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An Event-Related Potential Investigation of Posthypnotic Recognition Amnesia

John J. Allen, William G. Iacono, John J. Laravuso, and Laurie A. Dunn
University of Minnesota

Forty-two individuals selected for high hypnotizability or for low hypnotizability were taught lists of words during hypnosis and assessed for recognition following hypnosis using event-related potential (ERP) procedures, both before and after the cue to reverse amnesia. A subgroup of low-hypnotizable participants were asked to simulate hypnotic behavior. All participants had larger late positive component (LPC) amplitudes to learned than to unlearned words, regardless of whether amnesia was reported. The highly hypnotizable participants who reported recognition amnesia, however, had significant changes in attention-related (P1 and N1) and recognition-related (N400 and LPC) ERP component amplitudes as a function of whether amnesia was reported. These data suggest that posthypnotic amnesia may involve alterations in the processes of attention, selection, and accessibility.

The aim of the present study was to use an event-related potential (ERP)-based memory assessment procedure (Allen, Iacono, & Danielson, 1992) to investigate information processing during posthypnotic recognition amnesia. To our knowledge, the present study represents the first use of psychophysiological measures as dependent variables in the study of posthypnotic amnesia other than a case study using autonomic responses (Bitterman & Marcuse, 1945).[1] The changes in perception, cognition, and memory that are observed in responsive hypnotic individuals appear well suited to investigation using ERPs.

Although to date no investigators have used ERPs to study posthypnotic amnesia, several other hypnotic phenomena have been studied using ERPs. Spiegel and his colleagues (Jasiukaitis, Nouriani, Hillyard, & Spiegel, 1993; Spiegel, Bierre, & Rootenberg, 1989; Spiegel, Cutcomb, Ren, & Pribram, 1985) have used ERPs in the study of hypnotically suggested visual and somatosensory perception. These investigators have shown that giving highly hypnotizable individuals suggestions to alter their perception of sensory stimuli can affect the amplitude of both early (occurring about 100 ms after stimulus presentation) and late ERP components. That early ERP components are altered is of particular interest because the character of components is determined primarily by the physical properties of the stimulus (Donchin, Ritter, & McCallum, 1978) rather than by a cognitive analysis of the stimulus. These findings suggest that highly hypnotizable individuals are capable of alterations in attention, sensory perception, and information processing that occur early in the chain of information processing both during (Jasiukaitis et al., 1993; Spiegel et al., 1985, 1989) and outside of (Galbraith, Cooper, & London, 1972) hypnosis.

Late components of the ERP may be especially well suited for investigations of posthypnotic amnesia. Research to date has identified two late components of the ERP that most clearly tap verbally mediated memory-related processes: the N400 component and the late positive component (LPC). Although the first studies of the N400 suggested that it was sensitive to semantic relationships among stimuli, subsequent research has shown it to be sensitive to a broader array of contextual features that surround stimulus presentation, including not only the semantic context in which a word appears, but also the repetition of stimuli, the frequency with which the word appears in the language, categorical relationships, and recognition memory (cf. Halgren, 1990; Van Petten, Kutas, Kluender, Mitchiner, & McIsaac, 1991). Halgren (1990) summarizes the meaning of the amplitude of the N400 component by suggesting that the amplitude of the N400 component is inversely proportional to the

John J. Allen, William G. Iacono, John J. Laravuso, and Laurie A. Dunn, Department of Psychology, University of Minnesota.

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Correspondence concerning this article should be addressed to John J. Allen, who is now at the Department of Psychology, University of Arizona, Tucson, Arizona 85721.

[1] Although Coe and his colleagues (Coe & Yashinski, 1985; Schuyler & Coe, 1981, 1989) have recorded skin conductance and other autonomic responses during the assessment of posthypnotic amnesia, these measures were not used as dependent measures to distinguish between learned versus unlearned material. Rather, these measures were designed to be part of a manipulation to induce anxiety and therefore breaching of amnesia, as participants believed that they were connected to a lie detector.

ease with which a word can be integrated into the individual's current cognitive context.

The LPC occurs after the N400 and includes the latency range of the classic P3 or P300 (cf. Donchin, 1981; Johnson, 1986). The LPC is sensitive to a variety of memory-related processes, with larger amplitudes being predictive of subsequent recall of words (Karis, Fabiani, & Donchin, 1984) and names (Fabiani, Karis, & Donchin, 1986). The amplitude of this component also can differentiate previously learned words from new words (Allen et al., 1992; Farwell & Donchin, 1991) and has been hypothesized to reflect both the retrieval of information from long-term memory (Van Petten et al., 1991) and the subsequent updating of working memory (Donchin & Coles, 1988; Van Petten et al., 1991).

Rationale and Overview of the Present Study

Because ERPs rely on the presentation of items to elicit the brain's electrical response, *amnesia* had to be defined in the present study as the inability to recognize (not simply the inability to freely recall) previously familiar material. For the present study, a screening procedure identified a group of highly hypnotizable individuals who reported recognition amnesia. In addition to this select group (who represented approximately 2% of the original subject pool), three other groups were selected: (a) high-hypnotizable individuals with recall (but not recognition) amnesia; (b) low-hypnotizable individuals who were asked to simulate hypnotic performance; and (c) low-hypnotizable individuals who were not asked to simulate hypnotic performance.

For the present study, all participants learned words during hypnosis, and ERPs were obtained to these words and to new words following hypnosis. ERPs were obtained first during the time when the amnesia suggestion was in effect, and once again following a cue to reverse amnesia. Several research questions were of interest that provided a basis for hypothesis testing using regression coding:

1. Do highly hypnotizable individuals who report amnesia (HH-Amn) differ electrophysiologically from all other individuals? Presumably, only such highly hypnotizable individuals experience amnesia.
2. Do low-hypnotizable simulators (LH-SimAmn), who mimic high-hypnotizable individuals in the behavioral report of amnesia, differ electrophysiologically from HH-Amn individuals? Although both groups of individuals may report amnesia, presumably only the latter experience amnesia.
3. Among low-hypnotizable individuals, are there electrophysiological features that differentiate simulators (LH-SimAmn) from nonsimulators (LH-NoAmn)? Such differences would be related to the phenomenon of simulation.
4. Among highly hypnotizable individuals, are there electrophysiological features that differentiate those who report recognition amnesia (HH-Amn) from those who do not (HH-NoAmn)? Such differences would be related to the phenomenon of amnesia, even among highly hypnotizable individuals.

These hypotheses concern the experience of amnesia and the process of simulating amnesia. Following the release of the amnesia suggestion, no amnesia or simulated amnesia is expected. Thus, any group effects related to these hypotheses would be expected to change on the retest following the cue to reverse amnesia. Otherwise, such differences should be ascribed to differences related to trait levels of hypnotic susceptibility.

Method

Participant Screening and Selection

Group screening. An initial pool of 484 university students was screened with the Harvard Group Scale of Hypnotic Susceptibility, Form A (HGSHS:A; Shor & Orne, 1962), administered by audiotape. These individuals provided informed consent and participated in exchange for extra credit toward their grades in a psychology class. The HGSHS:A includes 11 suggestions (e.g., arm is so stiff that it cannot bend) that follow a standardized hypnotic induction. This scale had been amended for the present study to include a recognition test (Allen, 1992; Allen, Law, & Laravuso, in press) in addition to the standard recall test. The recognition test was given immediately following the recall test—once before the cue to release participants from amnesia and once following the release cue. Aside from the addition of this recognition test, all portions of the HGSHS:A were administered in standard fashion.[2]

Scores on the HGSHS:A range from 0 to 11, reflecting the number of suggestions individuals report they actually experienced. Those individuals meeting criteria for either low- or high-hypnotic susceptibility were invited back for individualized screening. Low-hypnotic susceptibility criteria were an HGSHS:A score of 0 to 3 and recall of four or more items prior to the release of the amnesia suggestion (release cue). High-hypnotic susceptibility criteria were an HGSHS:A score of 8 to 11; recall of three or fewer items prior to the release cue; and reversibility of amnesia as defined by recall of at least 3 additional items, either during the recognition test or following the release cue. This reversibility criterion is slightly more stringent than the reversibility criterion of Kihlstrom and Register (1984), who required that only 2 additional items be recalled following release. A more stringent criterion was selected in the present study because not only did the standard release cue intervene between the two attempts at recall, but so did the recognition test, which would provide cues that would aid in subsequent recall.

Individual screening. Individual screenings were conducted using the Stanford Hypnotic Susceptibility Scale, Form C (SHSS:C; Weitzenhoffer & Hilgard, 1962). The SHSS:C contains 11 suggestions (e.g., being unable to smell ammonia that is held below the nose) that follow a standardized hypnotic induction. The SHSS:C, as compared to the HGSHS:A, has more difficult suggestions involving cognitive–perceptual distortions in addition to the simpler psychomotor suggestions. For the present study, the SHSS:C, like the HGSHS:A, had been amended to include assessment of recognition (Allen, 1992; Allen et al., in press) in addition to the standard assessment of recall. Aside from this change, all portions of the SHSS:C were administered in standard fashion. Participants again provided informed consent and received extra-credit points toward their psychology course grades.

Scores on the SHSS:C range from 0 to 12, reflecting the number of items to which an individual responds (the 12th item being response to an amnesia suggestion). Those individuals with SHSS:C scores that met criteria for low- or high-hypnotic susceptibility were invited back to participate in the main study. Criteria for low-hypnotic susceptibility

[2] Participants were given the standard period to freely recall what had occurred during hypnosis and then were tested for recognition using a list of 30 experiences, 11 of which had occurred during hypnosis. Following the recognition task, participants were given the prearranged amnesia release cue ("Now you can remember everything."). Following the cue to release amnesia was the standard second recall period, followed by a second recognition task (using exactly the same list as before). Finally, participants indicated whether they had responded to each of the 11 experiences.

on the SHSS:C were an SHSS:C score of 0 to 3 and recall of 4 or more items prior to the release cue. High-hypnotic susceptibility criteria were an SHSS:C score of 9 to 12, recall of 3 or fewer items prior to the release cue, and reversibility of amnesia (recall of at least 3 additional items, either during the recognition test or following the release cue).

Group composition. All participants in the main study were tested individually and were paid $15. On the basis of the HGSHS:A and SHSS:C screening scores, participants were classified into one of four groups. Half of the 20 selected persons meeting criteria for low hypnotizability on both the HGSHS:A and the SHSS:C were randomly assigned to the group of low-hypnotizable simulators (simulators; $n = 10$; mean SHSS:C score = 1.6, $SD = 1.1$). They were asked to simulate hypnotic performance (described below) throughout the entire procedure.

The other half of the low-hypnotizable persons were randomly assigned to the low-hypnotizable nonsimulators group (nonsimulators; $n = 10$, mean SHSS:C score = 1.8, $SD = 1.1$). Persons meeting high-hypnotizability criteria on both the HGSHS:A and the SHSS:C, but who showed breaching of amnesia when presented with recognition items, were assigned to the high-hypnotizable group (high; $n = 10$, mean SHSS:C score = 10.0, $SD = 1.1$). Participants in this group showed recall amnesia but not recognition amnesia during screening. Persons meeting high-hypnotizability criteria on both screening measures who additionally showed evidence of posthypnotic recognition amnesia (defined as three or fewer items from the SHSS:C recognized before the amnesia release cue, as well as reversibility of amnesia) were assigned to the virtuosos group (virtuosos; $n = 11$; mean SHSS:C score = 11.2, $SD = 0.4$). The groups did not differ in terms of age, $F(3, 37) < 1$, *ns*, gender ratio, $\chi^2(3, N = 41) = 5.90$, *ns*, or handedness score, $F(3, 37) < 1$, *ns*, on a standardized handedness test (Chapman & Chapman, 1987).

Procedure and Apparatus

Individuals provided informed consent to participate, completed a handedness questionnaire, and provided information concerning psychiatric and neurological history (negative for all participants). They were then given introductory information; members of the simulator group were given simulation instructions.

Introductory information and instructions. All participants were told that their hypnotist would be a PhD-level clinical psychologist whom they had not met previously. They were explicitly instructed not to discuss previous hypnosis experiences with the hypnotist, who was blind to experimental condition. Those assigned to the simulator group also received simulation instructions modelled after Orne (1959, 1979), which instructed each of them to behave like an excellent highly hypnotizable individual throughout the entire procedure (i.e., before, during, and after hypnosis), until they were free of the recording wires and back in the recording room. Participants were then brought to the adjacent room, introduced to the hypnotist, prepared for psychophysiological recording, and seated in a reclining chair.

Hypnosis and learning phase. The hypnotic induction was taken verbatim from the SHSS:C. After the induction, participants learned a list of six unrelated words to a criterion of two perfect serial recitations. This list was selected randomly from among a set of seven lists of six high-frequency words that had been matched for word frequency using the word frequency norms of Carroll, Davies, and Richman (1971). For learning, the words were presented at a rate of one word every 2 s (stimulus duration = 1,530 ms) on a computer screen mounted on a movable arm and positioned approximately 70 cm in front of the reclined participant's face. The hypnotist recited each word aloud as it appeared. Words subtended approximately 0.4° of visual angle vertically and between 0.8° and 1.5° of visual angle horizontally.

On completion of this learning task and some general deepening instructions (e.g., "let yourself relax completely"), participants performed a simple computerized recognition task in which they pressed a button with the thumb of their dominant hand to indicate recognition of words they had learned and pressed a button with their nondominant thumb for words they did not recognize. Electroencephalographic data were obtained during this task but will not be presented in this article. Learned words appeared on ⅓ of the trials, and unlearned words appeared on ⅔ of the trials. These unlearned words were matched for frequency of occurrence with the list that participants learned, and these unlearned words were never seen subsequently in any other tasks. Following this task and some more general deepening instructions, the following hypnotic amnesia suggestion was given for the list of words that participants had learned:

> You've done very good work on the task today. All that's important now is to enjoy the relaxation and listen to my voice. You may find that you've been so relaxed that you will have trouble recalling any of the words you have seen or heard in this room so far, and that's okay. In fact, it will prove to be so much effort to recall the words that you will prefer not to try. It will be much easier just to forget the words you've heard or seen so far in this room until I tell you that you can remember. You will just forget about the words you've seen or heard so far until I say to you: "Now you can remember everything." You will not remember anything about the words you've heard or seen so far in this room until then.

Approximately 30 s after the amnesia suggestion and following a few general relaxation instructions (e.g., "let yourself feel the comfort of deep relaxation"), participants learned a second list of six unrelated words (selected from among the remaining six of the original seven matched lists), presented in the same manner as the earlier list, but no recognition task followed. These words will be referred to as noncovered because, unlike the preceding list that was covered by an amnesia suggestion, no amnesia suggestion was given for these words. Participants received a few more general deepening instructions and then the hypnotist asked them to awaken from hypnosis (again using the SHSS:C instructions).

Prerelease assessment phase. Once awake, participants were asked to verbally recall what they could from their hypnosis experience. The hypnotist specifically asked what words they recalled learning during hypnosis. Following that, they participated in a skin-conductance assessment procedure, the results of which are not reported here. Of relevance to the present article, however, is that each of the six words on the list covered by the amnesia suggestion appeared once during this task intermixed with distractor items.

Next, individuals participated in the ERP assessment procedure, a computerized recognition oddball task that included randomly ordered presentations of words from the list covered by amnesia (covered list, on $^1/_7$ of trials), words from the learned list not covered by the amnesia suggestion (noncovered list, on $^1/_7$ of trials), and unlearned words from the five unlearned lists (unlearned lists, on $^5/_7$ of trials). This arrangement made it likely that the learned lists, appearing relatively infrequently against a background of unlearned material, would elicit a large LPC (P3) if they were recognized. Participants were presented with 5 blocks of 42 words, with each block containing a different random ordering of all six words from all seven lists (two learned and five unlearned). At the beginning of each block (in addition to the 42 words), the same three words appeared (*drive*, *after*, and *yellow*) and were not included for purposes of signal averaging. Stimulus ordering was constant across all participants. Stimulus duration was 306 ms, and onset-to-onset interval was 1,999 ms. Monitor distance and visual angles subtended by stimuli were identical to those of the learning phase.

In this phase, the hypnotist instructed participants that they would see a long list of words, some of which they had learned that day. Participants were instructed to press the "Yes" button with the thumb of their dominant hand if the word on the screen was one of the words they remembered learning during the session, and to press the "No" button with the nondominant thumb for all the other words. They were told to respond as quickly and accurately as possible.

Table 1
Number of Words Recognized Before and After the Release From the Amnesia Suggestion for Participants in Each of the Four Groups

	Nonsimulators		Stimulators		Highs		Virtuosos	
List	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Covered								
Before	29.0_a	1.2	$11.0_{b,c}$	13.3	22.1_b	11.0	11.6_c	11.5
After	28.7	1.8	28.9	1.7	27.0	4.4	28.5	1.6
Noncovered								
Before	26.8_a	2.6	24.8_a	3.3	23.9_a	5.9	12.3_b	10.6
After	27.6	2.7	28.2	2.0	25.8	3.9	26.1	3.5
Unlearned[d]								
Before	1.2	1.4	2.3	5.0	0.8	0.7	0.4	0.6
After	0.9	1.2	1.0	2.2	0.8	0.8	0.8	0.6

Note. *Covered* refers to the list of words learned during hypnosis that was covered by the amnesia suggestion, and *noncovered* refers to the list of learned words not covered by the amnesia suggestion. Maximum possible number of recognized words = 30; five presentations of each of the six words occurred during each event-related potential task. Within each row, means without common subscripts differ significantly ($p < .01$) by Tukey's studentized range method. Rows without subscripts indicate no significant differences between groups were observed. [d] Number mistakenly classified as words previously learned.

Postrelease assessment phase. Following the ERP task, the prearranged release cue was given (i.e., "Now you can remember everything."). A free recall period followed the release cue, during which the hypnotist specifically inquired what words were now recalled.

Two postrelease psychophysiological assessments followed: another skin-conductance response task identical to the one already mentioned (the result of which is not reported here) and another ERP task. The ERP procedure and stimuli (unlearned as well as learned words) were identical to the prerelease assessments. Stimuli were presented in the same order as when presented in the tasks prior to the release cue.

Psychophysiological Recording

Electroencephalographic (EEG) activity was recorded using Ag-AgCl electrodes affixed to Cz, Pz, and two off-midline sites at the junction of the parietal and temporal lobes, all referenced to linked mastoids. A ground clip was affixed to the right ear. Electrooculographic activity was recorded to monitor eye movements using Ag-AgCl electrodes in a bipolar arrangement, superior orbit referenced to the outer canthus of the right eye. All electrode impedances were less than 5K ohms. A Beckman Dynograph with AC differential amplifiers was used to amplify the signals. Analog filtering was accomplished using the Dynograph's 30 Hz low-pass filter and a 1-s time constant.

On-line digitization of EEG, electrooculogram, and two reaction channels ("yes" and "no") occurred at 200 Hz. Digitized data were subsequently analyzed off-line. Data were first corrected for blink artifact using the method of Gratton, Coles, and Donchin (1983). The blink-corrected data were then digitally filtered using a 21-point finite-impulse response low-pass filter with a half-amplitude frequency of 12.5 Hz. After the partitioning of the epoch to accommodate data points at each end of the epoch required for filtering, the remaining epoch of 1,250 ms extended from 125 ms before stimulus onset to 1,125 ms after stimulus onset. Data were finally averaged by word list (covered, noncovered, unlearned).

Results

Results from all repeated-measures analyses of variance (ANOVAs) were epsilon-corrected (Greenhouse & Geisser, 1959) where appropriate, as indicated by "$p\epsilon =$ " rather than "$p =$ "; unadjusted degrees of freedom are always reported.

Self-Report Data

Behavioral responses from the ERP task provided an opportunity to assess recognition amnesia. These data are presented in Table 1. These recognition data were subjected to a 4 × 2 × 3 repeated-measures ANOVA with group membership as the between-subjects factor and time of recall (before or after release) and list (covered, noncovered, unlearned) as within- subjects factors. All main effects were significant: for group, $F(3, 37) = 8.43$, $p < .001$; for time, $F(1, 37) = 37.44$, $p < .001$; and for list, $F(2, 74) = 531.05$, $p\epsilon < .001$, $\epsilon = .91$. Additionally, all interactions were significant: for Time × Group, $F(3, 37) = 8.62$, $p < .001$; for List × Group, $F(6, 74) = 5.48$, $p\epsilon < .001$, $\epsilon = .91$; and for Time × List × Group, $F(6, 74) = 6.48$, $p\epsilon < .001$, $\epsilon = .87$. To decompose the interaction, 4 (group) × 3 (list) repeated measures ANOVAs were conducted separately for each time of assessment. Before the release of amnesia, there were significant main effects for group, $F(3, 37) = 9.36$, $p < .001$, and for list, $F(2, 74) = 116.18$, $p\epsilon < .001$, $\epsilon = .86$, and a significant Group × List interaction, $F(6, 74) = 6.50$, $p\epsilon < .001$, $\epsilon = .86$. Following the release of amnesia, there was only a significant main effect for list, $F(2, 74) = 2{,}020.33$, $p\epsilon < .001$, $\epsilon = .90$, in the absence of any other significant effects.

To follow-up the interaction present before the release of amnesia, we conducted simple main effects analyses separately for each list (covered, noncovered, unlearned) with group as the between-subjects factor. As shown in Table 1, no groups differed significantly in number of unlearned words classified as learned. The virtuosos recognized significantly fewer ($p < .01$, Tukey's studentized range method) noncovered words than all other groups (who did not differ significantly from one another), indicating that the virtuosos displayed a spontaneous amnesia for words not covered by suggestion. For the covered words, the simulators differed significantly from the nonsimulators, and the virtuosos differed significantly from both the nonsimulators and the highs.

Following the release cue no groups differed significantly in the number of items recognized for either the covered or noncovered list (see Table 1). This latter finding suggests that any differences in how well the groups identified the material cannot be attributed to differences in how well the material was learned, because all participants later identified words from the learned lists equally well following the release from amnesia.

ERP Comparisons

The behavioral responses above indicated that not all participants within each group responded as predicted on the basis of their SHSS:C screening performances. To obtain homogeneous groups for the ERP analyses, therefore, participants were reclassified on the basis of these behavioral recognition responses into those who did and those who did not report recognition amnesia during the ERP assessment procedure. Recognition amnesia was operationalized in similar fashion to the amnesia criterion for the SHSS:C. Participants recognizing 25% or fewer presentations of the covered words were classified as having amnesia and those recognizing more than 25% of the words were classified as not having amnesia. This reclassification resulted in four groups: LH-NoAmn ($n = 14$); LH-SimAmn ($n = 6$); HH-NoAmn ($n = 14$); and HH-Amn ($n = 7$).[3] The mean number of covered words recognized by participants who did not report amnesia was 27.9 ($SD = 5.0$) for the LH-NoAmn participants and 24.0 ($SD = 7.2$) for the HH-NoAmn participants; the difference was not significant. For participants reporting amnesia, the means were 1.7 ($SD = 2.7$) for the LH-SimAmn participants and 1.9 ($SD = 2.9$) for the HH-Amn participants; the difference was not significant. All analyses presented are for the data at site Pz.

ERP Amplitudes

Five peak amplitudes were obtained by calculating the maximum positive or negative value within a search window: P1 (125–175 ms), N1 (175–225 ms), P2 (225–275 ms), N400 (275–475 ms), and LPC (350–700 ms). The amplitude of each peak was expressed as the μV change from the peak prior to it (e.g., N1 equalled N1 minus P1), with the exception of P1, which was expressed as μV difference from prestimulus baseline. Search windows were established after visual inspection of the obtained grand-average waveforms, which are presented in Figure 1. These five amplitudes were calculated for the ERP in response to the covered list, for the ERP in response to the noncovered list, and for the average ERP in response to all five unlearned lists.

Each of these five amplitude measures was treated as a separate variate in a repeated measures multivariate analysis of variance (MANOVA) with group (LH-NoAmn, LH-SimAmn, HH-NoAmn, HH-Amn) as the between-subjects factor and list (covered, noncovered, unlearned) and time of assessment (before or after release from amnesia) as the within-subjects factors. The MANOVA approach is conservative in that it tests the hypothesis that group, list, or time centroids (of all five peak measures) differ, whereas there is no reason to expect a priori that the group, list, or time centroids will differ across all five amplitude measures. In fact, it would be unlikely that the earliest components would be differentially affected by list. Because effects involving group were of interest, follow-up tests for the significant effects involving group were conducted using regression-coded hypothesis testing derived from the previously mentioned four research questions. Main multivariate effects were significant for time of assessment, Hotelling's $t(2) = 132.14$, approximate $F(5, 33) = 23.57$, $p < .001$, and for list, Wilks's $\Lambda = .206$, approximate $F(10, 140) = 16.85$, $p < .001$, but not for group, Wilks's $\Lambda = .728$, approximate $F(15, 91.5) = 0.74$, *ns*. Two of the multivariate interactions were also significant: Time × Group, Wilks's $\Lambda = .441$, approximate $F(15, 91.5) = 2.10$, $p < .02$, with significant univariate effects for the N1, $F(3, 37) = 3.41$, $p < .05$, N400, $F(3, 37) = 3.63$, $p < .05$, and LPC $F(3, 37) = 5.90$, $p < .01$) components; Time × List, Wilks's $\Lambda = .601$, approximate $F(10, 140) = 4.04$, $p < .001$, due to a significant univariate effect for the LPC component, $F(2, 74) = 11.49$, $p_\epsilon < .001$, $\epsilon = .94$). The List × Group and Time × List × Group interactions were not significant, Wilk's $\Lambda = .43$, approximate $F(30, 82.8) = .92$, *ns*, and Wilk's $\Lambda = .385$, approximate $F(30, 82.8) = 1.06$, *ns*, respectively.

To decompose the Time × Group interaction, planned group comparisons using regression coding (displayed in Table 2) were used to test four hypotheses concerning the change in ERPs from before to after the release of amnesia: (a) HH-Amns differed from the other three groups; (b) HH-Amns differed specifically from the LH-SimAmns; (c) the LH-SimAmns differed from the LH-NoAmns; and (d) HH-Amns differed from the other high-hypnotizable participants who did not report recognition amnesia (HH-NoAmns).

Table 2 displays the results of the regression contrasts. Hypothesis 1 was supported showing that from the first (before release of amnesia) to the second (after the release of amnesia) assessment, the HH-Amns responded with a pattern of electrophysiological change that was distinct from all other participants. Hypothesis 2 was also supported, indicating the HH-Amns showed a distinct pattern of electrophysiological change compared to LH-SimAmns, who reported a similar amnesia. Hypothesis 3 was not supported, indicating that no significant differences were observed between LH-SimAmns and LH-NoAmns in the pattern of electrophysiological change. Finally, Hypothesis 4 was supported, indicating that even among all participants identified as high hypnotizable, those who responded with recognition amnesia showed a distinct pattern of change in ERPs from before to after the release of amnesia.

ERP Latencies

The latencies associated with the five peak amplitudes (P1, 125–175 ms; N1, 175–225 ms; P2, 225–275 ms; N400, 275–475 ms; and LPC, 350–700 ms) were obtained and analyzed using a repeated measures MANOVA procedure analogous to that used to analyze the amplitude data. Only the multivariate main effect for time was significant, Hotelling's $t(2) = 110.23$, approximate $F(5, 33) = 19.66$, $p < .001$, due to significant latency changes in the P1 (before = 159 ms, after = 154 ms), P2 (before = 253 ms, after = 258 ms), N400 (before = 375 ms, after = 345 ms), and LPC (before = 573 ms, after = 532 ms)

[3] The reclassified groups were comprised of participants from the screening-defined groups as follows: LH-NoAmn = 10 nonsimulators, 4 simulators; LH-SimAmn = 6 simulators; HH-NoAmn = 8 highs, 6 virtuosos; HH-Amn = 2 highs, 5 virtuosos.

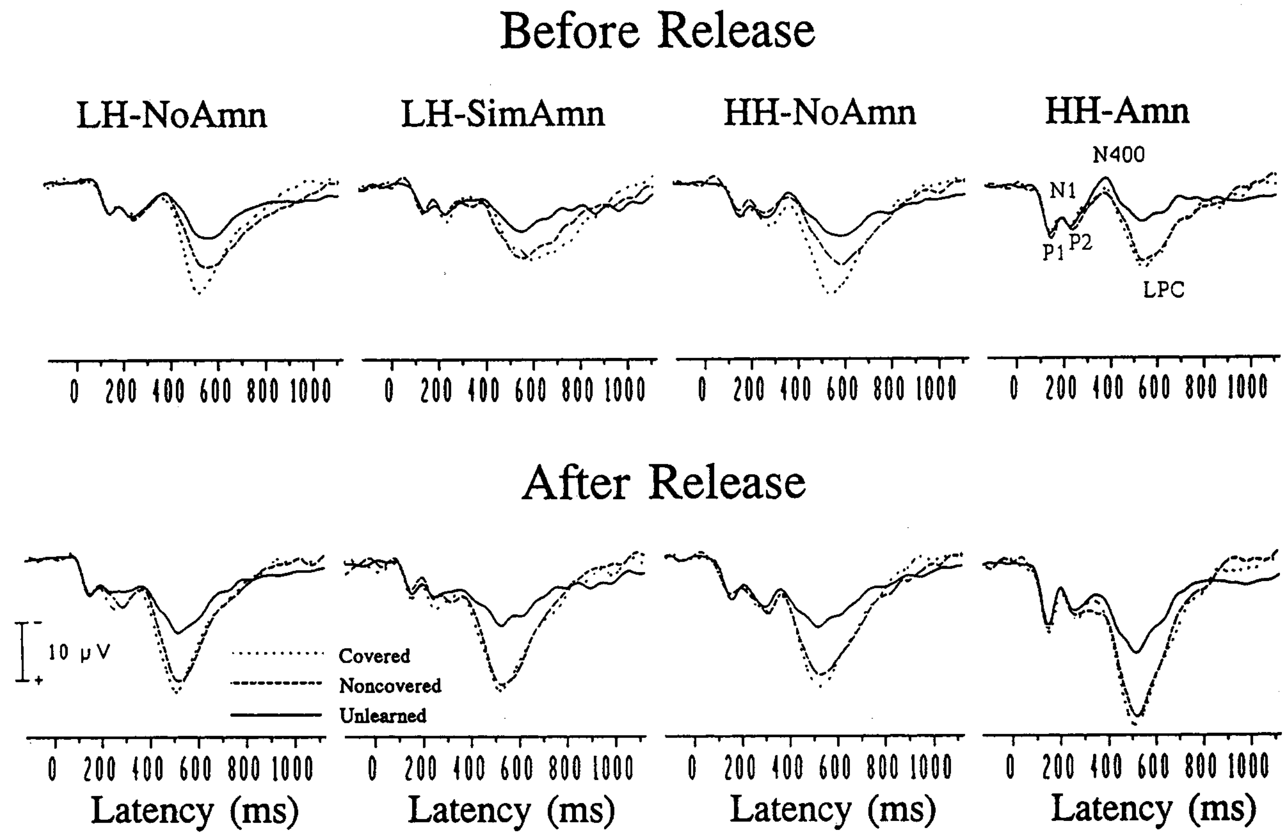

Figure 1. Grand-average event-related potentials before and after the cue to release amnesia for groups reclassified by whether they reported recognition amnesia in response to the list covered by the amnesia suggestion. LH-NoAmn = low-hypnotizable participants who did not report recognition amnesia; LH-SimAmn = low-hypnotizable participants who simulated recognition amnesia; HH-NoAmn = high-hypnotizable participants who did not report recognition amnesia; HH-Amn = high-hypnotizable participants who reported recognition amnesia.

components, all $Fs \geq 6.97$, $ps < .02$. Neither the main effects for group or for list nor any of the interactions were significant.

Reaction Times

The reaction time data to stimuli that evoked the ERPs were analyzed to describe the behavioral response patterns present during the ERP tasks. The mean reaction times for each list (covered, noncovered, unlearned) presented in Table 3 were examined in a 4 (group) × 3 (list) × 2 (before or after release from amnesia) repeated measures ANOVA. Significant main effects emerged for list, $F(2, 74) = 40.53$, $p_\epsilon < .001$, and for time, $F(1, 37) = 4.56$, $p < .05$, but not for group. Additionally, the List × Group interaction was significant, $F(6, 74) = 3.62$, $p_\epsilon = .01$. None of the other interactions was significant. Regarding the List × Group interactions, simple main effects conducted separately for each item type (covered, noncovered, unlearned) revealed that no groups differed significantly from one another in response latency, $Fs(3, 37) \leq 1.51$, $ps \leq .23$. As shown in the lower portion of Table 3, simple effects within groups found that all groups had longer response latencies to the learned than to the unlearned items, although not significantly so for the HH-Amn group. Follow-up Bonferroni-corrected tests collapsing across time showed that for the LH-NoAmn group, the latencies to the noncovered items significantly exceeded those to the unlearned items (no other significant pairwise comparisons); for the LH-SimAmn group and the HH-NoAmn groups, latencies to both the covered and noncovered items exceeded those to the unlearned items (but no significant difference between covered and noncovered).

To summarize the reaction time data with respect to amnesia, the HH-Amn group shows neither a slowing nor a facilitation of reaction time to learned items versus unlearned items. High-hypnotizable participants who do not report amnesia and low-hypnotizable participants who simulate amnesia, by contrast, show a slowing of reaction time to learned items relative to unlearned items. Low-hypnotizable participants who do not report amnesia also show a slowing of reaction time to learned items, but only to the list not covered by the amnesia suggestion.

Discussion

Members of all groups exhibited larger LPC amplitudes to learned than to unlearned words. Given what is known of the determinants of LPC (P3) amplitude (cf. Johnson, 1986), this finding suggests that all participants perceived previously learned items as a distinct and rare class of stimuli. An important question, however, is whether they perceived previously

Table 2
Contrasts and Regression Coding for Participants Classified on the Basis of Recognition Amnesia

Hypothesis	Results of contrasts (Time × Contrast interaction)		Regression coding			
	Hotelling's r^2	p	LH-NoAmn	LH-SimAmn	HH-NoAmn	HH-Amn
Hypothesis 1			−1	−1	−1	3
Multivariate	30.74	<.001				
Univariate P1		<.02				
Univariate N1		<.01				
Univariate N400		<.01				
Univariate LPC		<.01				
Hypothesis 2			0	−1	0	1
Multivariate	15.07	<.05				
Univariate P1		<.05				
Univariate N1		<.02				
Univariate N400		<.10*				
Univariate LPC		<.10*				
Hypothesis 3			−1	1	0	0
Multivariate	2.11	*ns*				
Hypothesis 4			0	0	−1	1
Multivariate	31.42	<.001				
Univariate P1		<.15*				
Univariate N1		<.01				
Univariate N400		<.01				
Univariate LPC		<.001				

Note. LH-NoAmn = low-hyponotizable participants not reporting recognition amnesia; LH-SimAmn = low-hypnotizable participants simulating recognition amnesia; HH-NoAmn = high-hypnotizable participants not reporting recognition amnesia; HH-Amn = high-hypnotizable participants reporting recognition amnesia.
* Not significant (included for descriptive purposes only).

learned words as distinct and rare for similar reasons (viz. explicit recognition as previously learned). The results of the regression-coding analyses identified that the HH-Amn group exhibited a distinct pattern of amnesia-related ERP effects, raising the possibility that for these individuals, the LPC effect may reflect something other than explicit recognition of once-familiar stimuli.

Findings in the literature outside the domain of hypnosis suggest that psychophysiological measures can tap recognition without awareness. For example, ERPs may be sensitive to once-familiar faces in the absence of a phenomenological experience of recognition in prosopagnosia (Renault, Signoret, Debruille, Breton, & Bolgert, 1989). Although it is possible that high-hypnotizable individuals who report amnesia do not recognize the previously learned words as having been learned, it is also possible that the high-hypnotizable individuals who report amnesia may not accurately report their experience (i.e., they may report amnesia, but not experience amnesia).

Is It Plausible That HH-Amn Participants Accurately Report Their Experience of Amnesia?

When simulators report amnesia, they report amnesia to only the list covered by the amnesia suggestion. HH-Amn participants, by contrast, report amnesia to not only the list covered by suggestion but spontaneously report some degree of amnesia to the list not covered by suggestion (see Table 1). Spontaneous amnesia, in addition to the suggested amnesia, characterized only some of these HH-Amn participants, but none of the other high-hypnotizable or low-hypnotizable participants. Simple simulation or capitulation to demand characteristics is therefore an insufficient explanation because the low-hypnotizable simulators failed to demonstrate this phenomenon.

The behavioral measure of reaction time also suggests that the HH-Amn participants who report amnesia are not attempting to conceal recognized information. Whereas responses to covered learned words are slowed relative to responses to unlearned words for the LH-SimAmns, reaction times do not differentiate the learned from the unlearned words for the HH-Amns, although it must be noted that the HH-Amn participants are more variable in their response latencies (see Table 3). The length of time required to evaluate stimuli (independent of response selection) can be indexed by the latency of the LPC component (e.g., Donchin et al., 1978; Kutas, McCarthy, & Donchin, 1977; McCarthy & Donchin, 1981). Stimulus evaluation time as indexed by LPC latency did not differ between lists or between groups of individuals. If stimulus evaluation time did not differ between lists or groups, then response-related processes must account for the reaction time slowing of the low simulators to the previously learned but covered items. These findings suggest that the LH-SimAmn participants experienced a deception-related response competition that the HH-Amn participants did not. The LH-SimAmn participants are slower to respond to all learned words. Presumably, the LH-SimAmn participants first identify the covered and noncovered

Table 3
Reaction Times (in Milliseconds) for Each List and Group and Results of Follow-up Analyses for Groups Classified by Recognition Amnesia

List	LH-NoAmn		LH-SimAmn		HH-NoAmn		HH-Amn	
	Reaction times							
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Covered								
Before	539	64	600	74	613	102	585	257
After	497	57	561	56	554	74	606	155
Noncovered								
Before	564	59	622	69	614	95	554	241
After	509	59	545	46	569	91	588	134
Unlearned								
Before	531	71	511	87	574	80	525	210
After	474	63	499	56	522	75	572	143
	Simple effects							
Effect								
Time	<.01		*ns*		<.05		*ns*	
List	<.01		<.01		<.01		*ns*	
Time × List	*ns*		*ns*		*ns*		*ns*	

Note. LH-NoAmn = low-hypnotizable participants not reporting recognition amnesia; LH-SimAmn = low-hypnotizable participants simulating recognition amnesia; HH-NoAmn = high-hypnotizable participants not reporting recognition amnesia; HH-Amn = high-hypnotizable participants reporting recognition amnesia. *Covered* refers to the list of words learned during hypnosis that was covered by the amnesia suggestion; *noncovered* refers to the list of learned words not covered by the amnesia suggestion; and *unlearned* refers to the list with which participants were not familiar.

words as learned, yet only the noncovered words require a *yes* response; LH-SimAmn participants must subsequently alter their response to appear amnesic. The longer reaction times for these covered items than for unlearned items (even though both require a *no* response) for the LH-SimAmn participants may therefore reflect deception-related response processes. The present data suggest that the output inhibition models of posthypnotic amnesia (e.g., Coe, 1978; Huesmann, Gruder, & Dorst, 1987) may account for the behavior of the LH-SimAmn participants, but not for that of the HH-Amn participants.

These findings in the present study are consistent with skin-conductance data of Kinnunen, Zamansky, and Block (1994) that show that LH-SimmAmn show a much larger incidence of deception-related skin-conductance responses than do high-hypnotizable individuals. The skin-conductance data of Kinnunen et al. (1994), the reaction-time data of the present study, and the finding that many high-hypnotizable participants (14 out of 21) in the present study did not report recognition amnesia collectively suggest that high-hypnotizable participants accurately report their subjective experience.

It is worth noting that participants were initially selected and classified on the basis of recognition amnesia during screening and were then reclassified on the basis of performance during an ERP memory assessment. That not all participants responded as initially expected could result from multiple factors, including the very different nature of the screening assessment (incidental learning) and the ERP assessment (intentional), and the time elapsed from screening to the psychophysiological assessment (typically 1–2 months). Replication is required to determine whether such changes from screening to a subsequent (and more difficult) assessment are typical.

Mechanisms of Posthypnotic Recognition Amnesia Suggested by ERP Data

If one accepts the premise that the HH-Amn participants are accurately reporting their subjective experience of amnesia, one could ask what mechanisms make this amnesia possible in them but not in other participants. The regression contrasts presented in Table 2 (Hypothesis 1) indicate the amplitudes of the P1, N1, N400, and LPC components of the ERPs of the HH-Amn participants change from the prerelease to the postrelease assessment in a manner distinct from those of the other three groups. When the HH-Amn participants reported amnesia, they had significantly smaller P1 (8.8 vs. 12.1 μV, $p < .001$), smaller N1[4] (− 4.4 vs. −8.3 μV, $p < .001$), larger N400 (−9.1 vs. −4.9 μV, $p < .001$), and smaller LPC (13.3 vs. 19.3 μV, $p < .001$) amplitudes than when they did not report amnesia (see Figure 1). Simulation of hypnotic amnesia by low-hypnotizable participants is insufficient to produce amnesia-related changes in the ERP.

Although the present study is the first to use ERP measures in the study of posthypnotic amnesia, these results are highly consistent with the few existing studies of hypnotic phenomena that demonstrate alterations in the amplitudes of early attention-related ERP components during perception-related hypnotic phenomena. Enhanced P1 amplitudes were found in highly hypnotizable participants during hypnosis with suggestions to intensify attention to somatosensory stimuli (Spiegel et al., 1989). Jasiukaitis and colleagues (1993) found that a sug-

[4] For negative components, smaller indicates less negative, and larger indicates more negative.

gestion for a hypnotic obstruction reduced P1 and N1 components of the visual ERP in highly hypnotizable participants in a manner similar to directed inattention. Outside of hypnosis, Galbraith et al. (1972) found enhanced positivity in the region from 100 to 300 ms poststimulus to only the task-relevant modality (visual or auditory) in high- (but not medium- or low-) hypnotizable individuals. Within-subjects augmentation of the P1 component has been related to sustained attention to stimuli appearing within a particular visual field (Heinze, Luck, Mangun, & Hillyard, 1990; Luck, Heinze, Mangun, & Hillyard, 1990), possibly reflecting a facilitation of early sensory processing that follows from a tuning or facilitation of the visual pathways (Luck et al., 1990). These findings raise the possibility that at the earliest stages of information processing the HH-Amn participants may attenuate or gate the stimulus input in a way that other individuals cannot.

The subsequent N1 component is similarly sensitive to attention (for a review, see Näätänen, 1992). The N1 component is larger when individuals recruit attentional resources to attend to a target (e.g., Luck et al., 1990). The present findings suggest that the HH-Amn participants recruit fewer attentional resources to stimuli when amnesia is experienced than when it is not. It must be cautioned, however, that the P1 and N1 amplitudes of the HH-Amn group are not significantly smaller than those of other participants; these components simply show an amnesia-related change in the HH-Amn participants not seen in other participants.

With respect to the N400 findings, many studies have examined the determinants of N400 amplitude, yet all involve paradigms that are quite different than the present study. As a generalization, smaller N400 amplitudes are observed when representations of a word are easier to access because, for example, it completes a sentence in a semantically appropriate fashion (Kutas & Hillyard, 1980), it has been seen before (Mitchell, Andrews, & Ward, 1993; Van Petten et al., 1991), or it is within episodic memory (Fischler, Bloom, Childers, Arroyo, & Perry, 1984; Fischler, Childers, Achariyapaopan, & Perry, 1985). These findings imply that the representations of words (unlearned as well as previously learned) may be more difficult to access for the HH-Amn participants. Other investigators have suggested that hypnotic amnesia may disrupt contextual cues that may usually aid in retrieval (e.g., Evans, 1988; Evans & Kihlstrom, 1973; Geiselman, Bjork, & Fishman, 1983; Kihlstrom, 1980; Kihlstrom & Evans, 1979; Kihlstrom, Evans, Orne, & Orne, 1980; Kihlstrom & Wilson, 1984). The mechanism by which this could occur remains speculative, and it is unclear whether such a mechanism operates to somehow raise the criterion of word recognition generally, or whether it could operate specifically on material that has been covered by an amnesia suggestion. In the present study, N400 failed to differentiate lists, implying that if such a mechanism were operative, it was not selective with respect to previously learned words. Further research that specifically manipulates the ease with words may be accessed is required to evaluate this possibility. For example, the ERP assessment could include words learned prior to the hypnosis session (which presumably could be recognized), in addition to words learned during the hypnosis session. If the amplitude of the N400 varies systematically with the accessibility of the words, this would suggest a mechanism that can selectively affect accessibility of material in memory.

In addition to further examination of individuals with posthypnotic amnesia, an examination of other amnesic individuals might prove useful. For example, it is plausible that individuals with amnesia of functional origin (e.g., Dissociative Identity Disorder, Dissociative Amnesia, amnesia in the context of posttraumatic stress disorder) may involve mechanisms quite different from those involved in amnesias of organic origin (e.g., cerebrovascular accidents, hypoxia, Korsakoff's) or pharmacological origin (e.g., following administration of amnesic agents such as Halcion or Scopolamine). Although it is possible that some of the amnesia-related ERP features identified in the present study would characterize amnesia without respect to etiology, it is also possible that such features would characterize only those amnesias of a functional origin that do not involve brain lesions or pharmacological disruption. A comparison of amnesias of diverse etiologies using ERP as well as other measures could help refine our understanding of the mechanisms of amnesia and, possibly, the brain systems involved.

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