 |
| | P3 and 4 | −0 03 | −0 62 | −0 32 | 0 53 | −0 84 | −0 16 |
| | O1 and 2 | −0 48 | −1 85 | −1 17 | −0 36 | −1 31 | −0 83 |
| New | FP1 and 2 | 3 48 | 5 30 | 4 39 | 1 09 | 3 15 | 2 12 |
| | F3 and 4 | −0 99 | 0 04 | −0 48 | −2 45 | −1 26 | −1 86 |
| | C3 and 4 | −1 67 | −0 22 | −0 95 | −2 47 | −1 40 | −1 93 |
| | P3 and 4 | −0 81 | −0 41 | −0 61 | −1 72 | −2 60 | −2 16 |
| | O1 and 2 | −0 38 | −0 36 | −0 37 | −2 18 | −3 12 | −2 65 |

*Note* FP = prefrontal F = frontal C = central, P = parietal O = occipital

In short, the pattern from the blocked condition was largely consistent with the PET results in showing differences between correct recognitions of old items and false positives to lures In contrast, these comparisons were not significant in the random condition [3]

Another notable finding was obtained from waveforms recorded from an electrode placed more laterally over the left parietal region (see Fig 2) The P7 and P8 sites were of particular interest because of the previous finding (Schacter, Reiman, et al , 1996) of increased blood flow in the left temporo-parietal region for old items compared with lures Figure 2 shows ERPs for "old" and "new" responses to old and lure items [4] As is clear from Figure 2a, in the blocked condition at the early poststimulus interval, there was a noticeable difference in left but not right parietal waveforms to old and lure items only for those lure items

3 Some caution is warranted in drawing conclusions based on null results, especially because this paradigm involves fewer observations for each subject than is typical for ERP studies Nevertheless, the design was sufficiently sensitive, with approximately the same number of observations, to produce old-lure differences in the blocked group Also, we would expect the relative magnitude of the difference between "old" responses to old and lure items in blocked and random conditions to vary depending on the distribution of criteria or response strategies used by subjects within each condition

4 One subject each from the blocked and random conditions was omitted from this analysis because they had too few "new" responses to have to analyze

that subjects correctly rejected The Condition × Item Type (old, lure) × Hemisphere interaction approached significance, $F(1, 14) = 3.75$, $MSE = 1.76$, $p < .07$ In separate analyses conducted on the P7 (left) and P8 (right) sites, there was a significant interaction between condition and item type at P7, $F(1, 14) = 6.47$, $MSE = 2.39$, $p < .02$, but not at P8 ($p > .87$) Confirming the impression from Figure 2, at P7 in the blocked condition, "new" responses to lures were different from "new" responses to old items ($p < .06$) and "old" responses to old items ($p < .09$) None of the other pair-wise comparisons for the P7 site approached significance [5] These findings should be viewed as tentative because of the small numbers of observations for rejected lures and incorrect responses to old items Nevertheless, if confirmed in subsequent work, they have interesting implications

One hypothesis is that this ERP difference found at P7 was produced by the same type of left temporo-parietal activity observed in the Schacter, Reiman, et al (1996) PET study If so, our finding for the blocked condition suggests that the difference in temporo-parietal brain activity between old and lure items obtained with PET might have been driven largely by the correct rejections within a block of lure trials and not by the false recognitions According to the SMF, source-monitoring errors result when items from Source A (lures) meet the criteria necessary to attribute items to Source B (old items) (Johnson & Raye, 1981) Thus, the finding that "new" responses to lures differed most from correct "old" responses supports our expectation that lures that subjects falsely recognized should be more similar to the old items than the lures that subjects correctly rejected

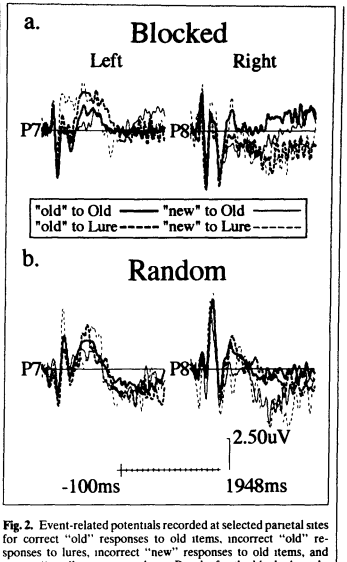


**Fig. 2.** Event-related potentials recorded at selected parietal sites for correct "old" responses to old items, incorrect "old" responses to lures, incorrect "new" responses to old items, and correct "new" responses to lures Results for the blocked condition are shown in (a), and results for the random condition are shown in (b) The onset of the test stimulus is indicated with the largest vertical marker at the left, and subsequent 100-ms intervals are indicated with smaller vertical marks Positive voltages are plotted up, and negative voltages are plotted down

## DISCUSSION

This experiment was directed at comparing the brain activity associated with veridical and false memories for individual words We investigated this question by comparing ERPs recorded when subjects correctly identified previously presented words (e g , *thread, sharp, eye*) as old with ERPs recorded when subjects incorrectly identified new but semantically associated lures (e g , *needle*) as old Such source confusions can occur when individuals mistake internally generated information for externally derived information (e g , reality-monitoring failures, Johnson & Raye, 1981) or, more generally, when the qualities of mental experiences from two or more sources are not distinguished (Johnson 1997, Johnson et al , 1993)

Previous PET results suggested that although brain activity is generally similar for true and false memories in this paradigm, some differences can be detected (Schacter, Reiman, et al , 1996) The present results indicate that how different the brain activity is for true and false memories depends on how individuals are evaluating their memories, that is, what they are looking for or the criteria they adopt for attributing mental experience to memory The PET findings were obtained with a test procedure, commonly required in designing PET studies, in which all items of a particular type were blocked (e g , a test block consisted of all lures or all old items) We compared such a blocked procedure with one in which items were presented randomly intermixed at test in order to manipulate the evaluative criteria subjects would engage in at test, while holding encoding conditions constant Based on the SMF (e g , Johnson et al , 1993), we predicted that

5 Although it is tempting to assume that greater positivity in ERPs would correspond to greater neural activity (and to greater blood flow in PET), such an assumption is not appropriate The relation under various conditions between the direction of ERP activity and blood flow has yet to be systematically investigated in memory tasks Thus, we focus here on differences between conditions but not on the direction (positive or negative) of the ERP differences The present study, providing converging evidence of differences between activity associated with old items and lures in brain regions assessed by ERP and PET techniques, suggests that comparisons of these two techniques under comparable conditions will be fruitful

## Brain Activity and False Recognition

brain activity would reflect not only the nature of what was encoded, but also the types of processes engaged at the time of test (see also Johnson et al , 1996)

As expected, we found that differences in waveforms between "old" responses to old items (true memories) and "old" responses to lures (false memories) were greatly reduced in the random compared with the blocked condition We suggest that in the random condition, subjects were making old-new judgments largely on the basis of an overall feeling of semantic familiarity In the blocked condition, subjects should have found it difficult to discriminate among successive items within a block on the basis of relative semantic familiarity and would therefore have been more likely to attempt to assess perceptual and contextual qualities of their memories This more extensive evaluation in the blocked condition was reflected in differences in waveforms for old and lure items, especially those waveforms recorded over frontal sites and over the left parietal region Although ERPs alone do not permit strong conclusions about the location of brain activity, the convergence of evidence from ERPs, PET, and brain-damaged patients is quite consistent The frontal-site differences presumably are associated with reflective activity such as retrieval and evaluation (e g , Johnson, 1991, in press, Schacter, Reiman, et al , 1996, Wilding & Rugg, 1996) and the parietal-site differences with one target of this reflective activity—auditory-phonological detail (Schacter, Reiman, et al , 1996)

These results have important implications for interpreting the outcomes of PET or functional magnetic resonance imaging studies using designs that require the blocking of test items by condition The resulting brain activity will not necessarily be the same as the brain activity that takes place in corresponding cognitive-behavioral paradigms, in which test items from various conditions are intermixed The point here is not that one type of test format is "correct" and another is "incorrect " Rather, the critical point is that subjects' mental activity is sensitive to test conditions (e g , see also Dodson & Johnson, 1993, Raye Johnson & Taylor, 1980) If brain activity is influenced as much by what subjects look for as by what is stored, we must be cautious in taking brain activity as a direct index of the nature of memory representations Thus, various test conditions (as well as various encoding conditions, e g , Johnson et al , 1996) must be investigated directly in order to obtain a clearer understanding of any particular cognitive phenomenon, such as the nature of false memories

In summary, as expected from the SMF, the present results highlight that whether "false" and "true" memories appear similar phenomenally (Mather et al , in press) and whether they appear similar in underlying brain activity (the present study) depend on what features are being examined and the evidence criteria an individual requires for attributing a memory to a particular source In combination with other recent studies of brain activity and source monitoring (Dywan & Segalowitz, 1996, Johnson et al , 1996, Schacter, Reiman, et al , 1996, Wilding & Rugg, 1996), these results illustrate that brain-imaging and ERP techniques can be used to test predictions and augment conclusions based on purely cognitive studies of source monitoring and that, conversely, expectations based on the SMF (Johnson, 1997, Johnson et al , 1993) can help guide the interpretation of imaging and electrophysiological data Finally, these findings also illustrate that the indices of brain activity time-locked to individual events of imaging techniques such as PET to clarify brain mechanisms of memory and cognition

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