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## AUDITORY EVENT-RELATED POTENTIALS WHILE IGNORING TONE STIMULI: ATTENTIONAL DIFFERENCES REFLECTED IN STIMULUS INTENSITY AND LATENCY RESPONSES IN LOW AND HIGHLY HYPNOTIZABLE PERSONS

HELEN J. CRAWFORD

*Department of Psychology Virginia Polytechnic Institute and  
 State University Blacksburg, VA 24061*

JAMES C. CORBY

*Psychiatry Service, Veterans Administration Hospital, Palo Alto*

BURT S. KOPELL

*Department of Psychiatry and Behavioral Sciences Stanford  
 University School of Medicine Stanford, CA 94305*

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Effect of hypnotic susceptibility level on auditory event-related potentials (AERPs) was studied as subjects were instructed to ignore tones while reading a novel or counting one's pulse. Assessed previously on two hypnotic susceptibility scales [Harvard Group Scale of Hypnotic Susceptibility; Stanford Hypnotic Susceptibility Scale, Form C (SHSSC)], subjects were 12 low (lows: SHSSC 0-2) and 12 highly (highs: SHSSC 9-12) hypnotizable, right-handed college students. AERPs were recorded at C3, C4, and Cz to 50 ms 1,961 tone pips 50, 60, 70 and 80 dB intensities, pseudorandomly presented at 1.5 intervals. As predicted, highs had significantly smaller N1 and P2 amplitudes than did lows when ignoring tones. As stimuli intensities increased, N1 latencies decreased for lows while N1 latencies increased for highs. N1 latency slopes across the 50 to 80 dB intensities were significantly more negative for lows than highs: slopes correlated significantly with both hypnotizability and absorption (Tellegen Absorption Scale). Thus, the highs appeared to divert greater attentional processing to the tasks at hand, particularly as the tones increased in intensity, and were slower to respond to not-to-be-attended stimuli. These results are interpreted as further evidence for hypnotic susceptibility being associated with efficient attentional processing such that highs can more effectively partition attention towards relevant stimuli and away from irrelevant stimuli than can low hypnotizables.

*Keywords: Auditory Event-related Potentials, Hypnotic Susceptibility, Hypnosis, Attention*

The components of the event-related potential (ERP) reflect hierarchically-organized stages of attention ranging from automatic to controlled processing of incoming stimuli (e.g., Hillyard, 1981, 1984; Näätänen, 1990, 1992). ERPs serve as a window on selective and fo-

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cused attentional processing, thereby permitting the investigation of how they and their inferred underlying processes are moderated by individual differences in cognitive and attentional abilities or personality traits (e.g., Buchsbaum, 1976; Buchsbaum, Haier, & Johnson, 1983; Carillo-de-la-Pena, 1992; Crawford 1994a,b; Crawford & Gruzelier, 1992; Jutai, Gruzelier, Golds, & Thomas, 1993; Stenberg, 1994; Zuckerman, 1990). The present study extended this line of research by examining differences in auditory ERPs (AERPs) among persons differing in hypnotic susceptibility, a stable cognitive/personality trait that has a high test-retest reliability over 25 years (Piccione, Hilgard, & Zimbardo, 1989) and is correlated with attentional and disattentional abilities (e.g., Crawford, Brown, & Moon, 1993), when asked to ignore irrelevant auditory stimuli (tone pips) and become attentionally focused and absorbed in relevant tasks of reading a novel or counting one's pulse.

Of particular relevance to the present study are the N1 and P2 AERP components, whose amplitudes and latencies are affected by stimulus characteristics, attentional focusing, and subject characteristics. While these two waves covary quite similarly in most conditions, they are distinctly separable (e.g., Näätänen, 1992; Paavilainen, Alho, Reinikainen, Sams, & Näätänen, 1991). With increasing stimulus intensity, there are increases in amplitude and decreases in latency of the N1 and P2 components, especially over the sensory cortex.

These components reflect an initial stage of selective attention among multiple channels or tasks (e.g., Hillyard & Picton, 1979; Näätänen, 1990, 1992). Selective attention to a relevant stimulus increases the amplitudes of N1 (e.g., Hillyard, Hink, Schwent, & Picton, 1973; for reviews, see Hillyard & Picton, 1979; Näätänen & Picton, 1987; Näätänen, 1992) and P2 (e.g., Alho, Woods, & Algazi, 1994; Picton & Hillyard, 1974). In their now classic paper, Hillyard et al. (1973) proposed that the N1 amplitude indexes the "stimulus set" or "filtering" mode of attention, as proposed by Broadbent (1970). Changes in N1 latencies indicate shifts in attentional processing: shorter latencies within the N1 component correlate with increased stimulus intensity (Näätänen, 1992) which suggests more attentional allocation to the stimulus (Hansen & Hillyard, 1988).

In some subjects the N1 amplitude continues to increase with stimulus intensity, whereas in others the N1 "saturates or becomes smaller at higher intensities" (Näätänen, 1992, p. 122). Whether this is due to differences in "augmenting" or "reducing" arousal characteristics of the subjects is open to debate (e.g., Buchsbaum, 1976; Carrillo de la Pena, 1992; Prescott, Connolly, & Gruzelier, 1984). In addition, the traditional augmenting-reducing paradigm in which personality differences, particularly extraversion and sensation seeking, are noted usually does not control for the subject's deployment of attention (Stenberg, Rosen, & Risberg, 1990). Since N1 amplitudes and latencies have been shown to reflect attentional allocation to the stimulus (Hansen & Hillyard, 1988) and serve as an index of how individuals distribute their attentional capacity in dichotic and multichannel selective listening tasks (e.g., Hillyard & Picton, 1979), we anticipated they should be sensitive to individual differences in focused and sustained attentional and disattentional processing abilities, assessed here by hypnotic susceptibility level, within an auditory augmenting-reducing task in which subjects were asked to ignore tones while engaged in another cognitive task.

Hypnotic susceptibility, as measured by standardized hypnotic susceptibility scales, is related to the abilities of extremely focused and sustained attention as well as the ignoring (disattending) of extraneous stimuli, as assessed by both experimental tasks and self-report questionnaires (e.g., Crawford, Brown, & Moon, 1993; Karlin, 1979; Tellegen & Atkinson,

1974; Wallace & Patterson, 1984; for review, see Crawford, 1994b). Concentration and suppression may be two sides of the same cognitive process—the willful movement of attention towards some things and away from others. Highly hypnotizable persons are found to have greater cognitive flexibility in their allocation of processing resources (Crawford, 1982b, 1989; Crawford & Allen, 1983; Crawford, Kapelis, & Harrison, 1995) and deployment of resources (Cikurel & Gruzelier, 1990; Gruzelier, McCormack, Cikurel, & Warren, 1989; Jutai et al., 1993).

There is some neurophysiological evidence that highly hypnotizable persons have more efficient controlled attentional and disattentional systems (for reviews, see Crawford, 1994b, Crawford & Gruzelier, 1992). A robust finding in the EEG literature is that highly hypnotizable persons often generate greater theta power, hypothesized to be associated with “selective, narrowly focused processing, and intensive ‘mental effort’ ” (Schacter, 1977, p. 59), both in waking and hypnosis conditions, than do low hypnotizable persons (e.g., Crawford, 1989, 1990; Mészáros, Crawford, Szabó, Nagy-Kovács, & Révész, 1989; Sabourin, Cutcomb, Crawford, & Pribram, 1990; for reviews, see Crawford, 1994b; Crawford & Gruzelier, 1992). Studies have often shown changes in ERP waveform morphology during hypnosis when highly hypnotizable persons are able to reduce or eliminate the conscious awareness of incoming auditory (Jutai et al., 1993; Kunzendorf & Boisvert, in press), visual (e.g., Spiegel, Cutcomb, Ren, & Pribram, 1985), olfactory (Barabasz & Lonsdale, 1983; Spiegel & Barabasz, 1988) or somatosensory (e.g., Arendt-Nielsen, Zachariae, & Bjerring, 1990; Crawford, 1994a; Crawford, Pribram, Kugler, Xie, Zheng, & Knebel, 1993; DePascalis, Crawford, & Marucci, 1992; Kropotov, Crawford, & Polyakov, 1995; Mészáros, Bányai, & Greguss, 1980; Sharev & Tal, 1989; Spiegel, Bierre, & Rootenberg, 1989) stimuli. During hypnotically suggested analgesia, only highly hypnotizable persons showed increases in regional cerebral blood flow in the orbitofrontal and somatosensory cortical regions, suggestive of the increased involvement of the frontolimbic attentional system in the inhibition of incoming painful stimuli to conscious awareness (Crawford, Gur, Skolnick, Gur, & Benson, 1993).

In the present study, we addressed attentional processing differences of low and highly hypnotizable persons in waking only conditions of attending to reading a novel or counting one's pulse. We proposed that highly hypnotizable subjects, due to their greater concentrative abilities and abilities to partition attention between that which is to be attended to or ignored, should show significantly smaller N1 amplitudes to irrelevant, not-to-be-attended tone pips than low hypnotizables who more often report greater difficulty ignoring distracting stimuli in their surrounding environments. In addition, we anticipated that the N1 latency, another index of relevancy of the irrelevant stimuli, might differ such that lows would show shorter latencies than highs due to lows' poorer ability to ignore irrelevant stimuli. Hypnotic group differences could also occur in the later P2 component (amplitude, latency) if selective attention to the irrelevant stimuli resolved differentially in the two groups. How these proposed differences might be moderated by stimulus intensity level (50 dB to 80 dB) was also investigated. Typically, increased stimulus intensity correlates with decreased N1 latencies (Näätänen, 1992); thus, lows were expected to show shorter latencies than highs as the intensities of the stimuli increased because of the lows' poorer ability to ignore irrelevant stimuli.

Finally, we assessed an important personality/cognitive variable, absorption, that is seen as “a state of receptivity or openness to experiencing in the sense of readiness to undergo whatever experimental events, sensory or imaginal, that may occur, with a tendency to

dwelling on, rather than go beyond, the experiences themselves and the objects they represent" (Tellegen, 1981, p. 222). Becoming deeply absorbed in certain experiences implies withdrawal from and disattention to other irrelevant experiences. As shown in prior research (e.g., Crawford, 1982a; Crawford, Brown, & Moon, 1993; Tellegen & Atkinson, 1974; for a review, see Roche & McConkey, 1990), we expected hypnotic susceptibility to correlate moderately with absorption as measured by the Tellegen Absorption Scale (Tellegen, 1982).

## METHOD

### *Subjects*

Subjects were 24 university student volunteers who were given monetary compensation for participation. In the prior year they had been administered both the Harvard Group Scale of Hypnotic Susceptibility, Form A (Shor & Orne, 1962) and the individual Stanford Hypnotic Susceptibility Scale, Form C (SHSS:C; Weitzenhoffer & Hilgard, 1962). Prior to the present study, they were administered an 11-point group version of the SHSS:C for final hypnotizability level assessment. For the 12 low hypnotizables (5 men, 7 women), the 11-point group SHSS:C mean score was 1.00 (SD = 0.83; range: 0–2). For the 12 high hypnotizables (men = 6; women = 6), the SHSS:C mean was 10.58 (SD = 0.79; range: 9–11). All subjects were strongly right-handed, as assessed by Annett's (1967) handedness questionnaire, without any familial history of left-handedness. Subjects self-reported excellent health with no history of concussions or physical disorders that might interfere with the study.

### *Procedure*

On a previous day, small groups of subjects were administered the group version of the SHSS:C and completed the Tellegen Absorption Scale (TAS; Tellegen, 1982). Subsequently, they were familiarized with the psychophysiology laboratory and the task. The experimenter involved in the psychophysiological testing was blind to the subjects' hypnotic levels.

During the experiment proper, subjects received the 252 tone sequence twice under two counterbalanced attention conditions. In the "reading" condition subjects were asked to read a popular book and told to ignore the tones as they would be questioned about what they had read. In the "counting" condition subjects were asked to count their pulse and told to ignore the tones.

Stimuli were 50 ms 1,961 Hz tone pips with a rise and fall time of 2.5 ms presented binaurally through earphones. The 252 tone pips were of 50, 60, 70, and 80 dB intensity, pseudorandomly presented at 1.5 s intervals.

### *ERP Recording System*

The subject sat in a comfortable chair in an electrically and acoustically shielded chamber. EEG was recorded from the C3, C4, and Cz electrode sites referenced to linked mastoids. An electrooculogram (EOG) was recorded from electrodes 3 cm above and 2.5 cm below the right eye. A ground electrode was affixed to the forehead. Silver-silver chloride electrodes were used at all sites. Electrode impedances were kept below 5 kohms. Before stimulation began, each subject performed a series of eye movement maneuvers in a manner

previously described (Roth, 1973) to allow quantification of ocular artifacts at each of the three EEG leads. The amplifiers were set to a bandpass of 0.03–100 Hz (3 dB points of 6 dB/octave rolloff curves).

#### *Data Reduction and Analyses*

Artifact free epochs of amplified EEG were selected and averaged for AERP analysis for each stimulus intensity and condition with a peak measurement program. The amplitudes and latencies of three AEP components (identified on the basis of polarity, latency and magnitude criteria) were analyzed: N1 (latency between 70 and 150 ms), P2 (latency between 150 and 250 ms), and P3 (latency between 250 and 500 ms).<sup>1</sup>

For each AERP component, the repeated measures ANOVA had one between subjects factor (low and high hypnotic level) and three within factors: Amplitude (4 levels), Site (3 levels), and Task Condition (2 levels). The significance levels for the  $F$  values were those obtained after Greenhouse-Geisser corrections when necessary. The interactions were followed up for simple effects with the Newman-Keuls statistic ( $p < .05$ ).

## RESULTS

### *Amplitude Effects*

*N1 amplitude.* As is typically found, as the intensity of the distracting tone stimuli increased from 50 dB to 80 dB (Figure 1), there was a highly significant increase in N1 amplitude,  $F(3,66) = 26.35, p < .001$ . For N1 amplitude, a significant 3-way interaction between hypnotic level, site and task was observed,  $F(2,44) = 3.12, p = .05$ . As shown in Figure 2, during the counting pulse condition, lows showed greater N1 amplitudes to the ignored tone pips than highs across all three sites (C3, Cz, C4). During the reading condition, lows showed a greater N1 amplitude at C4. Intensity level did not interact with hypnotic susceptibility level.

*P2 amplitude.* As expected, as the intensity of the distracting tone stimuli increased (Figure 1), there was a highly significant increase in amplitude for P2,  $F(3,66) = 16.27, p < .001$ . This was moderated by hypnotic level as shown in the significant interaction between hypnotic level, site, task and intensity,  $F(6,132) = 2.23, p < .05$ . The interaction was similar to that observed for N1, except that it occurred only at the higher tone intensities (70 and 80 dB).

### *Latency Effects*

*N1 Latency.* N1 latencies showed no main effects. One significant interaction between hypnotic group and stimuli intensity occurred,  $F(3,66) = 4.08, p = .01$ , supporting our hypothesis that highly hypnotizable persons process not-to-be-attended stimuli differently than do low hypnotizables. As shown in Figure 3, low and highly hypnotizable subjects did

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<sup>1</sup>We did not anticipate the P3 component to be moderated by hypnotic level or condition since this latter wave form is seen as an index of context relevance (infrequent, or cognitively important) rather than selective attention (for reviews, see Johnson, 1984, 1988). Our data analyses bore out this expectation. There were no significant main effects or interactions for P3 amplitude.

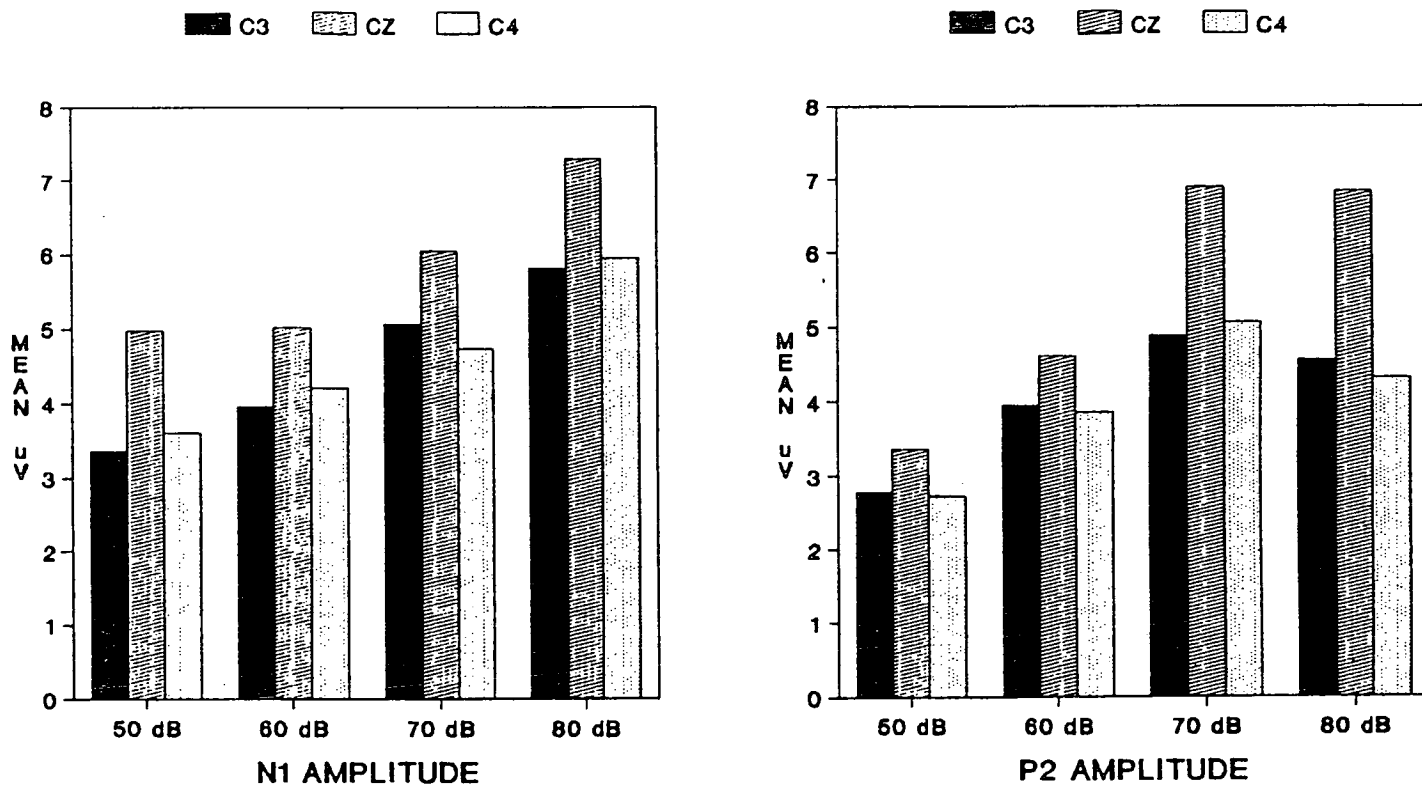


FIGURE 1 Mean amplitude of N1 and P2 auditory ERP components: Changes as a function of dB levels of tone pips.

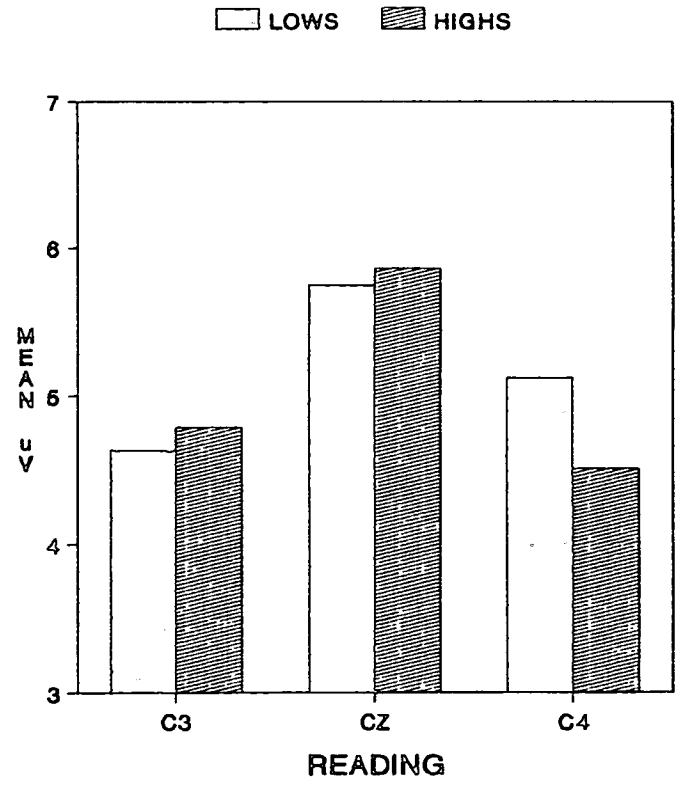
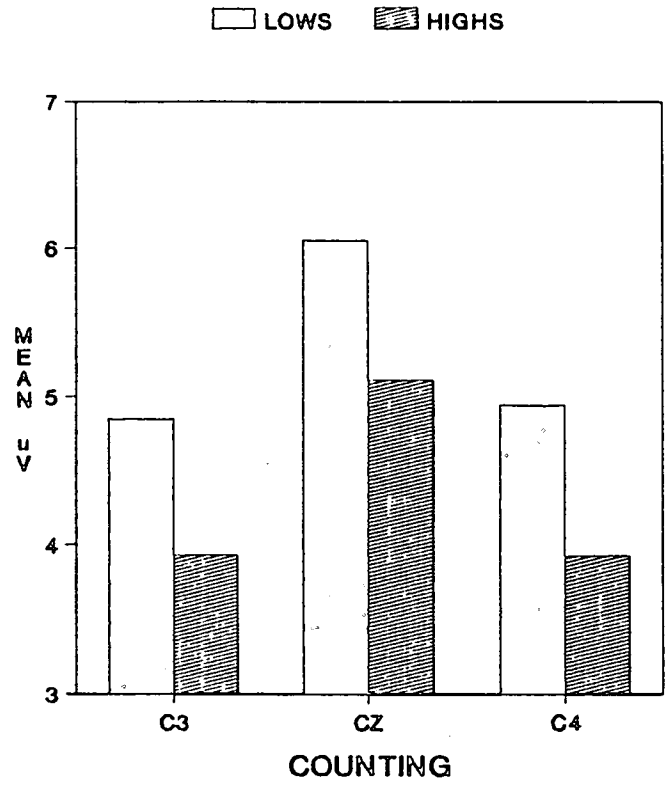


FIGURE 2 Mean amplitude of N1 for low and highly hypnotizable subjects when reading or counting pulse.

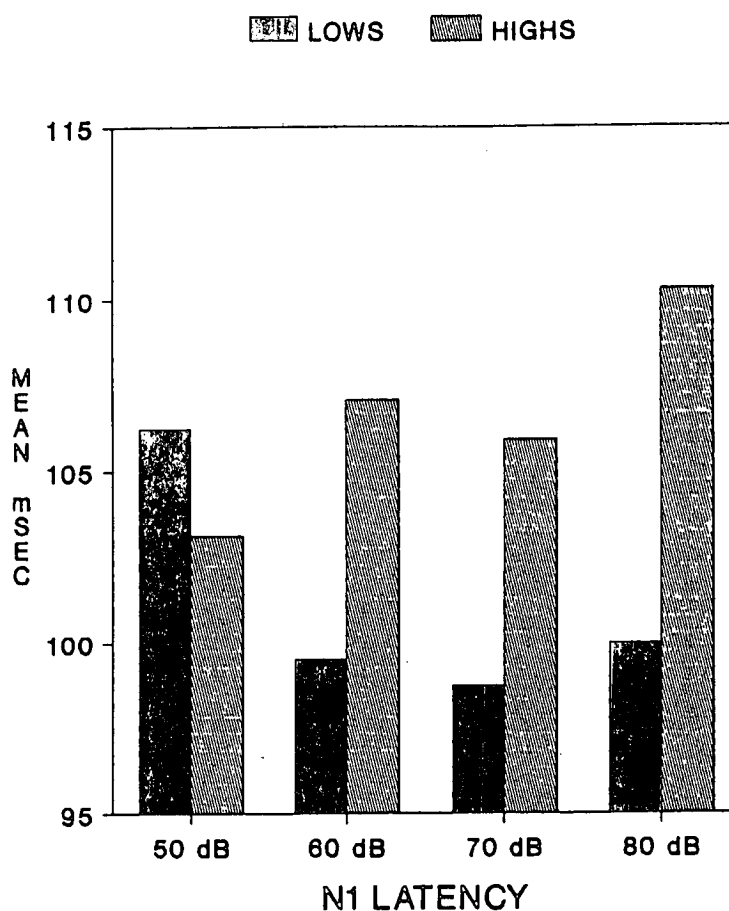


FIGURE 3 Mean N1 latency differences between low and highly hypnotizable subjects across dB levels of tone pips.

not differ in N1 latencies at 50 dB, but did as the dB intensity of the stimuli increased. The latencies of the lows at 60, 70 and 80 dB were significantly shorter than the 50 dB latency, while the latencies of the highs got longer with increasing dB level. There were no other significant interactions.

To explore further this hypnotic group difference, the slopes of the linear regression function relating N1 latencies to stimulus intensity was calculated for each subject. The slope of the low hypnotizables ( $M = -0.1877$ ,  $SD = 0.26$ ) was significantly more negative than that of the highs ( $M = 0.2047$ ,  $SD = 0.38$ ),  $t(22) = 2.99$ ,  $p < .008$ . The slope of the N1 latencies across the four dB levels correlated  $.44$  ( $p < .05$ ) with SHSS:C hypnotic susceptibility score, and  $.58$  ( $p < .05$ ) with absorption as assessed by the Tellegen Absorption Scale.

*P2 Latency.* Hypnotic level group had no significant main effects or interactions. As would be expected, the P2 latencies decreased significantly as the stimulus intensity increased,  $F(3.66) = 4.78$ ,  $p < .004$ . Mean latencies were 199.79 for 50 dB, 193.03 for 60 dB, 188.44 for 70 dB, and 188.37 for 80 dB. The P2 latency was significantly shorter at Cz ( $M = 188.60$ )



than either C3 ( $M = 194.09$ ) or C4 ( $M = 194.54$ ) which did not differ significantly from one another,  $F(2,44) = 7.96$ ,  $p < .001$ . There were no other significant interactions.

#### *Relationship between Hypnotic Susceptibility and Absorption*

As anticipated, highly hypnotizable subjects ( $M = 25.80$ ,  $SD = 6.5$ ) reported significantly more absorptive experiences in everyday life, as measured by the Tellegen Absorption Scale, than did low hypnotizable subjects ( $M = 16.3$ ,  $SD = 6.07$ ),  $t(22) = 3.69$ ,  $p < .002$ . With a correction for extreme groups (Feldt, 1961), hypnotic susceptibility level correlated  $.52$  ( $p < .01$ ) with absorption.

## DISCUSSION

The present study confirms previous research that low and highly hypnotizable persons exhibit neurophysiological differences that can be attributed to differences in abilities to focus and sustain attention and to ignore (disattend) irrelevant stimuli (for reviews, see Crawford, 1994a,b; Crawford & Gruzelier, 1992). The quantitative comparison of AERP amplitudes and latencies for N1 and P2 to irrelevant tone pips ranging in intensity from 50 to 80 dB while reading or counting provided supportive data. In comparison to low hypnotizables, highly hypnotizable persons exhibited (1) significantly smaller N1 and P2 amplitudes, and (2) significantly longer N1 latencies at the higher dB intensities.

According to Näätänen (1990, 1992), the N1 generator process of the auditory cortex can be seen as a transient-detector system. It is an index of an initial "input selection" stage of attention whereby stimuli are selected or rejected (e.g., Hillyard et al., 1973; Hillyard & Picton, 1979; Hink & Hillyard, 1976). Typically, as stimuli intensities increase, N1 amplitudes increase and latencies decrease. In augmenting-reducing paradigms, these changes have been interpreted as indices of increased attentional processing allocated to the distracting or novel stimuli (e.g., Hansen & Hillyard, 1988). In the present study, the low hypnotizable subjects exhibited these typical responses, whereas the highly hypnotizable subjects did not. First, the highs showed significantly smaller N1 amplitudes at all three central sites during the counting pulse condition and at C4 during the reading condition. Similar findings occurred for P2 amplitudes. This may be interpreted as evidence for the highs' giving *less attentional allocation* to the irrelevant stimuli. Second, the highs showed significantly longer N1 latencies at 60, 70 and 80 dB intensities. The slopes across the four intensities were significantly more negative for the lows than the highs. This, too, can be interpreted as further evidence that the highs diverted greater attentional processing to the task at hand and were slower to respond to the unattended stimuli, particularly as the stimuli intensities increased.

It is well known that there are descending inhibitory pathways which parallel the ascending sensory systems and can modulate quite early responses to sensory information. The above findings suggest that highly hypnotizable persons have a greater capacity to partition attention: they can focus upon relevant stimuli while also ignoring or actively disattending those stimuli that are irrelevant and not-to-be-attended. While not addressed in the present study, such inhibitory processing abilities suggest that highs may have a stronger attentional filtering system that is hypothesized to be associated with the prefronto-limbic attentional system (Crawford, Pribam et al., 1993; Crawford, Gur et al., 1993; for reviews, see Crawford, 1994a,b; Crawford & Gruzelier, 1992). Recent research suggests that this downward in-

hibitory processing may occur at both cortical and subcortical levels. Kunzendorf and Boisvert (in press) found that highs when extremely involved in inner auditory thoughts and imagery (hypnotically hallucinated music) showed significant brainstem AERPs amplitude decreases to irrelevant tone pips. Inhibition of incoming painful somatosensory stimuli among highs leads to reports of reduced or eliminated perception of pain and distress (for review, see Hilgard & Hilgard, 1994), often accompanied by reductions in somatosensory ERP amplitudes at cortical scalp recording sites (e.g., Arendt-Nielsen et al., 1990; Crawford, 1994a; Crawford, Pribram et al., 1993; DePascalis et al., 1992; Mészáros et al., 1980; Sharav & Tal, 1989; Spiegel et al., 1989); within intracranial cortical regions, specifically the anterior cingulate cortex and anterior temporal cortex (Kropotov et al., 1995), and at the level of the spinal nociceptive reflex (Kiernan, Dane, Phillips, & Price, 1995).

These results suggest fruitful avenues for further research. Since hypnosis is conceptualized as a condition of amplified attention and disattention (e.g., Crawford, 1982, 1994a,b; Crawford, Brown & Moon, 1993; Hilgard, 1965; Krippner & Bindler, 1974), we would anticipate that during hypnosis under instructed attentional and disattentional conditions, further AERP changes would be observed. Only the central sites (C3, CZ, C4) were assessed in the present study; this approach assesses the posterior attentional system that involves more sensory representation but fails to address the anterior attention system that is more involved in the planning and execution (or inhibition) of responses (e.g., for reviews, see Posner & Peterson, 1990; Pribram & McGuinness, 1975, 1992). Based upon Skinner and Yingling's (1977; Yingling & Skinner, 1976) and Pribram and McGuinness's (1975, 1992) models of attention that propose that the prefrontal cortex regulates the limbic system in the active gating of incoming sensory stimuli (e.g., thalamic reticular nucleus [Yingling & Skinner, 1976]), we would anticipate individual differences in ERPs in the anterior prefrontal region that reflect differences in the ability to disattend irrelevant stimuli. In a study of modality specificity of evoked potential augmenting/reducing, Blenner and Yingling (1993) suggested that augmenting/reducing does not result from "sensory modulation by a nonspecific mechanism, such as the mesencephalic reticular formation, and instead suggest that a more selective mechanism such as regulation of sensory transmission by the prefrontal cortex may underlie this phenomenon" (p. 131). Furthermore, in a study of frontal-lesioned patients, Blenner and Yingling (1994) found more rapid enhanced visual ERP augmenting to increasing stimulus intensity, reflective of a loss of frontally-mediated inhibition. Thus, N1 differences between low and highly hypnotizable persons might be noted in both frontal and central sites. Recent scalp current density and dipole model analyses suggest that separate components of the N1 originate from not only the auditory cortex but also the frontal cortex (Alcaini, Giard, Thevenet, & Pernier, 1994; Giard et al., 1994).

Of particular relevance to this study are those personality traits that can be described in terms of attentional and arousability processes. Individual differences in stimulus intensity control, as assessed by extraversion, impulsivity or sensation seeking, have been related to differences in ERP amplitudes (e.g., Buchsbaum, 1976; Carrillo de la Pena, 1992; Zuckerman, 1990). Albeit inconsistently shown across studies, there is evidence that in individuals termed "augmenters," certain ERP amplitudes increase with increasing intensity; whereas in others termed "reducers," amplitudes decrease or stagnate at a certain point of intensity. Our results involving low and highly hypnotizable individuals cannot at present be integrated with findings from the traditional augmenting/reducing paradigm which has demonstrated personality correlates with visual ERPs and AERPs. We need further research that examines the relationship between the processing of sensory stimuli, as assessed by

ERPs, under different attentional conditions and the dimensions of hypnotic susceptibility, extraversion, and sensation seeking and particularly its subcomponent of disinhibition (e.g., Orlebeke, Kok, & Zeillemaker, 1989).

In conclusion, the results strongly suggest that N1 and P2 components of the AERP can be modulated by attentional processes. Highly hypnotizable persons can partition their attentional resources more efficiently than can low hypnotizable persons. This was reflected in the present study's findings that highly hypnotizable persons, when asked to ignore irrelevant tone pips, exhibited (1) significantly smaller N1 and P2 amplitudes, and (2) significantly longer N1 latencies at the higher dB intensities.

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