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Explicit Contamination Contributes to Aging Effects in Episodic Priming: Behavioral and ERP Evidence

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We examined the impact of explicit contamination on age-related changes in episodic priming. We recorded event-related brain potentials (ERPs) from older and younger adults to primed and unprimed nouns tested in a recognition memory task. Results revealed that the magnitude of priming was greater in the younger adults. ERPs revealed a priming effect in the younger adults that was absent in older adults. Findings suggest that explicit contamination may account for the reported aging effect: Item memory was correlated with episodic priming and ERP priming in younger adults, but not older adults; item memory was associated with episodic priming after aging effects were controlled for; and the topographies of the young's priming and item memory effects were indistinguishable. Given the apparent vulnerability to contamination by explicit memory, we suggest caution when researchers use an episodic priming paradigm to assess aging effects in implicit memory.

EPISODIC priming reflects a form of implicit memory, whereby memory for previously studied material is revealed even though individuals are not instructed to intentionally recall having studied the material. Episodic priming is reflected by faster or more accurate responding to a word when it is accompanied by another word with which it was paired earlier in the experiment, though the initial pairing need not be consciously recollected for the facilitation in response to occur (Faust, Balota, & Spieler, 2001; McKoon & Ratcliff, 1979). It is controversial whether or not episodic priming tasks are "process pure" (Roediger & McDermott, 1993; also see Kinoshita, 2001 and McKone & Slee, 1997). Even when participants are not instructed to reflect back on the study episode to complete the priming task, many become aware of the mnemonic nature of the task and use the study session to facilitate their priming performance. This is more likely for tests in which item memory is being assessed, because participants are explicitly directed to encode the study items for later retrieval. The intrusion of explicit processes, or explicit contamination, is particularly vexing to researchers interested in aging, because younger participants are more likely than older adults to become aware that the implicit task includes a type of memory test, and they are more able to exploit the study item–cue relations (Mitchell, 1995).

Howard and colleagues (Howard, Heisey, & Shaw, 1986) performed a study of episodic priming in younger and older adults on which the current investigation is based. Participants studied sentences of the following form: Noun 1, Verb, Noun 2 (e.g., "The *dragon* sniffed the *fudge*."). The two nouns of each sentence were unassociated, such that the association created during the experiment was novel. During recognition memory testing, the studied nouns (along with foils) were presented under two conditions—(1) either preceded by a same-sentence noun (episodically primed) or (2) preceded by a different-sentence noun (unprimed)—and participants made speeded old–new recognition judgments for each noun. Because the nouns in the sentences were unassociated prior to the experiment, any priming that resulted would have had to be due to a retaining of the novel association in memory, even if this was not consciously appreciated. If older relative to younger adults had a deficit in episodic priming, this could be taken as evidence of an age-related deficit in implicit memory. Howard and colleagues (1986) reported that, after a brief study period, younger adults showed priming but older adults did not. However, differences between younger and older adults disappeared when two presentations of each sentence were administered. One possible interpretation of this finding is that the second exposure provided deeper encoding of the words during study, and thus it increased the contribution of explicit memory processes on the priming measure.

Explicit contamination is supported by findings among younger participants showing that only those who noticed the relationship between the test and the study phases of a lexical-decision priming task showed priming of new associations, whereas participants who were unaware of any connection between the study and test lists did not show priming (McKone et al., 1997). Studies that have contrasted aging effects between aware and unaware groups have shown that age differences exist between aware younger and older adults, but not between unaware younger and older adults (Park & Shaw, 1992). Further, aging effects on priming are eliminated under experimental conditions that reduce explicit memory, such as testing at a 46-min delay compared with testing after no delay (Chiarello & Hoyer, 1988). In patients, priming of new associations is shown by mild amnesiacs but not by dense amnesiacs (those with little or no explicit memory ability; Schacter & Graf, 1986; also see Mayes & Gooding, 1989 and Shimamura & Squire, 1989). In addition, the extent of new association priming correlates with cued recall in amnesic patients (Mayes & Gooding, 1989). Thus, new association priming effects observed in persons with mild amnesia may depend on residual explicit memory. In the present study we use event-related brain potentials (ERPs) to help elucidate the issue of explicit contamination on an episodic priming task.

Previous studies have investigated the electrophysiological correlates of priming by using ERPs. In a classic study, Kutas and Hillyard (1980) identified a negative-going component with a peak latency near 400 ms (N400) elicited by semantically anomalous sentence endings, such as "I take my coffee with cream and *transmitters*." The N400 was more negative when the target was semantically incongruent than when it was semantically congruent to the prime. Generally, the N400 is thought to reflect processes involved in integrating a word into the context in which it appears (Halgren & Smith, 1987). The amplitude of the N400 is larger when greater effort is required for the integration. N400 priming effects have also been shown for repetition priming (Rugg, 1987), and more recently for episodic priming (Trott, Friedman, Ritter, & Fabiani, 1999). As in the current study, Trott and colleagues (1999) compared ERPs with episodically primed nouns, that is, those preceded by the noun from the same studied sentence, to those not episodically primed, that is, those preceded by a noun from a different studied sentence. The expectation for this paradigm is that the presentation of Noun 1 creates a context for the presentation of the same-sentence Noun 2, but not for the presentation of the different-sentence Noun 2. Thus, the different-sentence Noun 2 should evoke a larger N400 compared with a same-sentence Noun 2. Confirming these expectations, Trott and colleagues showed that, at frontal–central scalp sites, the N400 to episodically primed nouns was reduced compared with unprimed nouns. Further, ERP priming effects did not differ significantly between younger and older adults, which was consistent with previous studies that used other priming paradigms (for a review, see Friedman & Fabiani, 1995).

ERP data may shed light on the issue of explicit contamination by comparing the electrophysiological signature of the ERP priming effect to that of the well-described episodic memory (EM) effect, which represents the difference between the ERP response to old words minus new words on a recognition memory test. Two ERP components have commonly been attributed to the old–new EM effect. The earlier of these has been identified with the N400 component of the ERP and reflects relatively automatic, familiarity-based recognition processes (e.g., Curran, 2000). Because the N400 is sensitive to semantic context and repetition of recently presented words, it has also been proposed as a neural correlate of conceptual priming (Olichney et al., 2000). The N400 has been reported to be reduced in epilepsy patients who have undergone medial temporal lobectomy (Smith & Halgren, 1989), suggesting that it receives contributions from structures within the medial temporal lobe memory system and reflects an explicitly based memory process. The later EM effect, the P3b, is a positive-going component with a peak poststimulus latency between 300 and 500 ms. The P3b is thought to reflect more effortful, recollection-based processes. The amplitude of this EM effect is larger for correctly recognized items that are subsequently recalled (Rugg, Fletcher, Frith, & Frackowiak, 1996) and for words whose study context is correctly retrieved (Trott et al., 1999).

The priming data presented here were generated as part of a replication and extension of a source memory study by Trott and colleagues (Trott et al., 1999). Our primary intent in replicating Trott was to explore ERPs associated with source memory; these data have been published elsewhere (Wegesin, Friedman, Varughese, & Stern, 2002). We modified the design of Trott's study in several ways to enhance deep encoding of the study nouns in order to improve source performance. First, our study list length in the present experiment was half as long as that used by Trott. Second, we presented sentences twice in the present study, compared with only once in Trott's. Third, we encouraged deep encoding by requiring a pleasantness rating of each study sentence. Fourth, our study time was unlimited in the present study, whereas presentation of the study items was limited in Trott's study. Finally, in the present study, we presented sentences on the screen in their entirety, whereas each word of the sentence appeared on the screen one at a time in Trott's study. These design modifications were effective at enhancing source memory. However, the deep encoding also affected episodic priming, and we conclude that the resultant aging effect on episodic priming was due to explicit contamination.

Behaviorally, explicit contamination may be suggested by a correlation between episodic priming scores and explicit item memory scores. If explicit contamination is more conspicuous in younger adults than older adults, then the correlation between episodic priming and item memory should exist for younger adults but not older adults. Differences in ERP scalp distributions are thought to reflect differences in the underlying cognitive processes. Conversely, a lack of differences in the scalp topography may suggest similar cognitive processes. If explicit processes are driving the priming of new associations, then the scalp topography of the ERP priming effect should resemble the scalp topography of the EM effect. We examine these hypotheses related to explicit contamination here.

Methods

Participants

Sixteen younger women (18–28 years of age) and 16 older women (60–80 years) recruited by community flyers, newspaper advertisements, and word of mouth participated in the study. We recruited only women, as they served as controls for a study of hormone replacement therapy. However, priming has been shown to be relatively gender insensitive (Herlitz, Nilsson, & Baeckman, 1997). We paid all participants for their time. The institutional review boards of Columbia University and the New York State Psychiatric Institute approved the project, and all participants provided written informed consent. Because we used only trials in which Noun 1 and Noun 2 were both correctly recognized, we removed two older adults from analyses as a result of an insufficient number of artifact-free trials available to compute an ERP average for one of the priming conditions (minimum of 10 trials/condition).

Younger adults reported being of a lower socioeconomic status (SES) than the older adults [$t(28) = 2.3$, $p < .05$] on a two-factor measure of SES (Hollingshead & Redlich, 1958). This is attributable to their occupational status as "student" and may not accurately reflect their SES. Younger adults, of whom 40% were White, were more ethnically diverse than the older adults, of whom 92% were White [$\chi^2(2) = 8.7$, $p < .05$]. We observed no group differences in years of education (young, 15.4 vs. old, 15.8) or in general cognitive function, as measured

Table 1. Examples of Studied and Foil Sentences and Recognition Memory Conditions

Sentences		Recognition Test			
Set A (Studied)	Set B (Foil)	Condition	Label	Noun 1	Noun 2
1. The *plow* created the *delay*.	5. Her *nephew* joined the *cult*.	1	Old–old same	1. plow	1. delay
2. The *lyrics* reflected his *wit*.	6. His *singing* filled their *dwelling*.	2	Old–old different	2. lyrics	3. cereal
3. The *monkey* ate the *cereal*.	7. The *elevator* became a *tomb*.	3	Old–new	3. monkey	6. dwelling
4. The *deputy* read the *script*.	8. The *candy* eased her *sorrow*.	3	Old–new	4. deputy	8. sorrow
		4	New–new	5. nephew	5. cult
		4	New–new	6. singing	7. tomb
		5	New–old	7. elevator	2. wit
		5	New–old	8. candy	4. script

Notes: For the label, $n = 32$.

by the modified Mini-Mental State Exam (young, 55.3 vs. old, 54.3) and the Weschler Adult Intelligence Scale-III Vocabulary subtest (young, 56.3 vs. old, 56.6).

Experimental Procedures

Participants completed 16 study-test blocks of the episodic priming test. During the study phase, participants studied two separate lists of sentences of the following type—Noun 1, Verb, Noun 2 (e.g., "The *chef* created a *spread*")—in which the two nouns were unassociated (as determined by a previous study; see Trott et al., 1999). Each list contained four sentences, and each sentence contained two nouns, for a total of eight nouns per list. Interviewers instructed participants to memorize the two nouns, as well as the list in which they occurred, for a subsequent item–source memory test. To enhance elaborative encoding, interviewers asked participants to rate the pleasantness of the study sentences, indicating via a button press whether or not they liked the sentence. Participants had an unlimited amount of time to study the sentences, and their "like it–don't like it" judgments prompted the display of the next sentence on the computer screen. In order to aid encoding of the study nouns, each sentence appeared twice within the list in randomized order.

During the test phase, the computer presented nouns sequentially in pairs, each with a 300-ms duration separated by a 2000-ms interstimulus interval. The two conditions of interest included when studied nouns were (1) preceded by a same-sentence noun, that is, they were episodically primed, or (2) preceded by a different-sentence noun, that is, they were unprimed. Participants made speeded old–new recognition judgments to each noun (responding hands counterbalanced across participants). All possible combinations of pairings were used, such as old Noun 1–old Noun 2 from the same sentence; old Noun 1–old Noun 2 from different sentences; old–new; new–new; and so on as shown in Table 1. A total of 256 sentences were divided into two sets, balanced for word frequency and length, and served as either study or foil sentences (counterbalanced across participants). The target, that is, old, and foil nouns were rotated across pair types, that is, old–old same sentence, old–old different sentence, old–new and so on, so that, across participants, each noun served equally often in each of those pair types.

Behavioral Data Analysis

Unadjusted raw scores on behavioral priming measures may appear to differ in magnitude across age as a result of overall performance differences. For example, though younger adults respond faster than older adults, their performance may actually reflect equivalent proportional changes relative to baseline compared to older adults. To control for the influence of baseline group differences, we calculated relative priming scores for all between-group comparisons. Relative priming scores represent the difference between the primed and unprimed conditions divided by the mean of the baseline (in this case, unprimed) condition.

We tested the homogeneity of variances, and when Levene's statistic was significant, we reported adjusted degrees of freedom and corresponding p values. We used t tests to evaluate the magnitude of the priming effect within each group.

ERP Recordings

We recorded electroencephalograms (EEGs) from 62 scalp sites by using an Electrocap (Electrocap International, Inc.) including left and right mastoids, referenced to the nosetip, from extended 10–20 system placements (e.g., Nuwer, Comi, Emerson, Fagslang-Frederiksen, & Guerit, 1998). We bipolarly recorded horizontal and vertical electro-oculograms (EOGs) with electrodes placed, respectively, at the outer canthi of both eyes and above and below the right eye. We recorded EOGs and EEGs continuously (5-s time constant; 50-Hz upper cutoff) with Sensorium amplifiers (Sensorium, Inc.), digitized at 200 Hz. We epoched data offline with 100-ms prestimulus and 2,000-ms poststimulus intervals for the test phase. We corrected EEGs offline for the intrusion of eye movement artifacts by using the procedure developed by Gratton and colleagues (Gratton, Coles, & Donchin, 1983).

ERP Analyses

Initially, we generated surface potential maps for each 100 ms of poststimulus activity to visualize the topography of the ERP priming effects. By visual inspection of the maps we identified a robust, centrally focused (Cz) priming effect in the younger adults coincident with the N400 component of the ERP, which corresponded to the episodic priming effect reported in a previous study (Trott et al., 1999). For older adults, suggestions of a difference between primed and unprimed nouns at the Cz electrode site appeared to occur later, coincident with the P3b component of the ERP. To examine the priming effect, we measured ERPs at the Cz electrode site as averaged voltages (computed with respect to the 100-ms prestimulus baseline) for two windows corresponding to the N400 and P3b components of the ERP. These

Table 2. Reaction Times, Accuracy, and Number of ERP Trials for Primed and Unprimed Nouns

Data	Young		Old	
	M	*SD*	*M*	*SD*
Reaction time				
Primed nouns	638.2	(105.7)	897.4	(199.1)
Unprimed nouns	760.1	(109.3)	982.0	(220.4)
% relative priming	16.0	(6.8)	7.7	(13.2)
Number of trials (range)				
Primed nouns	26.75 (17–32)	4.7	20.14 (10–28)	5.1
Unprimed nouns	25.50 (17–32)	3.9	19.29 (11–27)	5.5
New nouns	106.62 (68–122)	17.4	87.00 (44–108)	21.3
Accuracy				
d_L primed	7.9	(1.8)	4.5	(0.9)
d_L unprimed	6.9	(1.7)	4.2	(0.7)

Notes: ERP = event-related brain potential. For young and old adults, $n = 16$ and $n = 14$, respectively. Reaction time is given in milliseconds and item discrimination (d_L) is the discrimination index for item recognition.

averaged voltages were 270–420 ms (younger) and 280–430 ms (older) for the N400 and 485–735 (younger) and 510–760 (older) for the P3b. We included only those trials with correct responses in the averages. For all analyses of variance (ANOVAs), we used the Greenhouse–Geisser method to adjust the degrees of freedom for nonsphericity.

Scalp Distribution

To determine if the scalp distribution of the ERP priming effect was similar to the ERP old–new EM effect, we conducted a set of topographic analyses. To compare the topography between the priming and item memory conditions, we first normalized the data by using the root mean square method described by McCarthy and Wood (1985). This manipulation removes overall amplitude differences between conditions to allow a comparison of the shape of the distribution across the scalp.

Results

Behavioral Results

We based measures of item discrimination (d_L) and response bias (c_L) on logistic distributions in a signal-detection model (Snodgrass & Corwin, 1988). Overall, younger adults ($d_L = 7.4$) more accurately discriminated old and new words than the older adults ($d_L = 4.4$) [$F(1, 30) = 31.7$, $p < .001$]. No differences were revealed between the younger adults ($c_L = 0.75$) and the older adults ($c_L = 0.47$) on a measure of response bias, as both groups were relatively conservative in their judgments. Table 2 presents the reaction time and accuracy data for the primed and unprimed conditions of the experiment, in addition to the relative priming scores. We calculated discrimination measures for the priming conditions by using the overall false alarm rate. We utilized only correct responses preceded by correct responses in order to be as sure as possible that both prime and target items were in memory (Howard et al., 1986). Relative priming measures, which correct for group differences in overall speed, revealed an aging effect [$t(28) = 2.2$, $p < .05$]. Younger adults showed greater priming for reaction time compared with the older adults. The discrimination index, reflecting the ability to discriminate between old and new items, failed to reveal differences between younger and older adults' relative priming.

We examined the influence of explicit contamination in two ways. First, we examined the correlation between priming and item recognition in each group separately. Figure 1 illustrates a significant correlation in younger adults [$r(16) = .49$, $p = .05$], but not in the older adults [$r(14) = .18$, $p > .10$]. Second, we conducted a regression analysis in which item discrimination was entered after group, to examine if item discrimination influenced priming once group difference had been controlled. Results revealed significant findings for both steps of the model. The significant effect of the second step [$F(2, 27) = 3.7$, $p < .05$] confirms a significant impact of item memory on priming performance.

ERP Results

The mean and range of trial numbers per condition are shown in Table 2. Figure 2 shows the grand mean waveforms at the Cz electrode to primed, unprimed, and new words for the younger and older participants. Generally, for the younger adults, primed old words were more positive-going than unprimed old words from approximately 265 ms to 465 ms poststimulus. This effect reflects the attenuation of N400 activity to the primed old words. ERPs of the older adults indicate a much less conspicuous difference between primed and unprimed nouns from approximately 575 ms to 700 ms. Surface potential maps for the primed-minus-unprimed difference waveforms are depicted in Figure 3A for the early N4 and late P3b windows (note the difference in scale used for younger and older adults).

We submitted averaged voltages for the N400 and P3b regions to a Priming Condition (primed vs. unprimed) × Window (N400 vs. P3b) × Group (younger vs. older) ANOVA. Results revealed main effects of priming condition [$F(1, 28) = 11.2$, $p < .01$], window [$F(1, 28) = 30.5$, $p < .001$], and group [$F(1, 28) = 6.7$, $p < .05$]. The effect of priming condition revealed that mean amplitudes to the primed condition were greater than those to the unprimed condition. Amplitudes were also greater overall in the N400 window compared with the later P3b window. These main effects were subsumed by an interaction among Priming Condition × Window × Group [$F(1, 28) = 33.4$, $p < .001$]. As shown in Figure 2, mean amplitudes to primed nouns were greater than those to unprimed nouns for the younger participants within the N400 window [$t(15) = 7.9$, $p < .001$], but not in the later P3b window. For older participants, ERP priming effects did not approach significance in either time window.

We next tested whether the scalp topography of the ERP priming effect among younger adults was different from their ERP EM effect (see Figure 3B). The EM effect reflects a subtraction of unstudied new items from studied old items (independent of their priming condition). We did not conduct topographic analyses among the older adults, as they did not produce a reliable ERP priming effect in either time window. A significant difference in scalp distribution, suggestive of a change in the underlying generators, is revealed by an

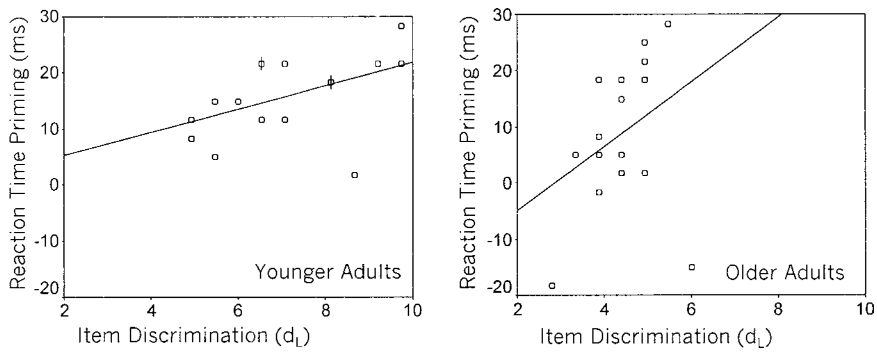

Figure 1. Scatter plot illustrating the correlation between episodic priming and recognition memory, which is significant for younger but not older adults.

interaction of electrode site and condition. The analysis included a subset of 26 representative electrodes, which formed two concentric circles around and included the Cz priming effect. An ANOVA revealed that the interaction between electrode site and condition was not significant [$F(2, 30.1) = 0.9$, $p > .10$], indicating a similar topography for the ERP priming effect and the old–new EM effect.

Discussion

In this study we examined the effects of aging on priming of newly associated noun pairs and explored the influence of explicit contamination on aging effects in an episodic priming task. The main findings revealed aging effects on the behavioral index of episodic priming, with the facilitation of speed of response to primed nouns compared with unprimed nouns being greater in younger adults than in older adults. However, correlation and regression analyses suggested that the aging effect was influenced by group differences in item memory. ERPs showed a centrally focused priming effect among younger participants that was absent among older participants. This ERP priming effect in the younger adults was topographically indistinguishable from their ERP old–new EM effect. We discuss these results in light of explicit contamination on episodic priming tests.

Younger adults showed larger priming effects than older adults in terms of speed, but not accuracy. These results are not simply due to the fact that younger adults were faster than the older adults, because we controlled for overall performance differences by using a relative priming index. Previous studies exploring age-related deficits in episodic priming have produced mixed results. Whereas several studies have reported intact episodic priming in older adults (e.g., Balota & Duchek, 1989; Burke, White, & Diaz, 1987; Howard et al., 1986), others have reported aging deficits under certain testing conditions (Cermak, Blackford, O'Connor, & Bleich, 1988; Ergis, Van Der Linden, & Deweer, 1998; Faust et al., 2001; Howard et al., 1986; Spieler, Balota, & Faust, 1996). The literature suggests that the effects of aging on priming are moderated by the type of priming being assessed. Specifically, aging effects have been reported to be more common on tests of conceptual priming, compared with tests of perceptual priming, (Jelicic, 1995; Rybash, 1996) on priming tests of a semantic compared to a nonsemantic nature (Brown & Mitchell, 1994), and on priming tests that may include an explicit memory component (Light & Kennison, 1996). Accordingly, aging effects are not unanticipated, as the present task is conceptual and semantic in nature. Our priming effects do not likely represent strong perceptual priming because the presentation of the words differed at study and test (i.e., underlined and lower case at study and no underline and upper case at test). What is most important is that the implicit task used here is clearly susceptible to explicit memory processes.

Because participants were instructed to actively encode the study sentences for a subsequent item recognition test, explicit memories of the full sentence or of self-generated associations between Noun 1 and Noun 2 were likely created. Upon being presented with Noun 1 at test, participants may have spontaneously generated the associated Noun 2, if not the full

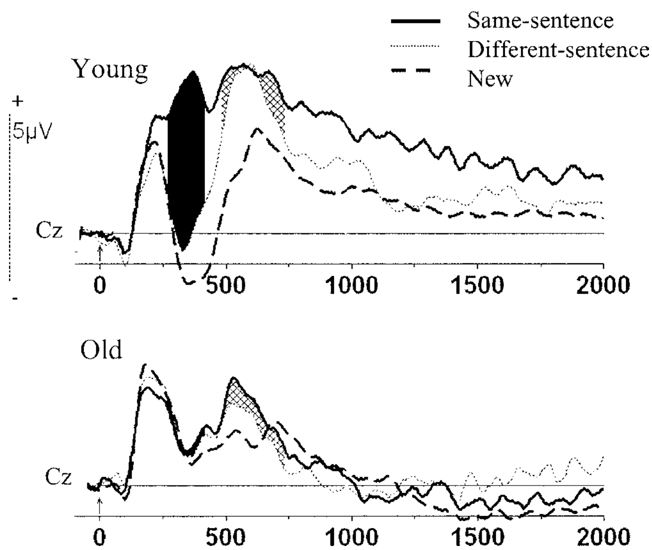

Figure 2. Grand mean event-related potentials recorded from the young and old adults at the central scalp site (Cz). Data are depicted for Noun 2 following a same-sentence Noun 1, a different-sentence Noun 1, and a new foil Noun 2 preceded by a studied Noun 1. The episodic priming effect is denoted by solid shading for the N4 window and hatched shading for the P3b window. Data are depicted for a 2,000-ms epoch with a 100-ms prestimulus baseline. Arrows mark the stimulus onset.

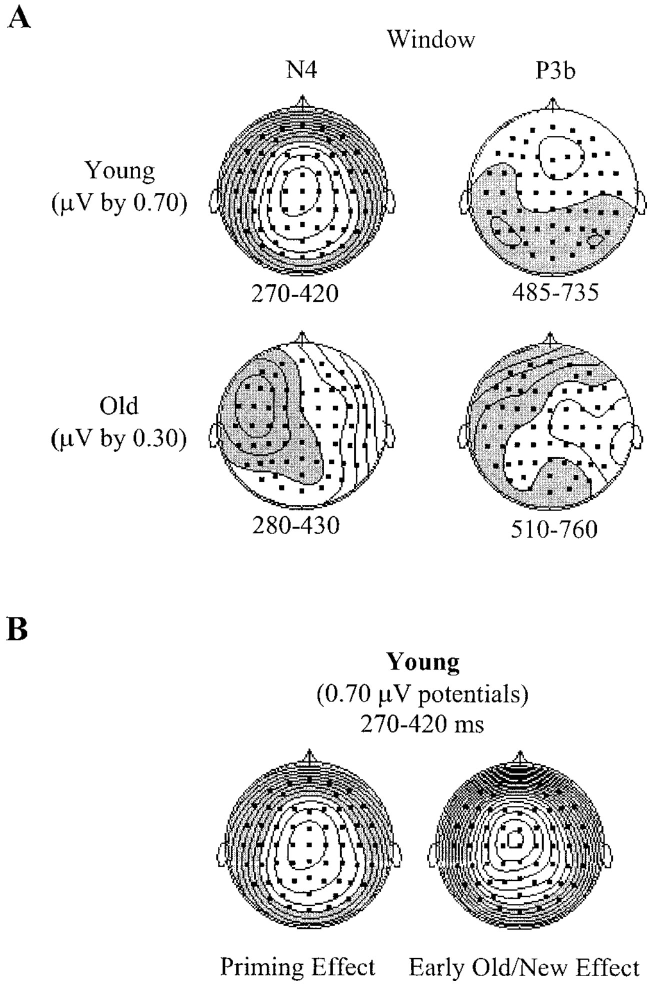

Figure 3. **A**. Surface potential maps based on the same-sentence Noun 2 minus different-sentence Noun 2 difference waveforms of the young and old adults for the N4 and P3b epochs. Note the centrally focused priming effect among young adults in the N4 epoch map. White is positive. **B**. Surface potential maps of young adults comparing the topographies of the event-related brain potential (ERP) priming effect and the ERP old–new episodic memory effect within the N4 epoch. White is positive.

sentence. ERP data provide support for this proposal. If Noun 1 automatically brought to mind Noun 2, the strong contextual expectations built up would result in an attenuated N400 when Noun 2 turned out to be the same-sentence noun, and larger N400 activity when it was either a new item or a different-sentence noun. The large N400 to new items, and, to a lesser degree, different-sentence items, among younger adults shown in Figure 2 is consistent with this hypothesis. By contrast, the N400 did not vary by condition among the older adults.

Moscovitch (1992) describes that the hippocampal memory system automatically activates a memory trace upon the presentation of an appropriate cue, even without a voluntary intention for retrieval. Tulving has described this process as ecphory (Tulving, 1985); others have referred to this phenomenon as "involuntary explicit memory" (Richardson-Klavehn, Gardiner, & Java, 1994). The automatic intrusion of explicit processes on this implicit memory task may account for differences obtained in our study compared with the study by Trott and colleagues (1999), in which they used a similar paradigm but failed to obtain aging effects. Deep encoding has been reported to enhance involuntary retrieval on implicit memory tasks (Kinoshita, 2001), and we modified the design of the present study in several ways from Trott's study to enhance deep encoding of the study nouns, as described in the introduction. Correlational analyses of the present study's data revealed that item memory was related to relative priming in younger adults, but not in older adults, consistent with the proposal that explicit memory processes may have influenced the priming scores in the younger participants. Mitchell and Bruss (2003) also described a significant relationship between implicit and explicit memory tests in younger adults that was absent in older adults. Relatedly, the amount of priming for new associations has been shown to correlate with the level of explicit memory ability retained by amnesic patients (Shimamura & Squire, 1989). In an attempt to verify the effects of explicit memory on our episodic priming results, we conducted regression analyses, which revealed that item memory significantly affected priming performance beyond the influence of group effects. In sum, these behavioral findings suggest that aging effects in episodic priming are affected by differences in explicit memory ability instead of differences in implicit memory. The ERP data provide further support of this claim.

As expected, ERPs in younger adults revealed a centrally focused priming effect that reflected the attenuation of N400 activity to the primed words compared with unprimed words, replicating the findings of Trott and colleagues (1999). They described the priming effects in the older adults as less marked than those of the younger adults, though the aging effect did not reach statistical significance. In the present data, aging effects were evident, as older adults failed to elicit a reliable ERP priming effect. In order to explore whether an ERP priming effect existed among the older adults at a different scalp location, we examined their ERP data at scalp locations that appeared to show the strongest priming effect, based on the topographic maps in Figure 3A. Supplementary analyses of electrodes where the priming effect peaked in the N4 and P3b windows failed to reveal significant priming effects, confirming the absence of an ERP priming effect among the older adults. We also conducted supplementary analyses to examine whether the age differences noted to the primed and unprimed Noun 2 items were affected by differential responses between the groups to Noun 1 items. A repeated-measures ANOVA of the EM effects for Noun 1 and Noun 2 showed a main effect of Noun in the absence of an interaction with Group. Therefore, though the ERP signature of the EM effect varies between Noun 1 and Noun 2, the manner in which it varies is similar across older and younger adults, suggesting that the differences noted in the priming effects are not a consequence of between-group differences to Noun 1.

The N400 priming effect has been shown to be significantly reduced and delayed in older compared with younger adults for unassociated prime-and-target pairs in a semantic priming task, though the N400 priming effect remained intact among older adults for associated prime-and-target pairs (Gunter, Jackson, & Mulder, 1998). Because we selected the word pairs in the present study as being unassociated, the aging effect reported here is consistent with those of Gunter and colleagues. Together, these data suggest that older adults show impairment on the encoding of novel associations.

Finally, the scalp topography of the younger adults' priming effect was indistinguishable from the topography of their early old–new item memory effect (Figure 3B). Though this null finding is not conclusive, it is also not inconsistent with the possibility that the cognitive processes involved in discriminating old and new nouns, i.e., explicit memory processes, were manifest in younger participants' distinctions between primed and unprimed nouns. Further evidence of this association is revealed by a significant correlation between item recognition scores among the younger participants and their ERP priming effect [$r(16) = .67$, $p < 01$]. Gunter and colleagues (1998) also examined the relationship between item memory and the ERP priming effect. In their study, free recall was conducted after the presentation of word pairs, and younger participants with low recall showed a reduction in the N400 priming effect akin to the reduction seen in the older adults. These results suggest that neural processes associated with explicit memory are represented in the N400 priming effect.

An important clarification to make is that "explicit memory" does not necessarily imply intentional retrieval. In fact, the ERP data suggest that the influence of explicit memory here may reflect relatively automatic processes, as the N400 portion of the ERP EM effect is associated with automatic recognition, whereas the P3b portion of the EM effect is thought to reflect more effortful and deliberate retrieval. Though under certain taxonomies of memory, any nonintentional mode of retrieval would be classified as an instance of implicit memory (Schacter & Bowers, 1989), the explicit contamination described here conforms to Moscovitch's framework of memory (Moscovitch, 1995) whereby both automatic and more controlled processes are considered to be instances of explicit memory. As we have shown in the present study, episodic priming paradigms confound automatic and controlled processes, and are thus insufficient for exploring relative declines in these processes with age. A more apposite paradigm has been developed by Jacoby (Jacoby, 1991). The Process-Dissociation Procedure contrasts results from a condition in which automatic and consciously controlled processes act in opposition to results from a condition in which the two types of processes act in concert. Using simple algebra, one can estimate the independent contributions of automatic and controlled processes. The Process-Dissociation Procedure has been used to demonstrate that implicit memory tests are often confounded by conscious explicit memories (Toth, Reingold, & Jacoby, 1994).

Conclusions

Aging effects were revealed on an episodic priming test of newly associated word pairs, a test thought to reflect implicit memory processes. However, a close inspection of the results suggested that explicit memory processes confounded the priming test: (1) item memory was correlated with episodic priming in younger adults, but not older adults; (2) item memory was associated with episodic priming in regression analyses that controlled for group differences in priming; (3) ERPs of younger participants showed similar topographies for their priming effect and item memory effect; and (4) ERP priming effects in younger adults were correlated with item memory performance. In sum, results suggest that the aging effects on episodic priming are likely confounded by differences in explicit memory abilities between younger and older adults; thus, we suggest caution in future research when one uses an episodic priming paradigm to assess aging effects in implicit memory.

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