Event-related Potential Correlates of Suggested Hypnotic Amnesia

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An indirect event-related potential (ERP) memory assessment procedure was used to study ERP correlates of suggested hypnotic amnesia. Subjects selected for high or low hypnotic susceptibility learned two 5-word lists prior to hypnosis. They then listened to a recorded hypnotic induction and amnesia suggestion for one of the two lists. After being aroused from hypnosis, they learned a third list. ERPs were then collected during a recognition task in which subjects were presented with a random ordering of the three lists intermixed with seven lists of unlearned words. Subjects were required to press one button if the word was from the third list learned, and another button if the word was unlearned or from words learned pre-hypnosis. Thus response requirements were identical for the first two lists learned. A subgroup of low-hypnotizables were asked to simulate hypnotic amnesia. Only subjects who later demonstrated hypnotic amnesia on a recognition test showed significantly different ERP responses (larger P300 amplitude) to words for which amnesia had been suggested compared to control words. The ERPs of these high-hypnotizable amnesics significantly differed from those of both the other groups (i.e., high- and low-hypnotizables who did not report amnesia, and simulators who reported, but did not experience amnesia). This result indicates that the phenomenon of suggested hypnotic amnesia cannot be explained solely by behavioral compliance or simulation. (Sleep and Hypnosis 1999;1:122-128)

Key words: suggested hypnotic amnesia, amnesia, hypnosis, ERP, P300

INTRODUCTION

It has long been established that hypnotized subjects sometimes act in accordance with suggestions that they will not be able to remember specific information or events until given a retrieval cue (1-4). Subjects who exhibit this behavior, known as suggested hypnotic amnesia, when tested for recall, report none or only a portion of the specific information targeted by the amnesia suggestion. After they receive the retrieval cue, they then report recalling more, or all, of the previously inaccessible information.

Considerable controversy surrounds the explanation of this phenomenon. What is going on in the mind of the subject acting under the influence of an induced suggestion for hypnotic amnesia? Subjects frequently report experiencing a temporary involuntary inability to recall the suggested information. These reports are consistent with the notion that the information for which subjects are hypnotically amnesic is being stored in a special manner precluding consciousness of the information (5). In general, cognitive perspectives regard hypnotic amnesia as a genuine phenomenon of memory similar to clinical amnesia and perhaps related to motivated forgetting (2-4,6). From this point of view, subjects reporting hypnotic amnesia are experiencing an actual disturbance of memory - a blocking or interference with retrieval processes.

A contrary view sees hypnotic amnesia as mere behavioral compliance. According to this account, subjects are fully conscious of the information for which amnesia has been suggested: they remember the information perfectly well, but simply are not reporting it, playing a role in accordance with the demand characteristics of the experiment (7-9). From this perspective, suggested hypnotic amnesia is seen as nothing more than a reporting inhibition motivated by social-psychological factors in the

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experimental setting (10). Advocates of this perspective argue that the information is not being stored in any special manner precluding conscious recall; presumably it is being treated in exactly the same manner as other information until the experiment challenges the subject (to not be able) to report the information. Although a number of studies have utilized event-related potentials (ERPs) to investigate perceptual processes in hypnosis (see 11 for a review), only one (12) has previously addressed hypnotic amnesia. In the Allen et al. study, subjects selected for high or low hypnotizability were taught two lists of words during hypnosis; one list was subsequently covered by suggested amnesia. Following arousal from hypnosis, ERPs were measured while the subjects behaviorally indicated by button press whether or not they had learned words from the two learned lists randomly intermixed with five more word lists, both before and after an amnesia reversal cue. Subjects who exhibited amnesia showed a different pattern of ERP changes on reversal of suggested amnesia than subjects who did not report amnesia.

While the experimental design of Allen et al. s study demanded that subjects respond differently to learned and unlearned words, our design was based on an indirect ERP memory assessment procedure that identifies learned material, whether or not subjects give intentional responses indicating that they had learned it (13). This methodology thus unconfounds the cognitive, or brain-based assessment of suggested hypnotic amnesia from the overt motor response of identifying recalled information.

In the current study, all subjects first learned two simple word lists. They were then hypnotized and given amnesia suggestions for forgetting one of these lists. A third list of comparable words was learned after the hypnotic induction was lifted. These post-hypnosis words served as the target words to be identified in a recognition task. The recognition task presented a random ordering of all three learned lists (Target, Amnesia-suggested, and Control words from the first two lists), which were inter-mixed with seven Unlearned word lists of comparable frequency. To eliminate the possibility of compliant role-playing by hypnotized subjects who might actively inhibit reporting that they recalled the words for which amnesia was suggested, the following response procedure was used. Subjects were instructed to respond yes (by pressing the appropriate button) if the word appearing on the computer monitor was from the Target list they had learned after hypnosis. If it were not a Target word, then they were to respond with the no button. That no response applied to those words from the seven Unlearned lists as well as the words learned from the first two lists, both the Amnesia and the Control words. In this way, subjects were never asked to indicate explicitly whether or not they remembered the words for which they had been given amnesia suggestions. Moreover, response requirements were identical (no) for both the Amnesia word list and the non-amnesia, Control word list learned prior to the hypnotic induction. The primary dependent measure compares the ERP waveforms for each of the four types of lists.

If hypnotic amnesia affects only overt motor response processes and not internal, cognitive processing of information, then the ERP waveforms elicited by the Amnesia-associated word list and the Control lists should be identical. Our contrary prediction was that Amnesia-suggested word lists would elicit ERPs that were distinctive and statistically different and from the waveforms elicited by the non-amnesia words.

The particular waveform selected for analysis was the P300 component of the ERP. It has been found to index task relevance and stimulus significance (14). P300 amplitude is also greater for unexpected, or surprising, stimuli than familiar ones (15). We expected that P300 amplitude would be significantly different in response to Amnesia list words compared to the Control list words for subjects who reported experiencing amnesia. There should be no difference in the P300 amplitudes between the two types of word lists for those subjects who do not experience hypnotic amnesia.

METHOD

Subjects

Subjects (Ss) were college students in the introductory psychology course at Stanford University who had scored high (8-10) or low (0-4) on a modified version of the Harvard Group Hypnotizability Scale, Form A (10 items, scored 0-10; 16). In addition, Ss received a 60-minute hypnosis training session conducted by P.G.Z., during which they also listened to a brief taped hypnosis induction. This tape was used later as the standardized induction during the experiment. Twelve of the low-hypnotizable subjects were randomly selected to act as simulators. The 47 Ss (23 male, 24 female, ages 17-22) were paid $10 each for their participation. Data from three subjects who failed to follow the instructions were subsequently discarded.

Procedure

Upon arrival at the laboratory, Ss read and signed a consent form (describing the experiment as studying hypnosis, learning and memory) and were paid. They were fitted with an elastic electrode cap (ElectroCap, Intl.) for EEG monitoring, and seated in a comfortable partially reclining chair inside a sound-insulated, electrically shielded booth. A 14 inch gray-scale computer monitor was visible through a small window in the booth at a distance of 100 cm from the subject. A two-button computer mouse was mounted on the right arm of the chair. The experimenter communicated with the subject from an adjacent room via intercom. Before the experiment began, subjects in the Simulator group were instructed to pretend that they were hypnotized, and to follow any hypnotic suggestions as if they were really hypnotized.

Learning-Memory Tasks

In the course of the experiment, all subjects learned the same three lists of 5 words: a list of Animals (DOG, CAT, HORSE, COW, TIGER); a list of Fruits (GRAPE, APPLE, PEACH, ORANGE, PEAR); and a list of Metals (IRON, COPPER, STEEL, GOLD, SILVER). The order of the three lists was counterbalanced. An identical procedure was used for learning each of the lists: The five words from the selected list were presented in sequence on the monitor. The words were displayed against a black background in all capital, white letters 7.5 cm tall and 11-20 cm wide. Each word appeared for 2 seconds, with 3 seconds stimulus-onset asynchrony (SOA). The Ss were instructed to pronounce each word aloud with every presentation and to memorize the list. After each of four repetitions of the entire list, Ss were asked to recite the list from memory. To ensure their encoding of the words in each list, Ss were required to recite the 5 words in order after each of the first two trials, then in reverse order after the third trial; and in alphabetical order after the fourth trial). All Ss correctly recited the lists by the second trial. A recognition task immediately followed: three words were displayed in sequence: one word from the list just learned and two words not from any learned list. Subjects were instructed to press the left button of the mouse (labeled YES) if the presented word was from the list just learned, and the right button (labeled NO) otherwise. All Ss perfectly classified the words. These procedures assured that all Ss memorized the words on the three experimental lists to a relatively high common criterion.

Hypnotic Amnesia Induction

After Ss learned two of the three lists, they were instructed to shut their eyes and relax for 2-3 minutes. They then listened to one of three audio tapes containing amnesia suggestions for one of the two lists just learned. The three 8-minute tapes were constructed from an identical 5-minute trance induction segment, one of three different 30-second amnesia suggestions, and an identical 2.5 minute distraction and hypnosis de-induction segment. The amnesia suggestion for Animals was as follows: You have just learned several lists of words, including a list of animals. You will forget the list of animals and you will not be able to remember that you saw or learned any of the animal words on the list today...until you hear the phrase The experiment is over and the sound of finger-snapping, like this [finger snaps]. Then you will be able to remember all of the words you learned today. Amnesia suggestions for Fruits and Metals were analogous.

After the hypnosis phase was completed, the Ss learned the last of the three lists, following the procedure previously described. Thus, each S learned two of the three word lists prior to hypnosis, received amnesia suggestions for one of them, then after removal of the hypnotic induction, learned the words on the third list (following the same procedure as described previously).

Evoked Response Potential (ERP) Collection and Recognition Task

Subjects then participated in a recognition task similar to the one previously practiced in the three learning tasks. Immediately afterward, the experimenter read them the following instructions over the intercom:

> In the last part of the experiment, you will see a series of words briefly displayed on the monitor, one at a time. The words will be either words you learned today, either just now or before the hypnosis, or other words you haven t learned today. Press the left (or yes) button if the word on the screen is one of the words from the list you just learned, and press the right (or no) button if it is not. Respond as quickly and accurately as you can.

Most people find it difficult to completely ignore the other words they learned before hypnosis and their brainwaves give an indication of these other words. Please try to hide the fact that you learned those other words during this task; that is, see if you can keep your brainwaves from letting us know which words you learned before the hypnosis. OK? Any questions?

Alright, the words will be presented in 5 blocks of about 50 words. You will have the opportunity to rest between blocks. Please get into a position that you can comfortably hold for about 2 minutes. While the words are being presented, keep your eyes on the fixation point at the center of the screen, and please try not to make any unnecessary movements. When you are ready to begin, let me know.

The instruction to completely ignore the words learned before hypnosis, served to give the amnesia and control lists increased, but equal task relevance. On the S s prompt, stimulus presentation was begun. For each block, the 15 words from the three learned lists and 35 words from seven other unlearned, categorized lists (Furniture, Musical Instruments, Trees, Body Parts, Clothing, Birds, and Fish) were presented in random order. The words were the same size as during the learning phases and were displayed for 300 msec with 2000 msec SOA. To avoid first-position effects, each block began with two additional dummy words not used in the ERP analysis (described below). One of the these words was an unlearned member of the target category (e.g., LEAD for the Metals list) to prevent the S from using a categorization rather than a memory strategy for the recognition task. At the end of each block, Ss were given the opportunity to rest and readjust their posture before continuing.

Immediately after the ERP session, the experimenter handed the S a clipboard containing a randomized list of the 50 stimulus words with the instruction: Please check all the words you learned today.

When the S finished the recognition task, the experimenter collected the clipboard, and delivered the amnesia reversal cue, saying The experiment is over and snapping his fingers twice. While the experimenter was removing and cleaning the Electrocap, the S filled out a post-experimental questionnaire which included a free recall test of all of the words learned (used instead of repeating the recognition test so that Ss would feel less pressure to be consistent with how they answered on the previous recognition test). After the S completed the questionnaire, the experimenter explained the full purpose of the experiment, answered any questions, and thanked the S for participating.

EEG Recording and Analysis

The Electroencephalogram (EEG) was recorded with an ElectroCap using electrodes positioned at Cz, Pz, P3, and P4. Only the results from the Pz electrode will be reported here. A vertical electrooculogram electrode was positioned at FP1 to monitor blinks. All sites were measured relative to a linked mastoid reference. Electrode impedances were less than 5 K?. The signals were amplified, digitized at 250 Hz, and digitally filtered (0.01—50 Hz) using a NeuroSCAN SYNAMP system, with SCAN software running on a 486 microcomputer. The SYNAMP system was linked to another microcomputer running the stimulus presentation software (VLT from NeuroSCAN, Inc.) which inserted event marks into the EEG data file labeling the category of word displayed. The stimulus computer also recorded the S s behavioral response (yes or no button press) and reaction time.

Digitized data were subsequently analyzed off-line using EDIT software (NeuroSCAN, Inc.). The raw EEG record was first visually inspected and any sections containing movement artifact were deleted. All remaining data were corrected for blink artifact using a regression method in combination with artifact averaging (17). The blink-corrected data were then digitally low-pass filtered (cutoff: 7.0 Hz; slope 24 dB/octave), sectioned into 1200 msec epochs (-200 msec pre-stimulus to 1000 msec post-stimulus), baseline-corrected, and binned according to list type (1. Amnesia words, the first or second learned list for which the amnesia suggestion had been given (N = 25); 2. Control words, the first or second learned list for which the amnesia suggestion had not been given (N = 25); 3. Target words, the third learned list (N = 25); 4. Unlearned words, from the seven unlearned lists (N = 175)). Finally, all artifact-free and behaviorally correct responses were averaged to produce four averaged ERP waveforms (Amnesia, Control, Target, and Unlearned). Figure 1 shows the grand mean waveforms.

RESULTS

Amnesia Scores

An amnesia score was determined for each subject from the recognition test by counting the number of amnesia words not checked; this score was used to classify the Ss into to Amnesic and Nonamnesic groups. Seventeen Nonamnesic Ss (including all 9 of the low-hypnotic susceptibility Ss) received amnesia scores of 0. Fifteen Amnesic Ss received amnesia scores ranging from 1 to 5 (M=3.267, SD=1.534). Amnesia scores were significantly ($p<.01$) reduced on the free recall test following the amnesia reversal cue (M=.556, SD=1.333). Thus, on average, Amnesic Ss remembered less than two words before the reversal cue, and more than four after (in spite of the fact that recall tests are generally more difficult than recognition tests). Only one Amnesic subject failed to remember additional words on the recall test.

A measure of selectivity for the amnesia was derived by counting the number of control words not checked on the recognition test. The Amnesics failed to check 0 to 2 control words (M=.333, SD=.617), significantly fewer than the number of amnesia words unchecked ($t(14)=5.956$, $p<.0001$). The Nonamnesics checked all of the control words as well as the amnesia words. Memory for control words did not significantly change following the amnesia reversal cue for either Amnesics or Nonamnesics.

The 12 Simulators received perfect amnesia scores, significantly higher than the Amnesics ($t(25)=3.899$, $p<.0005$). The Simulators also showed a significantly different pattern of control words unchecked (75% checked all 5, and the other 25%, 0) compared to the Amnesics (Means comparison, Simulators vs. Amnesics: $t(25)=2.029$, $p<.05$; Variance comparison: $t(25)=3.899$, $p<.001$; Wald-Wolfowitz Runs Test, $z=3.512$, $p=.0004$).

In summary, Amnesic Ss exhibited selective, reversible amnesia for the relevant word list, different from the pattern of amnesia shown by the Simulator Ss, but did not differ from Nonamnesic Ss in regard to memory for the other learned lists (i.e., most importantly, the control lists).

Reaction Time

Reaction times did not significantly vary across groups ($F(2,41)=.342$, ns, =.75), but did significantly vary as a function of list type ($F(3,41)=43.04$, $p<.0001$, =.75). Reaction times clearly discriminated all three learned lists from unlearned words. Amnesia words (M=698 msec, SD=172) and control words (M=704 msec, SD=203) were significantly slower than unlearned words (M=621 msec, SD=167; $p<.0001$), which were in turn significantly faster than target words (M=775 msec, SD=193; $p<.0001$).

Error Rate

The total error rate did not significantly differ across the three groups (Amnesics: M=2.1%, SD=1.7; Nonamnesics: M=1.3%, SD=1.4; Simulators: M=1.0%, SD=0.7); F(2,41)=2.07, ns, =.35), but did differ as a function of list type (F(3,41)=59.65, p<.0001, =.35). Error rates were much higher for target words than other list types for all groups due to the strong response bias entailed by the fact that there were more than 10 times as many no responses as yes responses. Although list type did not interact with group (F(6,41)=.60, ns, =.35), Amnesic Ss made significantly more errors in responding to amnesia words compared to Simulator Ss (M=2.4%, SD=3.9 vs. M=0%, SD=0; t(25)=2.10, p<.05; Mann-Whitney U, z=-2.161, p=.03). This may suggest that the Amnesic Ss experienced uncertainty about the class to which the amnesia words belonged. Be that as it may, it also provides further evidence that the Amnesic Ss were not using the same cognitive strategy as the Simulator Ss.

P300 Amplitude

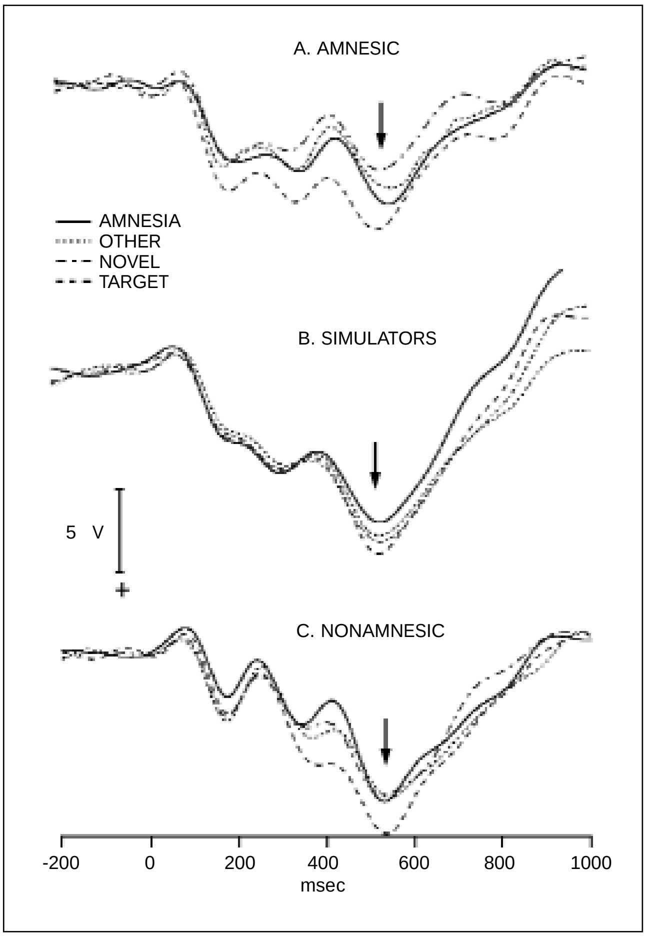
Our primary dependent measure, P300 amplitude of the ERP, was taken as the maximum positive value between 350 msec and 850 msec post-stimulus onset (13). Amplitudes were measured at the Pz electrode relative to a 200 msec pre-stimulus baseline for each of the four averaged waveforms.

Repeated Measures ANOVA revealed a significant effect for list (F(3,41)=3.869, p<.017, =.82), but not for group (F(2,41)=.499, ns,=.82); the group by list interaction neared significance (F(6,41)=1.965, p<.09, =.82). For the purposes of this experiment, the critical comparison is between the amnesia and control lists. P300 amplitude was significantly larger (Paired t(14)=2.617, p<.02) for the amnesia lists (M=8.133V, SD=5.51) than for the control lists (M=6.766V, SD=6.32) only for the Amnesic Ss. In contrast, there were no significant differences between amnesia and control lists for either the Nonamnesic or Simulator Ss.

Difference scores for P300 amplitude for the amnesia and control word lists (P3A-O) were computed for each S (See Figure 2). P3A-O was significantly greater than zero for the Amnesic group, (M=1.367, SD=2.02, t(14)=2.62, p<.02) but not for either the Nonamnesic (M=.173, SD=3.78, t(16)=.189, ns) or Simulator groups (M=-1.475, SD=4.69, t(11)=-1.08, ns). P3A-O was also significantly higher in the Amnesic group than in the Simulator group (t(25)=2.119, p<.04). Thus, Amnesic Ss significantly differed from both Nonamnesics and Simulators.

In oddball recognition tasks like this experiment, Ss typically exhibit larger P300 responses to the infrequent target words compared to the much more frequent unlearned words. However, some Ss do not show larger P300 amplitude to the rare targets in oddball tasks (18),

Figure 1. Grand mean ERP waveforms for Amnesic, Nonamnesic, and Simulator subjects. Panel A shows waveforms for Amnesic Ss (N = 15); Panel B for Simulator Ss (N = 12); Panel C for Nonamnesic Ss (N = 17). The waveforms are all derived from the Pz electrode. P300 peaks are indicated by arrows. Note that the P300 peak amplitude is larger (positive is plotted down) for the Amnesia list than for the Control list only in the case of the Amnesic Ss.

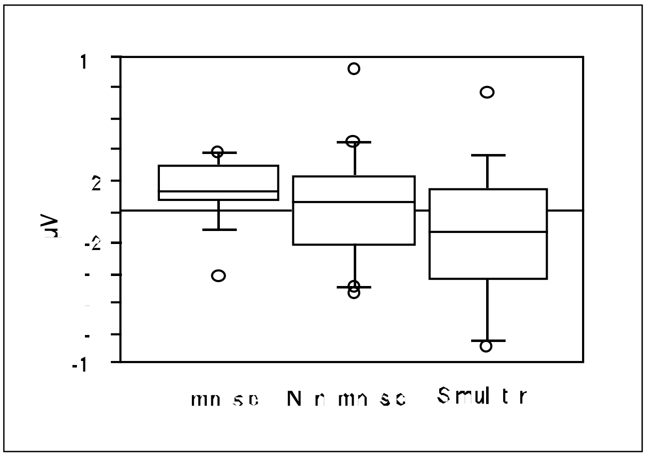


perhaps due to variations in the strategies used in the recognition tasks. We used the criterion of normal ordering of P300 response to frequent target vs. infrequent words to screen out Ss with difficult-to-interpret waveforms. Thirteen Ss (2 Amnesics, 5 Nonamnesics, and 6 Simulators) exhibited atypical P300 responses (i.e., larger P300 to unlearned than to target words).

We repeated the preceding analysis with the remaining 31 Ss, with the following results. Repeated Measures ANOVA revealed, as before, a significant effect for list (F(3,28)=20.176, p<.0001, =.85), but not for group (F(2,28)=.538, ns, =.85); However, now the group by list interaction was significant (F(6,28)=3.419, p<.0076, =.85). As before, P300 amplitude was significantly larger (Paired t(12)=4.444, p<.0008) for the amnesia lists (M=8.142V, SD=5.68) than for the control lists (M=6.397V, SD=6.02) only for the Amnesic Ss. There were still no significant differences for amnesia and control lists for either the Nonamnesic or Simulator Ss.

Again, P3A-O was significantly greater than zero for the Amnesic group, (M=1.745, SD=1.42, t(12)=4.444, p<.0008) but not for either the Nonamnesic (M=-.816, SD=3.27, t(11)=-.865, ns) or Simulator groups (M=-2.70,

Figure 2. Box plots for Difference scores for P300 amplitude (P3A-O) for the amnesia and control word lists for the Amnesic, Nonamnesic, and Simulator groups. (The box plots [20] are read as follows: The lines through the middle of the boxes mark the median values; the tops and bottoms of the boxes mark the 75th and 25th percentiles; the lines extending above and below the boxes mark the 90th and 10th percentiles; and the circles mark data points above and below the 90th and 10th percentiles.)



SD=3.97, t(5)=-1.67, ns). P3A-O was significantly higher in the Amnesic group than in the Simulator group (t(17)=3.66, p<.002) as well as the Nonamnesic group (t(23)=2.58, p<.02).

DISCUSSION

The central finding of this study is that subjects who later demonstrated selective hypnotic amnesia on a recognition test showed significantly different ERP responses to words for which amnesia had been suggested compared to a control list of words for which amnesia had not been suggested. This is in contrast to subjects who on the subsequent recognition test did not demonstrate amnesia as well as subjects who simulated amnesia: neither showed significant differences between amnesia and control lists. Response requirements (pressing the no button, indicating the word was not from the most recently learned, target, list) were identical for the amnesia and control lists. Therefore, during the ERP session, subjects were under no experimental demand to act as if they were experiencing amnesia. Nevertheless, subjects who later manifested amnesia on a recognition test showed differential ERP responses to the amnesia list. This result provides support for the cognitively based interpretation that hypnotic amnesia involves more than behavioral compliance.

Of course, cognitive and social-psychological mechanisms for hypnotic amnesia need not be contradictory (2, 3). No one denies the influence of social-psychological factors in hypnotic amnesia, nor does anyone propose that neurocognitive factors provide a complete account of the phenomenon. However, it has been frequently proposed that after social-psychological factors influencing hypnotic amnesia have been taken into account, there is nothing left to explain (7-10). The results of the present experiment argue against such exclusively social-psychological theories and for the inclusion of some form of cognitive, information-processing in hypnotically induced amnesia.

Broadly framed, Allen et al. s (12) results support the same conclusion. However, there are several differences between the two studies that merit discussion. The fact that Allen et al. directly assessed recognition while we did so indirectly has already been noted above. Equally important is the fact that Allen et al. s subjects learned the two lists during hypnosis. These differences may account for the fact that in contrast to the present study, Allen et al. found no significant differences in ERPs or recall between the amnesia and control lists either before or after the amnesia reversal cue.

More precise interpretation of the present findings depends upon the meaning attributed to the P300 component of the ERP. The amplitude of the P300 component correlates directly with stimulus significance and inversely with stimulus probability (14). The current study was designed so that the target stimuli would be relatively rare (10% probability) and thus likely to elicit large P300 responses compared to the frequent new stimuli (70% probability), as was found in 70% of the Ss. Larger P300 responses to both the amnesia and control lists, compared to the unlearned list, were also expected insofar as the Ss were instructed to keep your brainwaves from letting us know which words you learned before the hypnosis, thus giving these two lists higher salience and indirect task significance. The P300 amplitude enhancement shown for the amnesia list above that for the control list for Ss later reporting amnesia may represent the additional significance associated with a secondary, implicit task namely, hypnotic amnesia.

An alternative interpretation might be framed in terms of perceptual priming (19). The enhanced P300 may be due to the fact that the amnesia list items, while not consciously recognized, possess an increased perceptual salience due to preservation of implicit memory in the (temporary) absence of explicit memory. In this view, the larger P300 reflects the subject s surprise that the items from the amnesia list stand out perceptually.

Whatever the interpretation of the P300 component enhancement, the results indicate that Ss process recently-learned lists of words for which they are experiencing suggested hypnotic amnesia differently than other recently-learned words, even when they are not required to make any direct behavioral response indicating whether or not they are experiencing amnesia.

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