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BRAIN DYNAMICS AND HYPNOSIS: *Attentional and Disattentional Processes*[1, 2]

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Abstract: This article reviews recent research findings, expanding an evolving neuropsychophysiological model of hypnosis (Crawford, 1989; Crawford & Gruzelier, 1992), that support the view that highly hypnotizable persons (highs) possess stronger attentional filtering abilities than do low hypnotizable persons, and that these differences are reflected in underlying brain dynamics. Behavioral, cognitive, and neurophysiological evidence is reviewed that suggests that highs can both better focus and sustain their attention as well as better ignore irrelevant stimuli in the environment. It is proposed that hypnosis is a state of enhanced attention that activates an interplay between cortical and subcortical brain dynamics during hypnotic phenomena, such as hypnotic analgesia. A body of research is reviewed that suggests that both attentional and disattentional processes, among others, are important in the experiencing of hypnosis and hypnotic phenomena. Findings from studies of electrocortical activity, event-related potentials, and regional cerebral blood flow during waking and hypnosis are presented to suggest that these attentional differences are reflected in underlying neurophysiological differences in the far fronto-limbic attentional system.

There is a resurgence of interest in brain dynamics associated with hypnosis due to the increased availability of physiological neuroimaging methods such as computerized electroencephalographic (EEG) fre-

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Inhibición de la recuperación en olvido dirigido y amnesia poshipnótica

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Resumen: En el experimento 1, los sujetos recibieron instrucciones verbales o a través de una lista de olvido dirigido o instrucciones de amnesia poshipnótica. El desempeño en el recuerdo y en el reconocimiento de los sujetos que recibieron instrucciones de olvido dirigido fué consistente con hallazgos reportados por Basden, Basden, y Gargano (1993); los sujetos que recibieron instrucciones verbales mostraron déficits de recuerdo y reconocimiento para los ítems a ser olvidados. En contraste, los sujetos a los que se les dieron instrucciones en una lista mostraron déficits en el recuerdo y no en el reconocimiento, esto sugiere que aunque una codificación diferencial sustenta al método de olvido dirigido mediante palabras, la inhibición de la recuperación sostiene al método por listas del olvido dirigido. Los sujetos que recibieron instrucciones de amnesia hipnótica (sin tener en cuenta el método usado) mostraron déficits en el recuerdo, no así en la recuperación, lo cual sugiere que la inhibición de la recuperación sustenta la amnesia poshipnótica. En el experimento 2, los puntajes de reconocimiento fueron más bajos en los tests públicos (orales) que en los tests privados (escritos) y la recuperación fué equivalente en los ítems a ser olvidados y los ítems a ser recordados. Los resultados fueron interpretados como inconsistentes con los mecanismos diferenciales propuestos por Huesmann, Gruder, y Dorst (1987).

quency analysis, EEG topographic brain mapping, event-related potential (ERP) analysis, regional cerebral blood flow (CBF), positron emission tomography (PET), and single photon emission computer tomography (SPECT). This article reviews converging evidence from recent studies that suggests that hypnosis activates an interplay between cortical and subcortical brain dynamics. Both sustained attention and disattention are two major higher level, cognitive control processes associated with the "executive control system" (E. R. Hilgard, 1986; Pribram, 1991) or the "supervisory attentional system" (Shallice, 1988) that are of importance in our understanding of hypnosis and individual differences in hypnotic susceptibility. Research is presented that suggests that highly hypnotizable persons possess greater sustained attentional and disattention abilities that are reflected in underlying neurophysiological differences in the fronto-limbic attentional system. Finally, evidence suggesting shifts in brain dynamics during hypnosis, as moderated by hypnotic level, is provided in support of a recently developed, but still evolving, neuropsychophysiological model of hypnosis (Crawford, 1989, 1991; Crawford & Gruzelier, 1992).

ATTENTIONAL CORRELATES OF HYPNOTIZABILITY

What is attention? In his *Principles of Psychology*, William James (1890/1983) described attention eloquently:

> Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatter-brained state which in French is called distraction, and Zerstreutheit in German. (pp. 403-404)

Attention is a multidimensional phenomenon. While knowledge of its structure is incomplete, there is evidence for different neurophysiological systems of attention (e.g., for reviews, see Posner & Petersen, 1990; Pribram & McGuinness, 1975, 1992).

We all know of individuals who often cannot focus their attention and are quickly inattentive and drawn to distracting, irrelevant stimuli. We know, as well, of individuals who can become so focused on their projects or inner thoughts and fantasies that they appear oblivious to the world around them. Individual differences in attentional processing are observed in the cognitive literature (e.g., Berch & Kanter, 1984; Crawford, Brown, & Moon, 1993; Davies, Jones, & Taylor, 1984; Sack & Rice, 1974) for four major attentional dimensions: (a) focused and sustained attention: the ability to focus and sustain attention over time without distraction; (b) selective attention: the ability to select and discriminate between stimuli; (c) divided or dual attention: the ability to divide attention between two tasks, often one primary and the other secondary; and (d) ambient attention: the ability to attend to one task but also to have diffuse attention in preparation to respond to other stimuli.

Behavioral and Evoked Potential Attentional Correlates of Hypnotizability

Numerous studies have demonstrated that hypnotizability, as measured by standardized hypnotic susceptibility scales, is related to the abilities of extremely focused and sustained attention. [Other contributing factors (e.g., role-playing, imagery) are acknowledged as being important mediators of hypnotic behavior, but are not addressed in this article.] Concentration and suppression may be two sides of the same cognitive process—the willful movement of attention towards some things and away from others.[5] It is for this reason that we have argued that both sustained attentional and disattentional abilities are correlates of hypnotizability (Crawford, 1989, 1991; Crawford, Brown, & Moon, 1993; Crawford, Corby, & Kopell, 1994).

Correlational studies of hypnotizability have often used the Tellegen Absorption Scale (TAS; Tellegen, 1982), a measure of involvement in various imaginative activities suggestive of passive, effortless rather than active attention. The correlations between absorption and hypnotizability are usually in the .40s (e.g., Crawford, 1982b; Crawford, Brown, & Moon, 1993; Finke & Macdonald, 1978; Kilhstrom et al., 1980; Nadon, Laurence & Perry, 1987; Tellegen & Atkinson, 1974; for a review, see Roche & McConkey, 1990). An analysis of this literature and interview studies (e.g., J. R. Hilgard, 1970) led us to conclude that we are often intermingling two separate focused attentional abilities: (a) moderately focused attention: the ability to attend moderately so that noise in the environment is no longer disruptive, but may still be attended to some; and (b) extremely focused attention and disattention: the ability to attend so fully to a task that noise and irrelevant stimuli in the environment are apparently not even noticed and provide no distraction. The first is more closely related to ambient attention. The second, extremely focused and sustained attention, has been found to be more closely related to hypnotizability and to load with the TAS in factor analyses (Crawford, Brown, & Moon, 1993; Lyons & Crawford, 1991; Yanchar, 1983, 1984). This latter research used a questionnaire, the Differential Attentional Processes Inventory (DAPI; Crawford, 1981a; Grumbles & Crawford, 1981), that has separate scales for these two attentional dimensions along with two dual attention scales. Further, Lyons and Crawford (1991) found hypnotic susceptibility did not load on measures of arousability (e.g., extraversion as measured by the Eysenck Personality Inventory), another

[5]Treisman (1964) was one of the first to propose that inhibition of information plays a role in attention. The degree to which irrelevant information is processed, and how closely inhibitory processes are related to selective attentional processes, has been the center of considerable debate in the cognitive and neuropsychological literatures. A coverage of such issues is beyond the scope of this article.

attentional system wherein a person modulates and maintains one's homeostasis by either seeking out or retreating from highly arousing stimuli in the environment.

Relationships between hypnotic susceptibility and cognitive task performance, interpreted as a measure of attentional processing, have been reported. Hypnotic susceptibility was found to be associated with superior performance on visual search tasks (Wallace & Patterson, 1984), perception of fragmented stimuli (e.g., gestalt closure) tasks (Crawford, 1981b; Wallace, 1990), and searches for an object embedded within a pictorial scene (Priebe & Wallace, 1986; Wallace, 1988). In addition, Wallace (1990) has shown that highs who self-reported high vivid imagery perceived fragmented stimuli better than highs who reported less vivid imagery. In these studies by Wallace and his students, highs were more likely to report holistic, rather than detail, search strategies, similar to what Crawford (1981b) and Crawford and Allen (1983) have described. An intensification of such holistic strategies was found in hypnosis among highs who reported increased holistic processing accompanying increased successive visual discrimination memory (Crawford & Allen, 1983) and eidetic-like memory (Crawford, Wallace, Nomura, & Slater, 1986) performance.

Highs are more responsive to reversible figures and visual illusions, as evidenced in studies of the Necker Cube and Schroeder staircase (Crawford, Brown, & Moon, 1993; Wallace, 1986, 1988; Wallace, Knight, & Garrett, 1976) and the Ponzo illusion (R. J. Miller, 1975). Highs report significantly more autokinetic movement in a dark environment (Atkinson & Crawford, 1992; Wallace & Garrett, 1973; Wallace, Garrett, & Anstadt, 1974) and even greater movements during hypnosis (Atkinson, 1991). We propose that these findings are due to highs possessing greater sustained attentional and disattentional abilities.

Recent ERP research by Crawford, Corby, and Kopell (1994) provides neurophysiological evidence in support of the hypothesized attentional differences between low and high hypnotizables during waking. They recorded auditory ERPs at central sites (Cz, C3, C4) to 50 msec 1961 Hz tone pips of 50, 60, 70, and 80 dB intensities, in counterbalanced conditions where subjects were instructed to ignore the tones while reading a novel or counting their pulses. Highs showed significantly smaller N1 and P2 amplitudes than did lows. Typically, as seen in previous work using the augmenting-reducing paradigm (for a review, see Hillyard & Picton, 1979), as stimuli intensities increase, N1 latencies decrease. Such latency decreases are interpreted as an index of increased attentional processing allocated to the distracting or novel stimuli. The lows showed the expected decrease in N1 latencies as the stimuli intensities increased, but the highs did the opposite and showed a slowing down of the processing of distracting stimuli (longer N1 latencies) with increased intensities. This differential latency change was positively associated with both hypnotic susceptibility ($r = .44$, $p < .05$) and absorption as measured by the TAS ($r = .58$, $p < .01$). Kunzendorf and Boisvert (in press) provided preliminary evidence that inhibitory processing may even be seen in brain stem auditory ERPs of some highly hypnotizable persons.

It is well-known that there are descending inhibitory pathways that parallel the ascending sensory systems and can modulate quite early responses to sensory information. Thus this research suggests that high hypnotizables can better inhibit incoming sensory stimuli. Based upon Skinner and Yingling's (1977) and Pribram and McGuinness's (1975, 1992) models of attention that propose that the far frontal cortex regulates the limbic system in the active gating of incoming sensory stimuli, Crawford, Pribram, Kugler, Xie, Zhang, and Knebel (1992, 1993) have reported somatosensory ERP evidence (discussed further in a subsequent section) for a hypothesized far frontal (Fp1, Fp2) regional involvement in the inhibition of the conscious perception of pain in highly hypnotizable individuals. Thus there is some neurophysiological evidence to support the hypothesis that high hypnotizables have a more efficient far fronto-limbic attention system (e.g., Crawford, 1991; Crawford, Brown, & Moon, 1993; Crawford, Pribram, et al., 1992, 1993).

Far-Frontal Attentional System and Hypnosis

The disattending to extraneous stimuli in the environment so that one can sustain attention, also referred to as cognitive inhibition, may involve higher order neurophysiological control systems. Injury to the anterior region of the brain, more precisely the far frontal (prefrontal) cortex, often leads to major problems in controlled attentional focusing over time and sensitivity to interference (e.g., for reviews, see Graf, 1989; Stuss & Benson, 1986). By contrast, damage to the posterior region of the brain does not lead to such attentional deficits, but rather deficits in selective attention such as the ability to disengage and engage attention (Posner, Petersen, Fox, & Raichle, 1988; Stuss & Benson, 1986).

Human and animal studies of the localization of attention have led various neuropsychological researchers, including Posner (e.g., Posner et al., 1988) and Pribram (Pribram, 1991; Pribram & McGuinness, 1992), to propose at least two major attentional systems: (a) a posterior attention system that involves processing and encoding of incoming information, and is where selective attentional processes of engaging and disengaging occur; and (b) an anterior attention system that involves "attention for action" (Posner et al., 1988, p. 1628) and effortful attention over time (Pribram, 1991; Pribram & McGuinness, 1992). These higher attentional control processes involve both the frontal lobes and the limbic system to which there are major connecting fibers.

Thus neurophysiological evidence has shown that resistance to distraction, accompanied by sustained attention, is a function of the fronto-limbic attentional system, while selective attention is a function of the posterior cerebral cortex (e.g., Posner & Petersen, 1990; Pribram, 1991; Pribram & McGuinness, 1975). In addition, the fronto-limbic attentional system is involved in the modulation of emotionality and comfort-discomfort (e.g., Pribram, 1991; Stuss & Benson, 1986).

In light of these neurophysiological findings, a reanalysis of the hypnosis literature suggests that highs may also show greater performance on tasks that involve sustained attention without distraction and are associated with far-frontal lobe functioning. The perception of reversals in figures, such as the Necker Cube, is greatly reduced by frontal lobe pathology (Cohen, 1959; for a review, see Stuss & Benson, 1986). It is thought that perceptual judgments of figural reversals require sustained concentration without distraction. As discussed above, studies (Crawford, Brown, & Moon, 1993; R. J. Miller, 1975; Wallace, 1986; Wallace et al., 1976) have shown that hypnotizability correlated with frequency of reversals of the Necker Cube as well as other visual illusions. We (Crawford, Brown, & Moon, 1993) found approximately 70% of low and high hypnotizables were correctly discriminated between by tasks that represented two sustained attentional processing factors. Both involved focused attention without interference from distraction: (a) extremely focused and sustained attention, as reflected by the TAS and the extreme, focused attention scale of the DAPI, and (b) sustained attention in an impoverished environment, as shown by the Necker Cube and the autokinetic illusion tasks.

Stroop effects, a hallmark of focused attentional processing affected by distraction (MacLeod, 1991; Shiffrin & Schneider, 1977) that may involve the frontal cortex (Martinot et al., 1990; Perret, 1974), can also differentiate lows from highs. Dixon and his associates (Dixon, Brunet, & Laurence, 1990; Dixon & Laurence, 1992) have demonstrated that highly hypnotizable subjects process words more automatically than do low hypnotizables in a paradigm that separated strategic from automatic processes in the Stroop color-naming test. Reduced Stroop effects were obtained only among highs when they were given attentional focusing instructions during hypnosis (Sheehan, Donovan, & MacLeod, 1988), or outside of the hypnotic context (Dixon & Laurence, 1992). Highs may be able to better respond to directed attention instructions due to their greater cognitive flexibility (Crawford, 1989; Crawford & Allen, 1983) and ability to suppress irrelevant information.

Gruzelier and his colleagues (for reviews, see Crawford & Gruzelier, 1992; Gruzelier, 1990) have investigated hemispheric frontal lobe dynamics of lows and highs during waking and hypnosis by employing neuropsychological tests. In waking control conditions, highs (in comparison to lows) showed evidence of greater left hemisphere dominance in studies of tactile processing (Gruzelier, Brow, Perry, Rhonder, & Thomas, 1984) and bilateral electrodermal orienting (Gruzelier & Brow, 1985). Most recently, Gruzelier and Warren (1993) reported that highs showed greater word fluency to letter categories, implicated to involve frontal lobe functions primarily of the left hemisphere (Benton, 1968), during waking than did lows. Each of these studies demonstrated shifts in hemispheric dominance during hypnosis: only highs demonstrated inhibitory left hemispheric functioning on these tasks. Such research supports our argument (Crawford, 1989, 1990a; Crawford & Allen, 1983; Crawford & Gruzelier, 1992) that highs are characterized by greater cognitive flexibility, a greater adroitness to shift cognitive strategies in accordance with task demands that may be accompanied by greater neurophysiological hemispheric specificity.

EEG Correlates of Hypnotic Susceptibility and Hypnosis

Of particular interest to my thesis is the theta band (3 - 7 or 8 Hz) of the EEG. Theta power increments have been associated with problem solving as shown in studies of perceptual processing, cognitive processing, and during the production of imagery (for a review, see Schacter, 1977). Vogel, Broverman, and Klaiber (1968) differentiated between two classes of theta: (a) "Class I inhibition" which is associated with general inactivity or drowsiness, and sleep; and (b) "Class II inhibition" which is associated with efficient and attentive performance. According to them, this second class of theta represents "a selective inactivation of particular responses so that a continuing excitatory state becomes directed or patterned" (p. 172). It is apparent that this second class of theta may be associated with what I refer to as focused attention and disattention. Theta that is associated with Class I drowsiness is irregular and low voltage, whereas theta associated with Class II attention is more regular and higher in amplitude (Schacter, 1977).

Diverse studies have consistently found that theta power increases during performances that involve "narrowly focused processing, and intensive 'mental effort' " (Schacter, 1977, p. 59). Enhanced theta density and power are reported in studies of mental arithmetic (Nakagawa, 1988), concept formation (Lang, Lang, Kornhuber, Diekmann, & Kornhuber, 1988), and verbal and spatial tasks (Gutierrez & Corsi-Cabrera, 1988). A particularly distinct theta activity in the 6-7 Hz range, as measured by density and power, has been found anterior to the Fz derivation, an area in the midline of the forehead, and is associated with improved performance (e.g., Nakagawa, 1988; Yamamoto & Matsuoka, 1990). While subjects were observing the Necker Cube, Knebel (1993) found greater right (F4) than left (F3) frontal theta power, more so in active than passive conditions, while posteriorly there was greater left (P3) than right (P4) theta power. Interestingly, some subjects do not generate theta during task performance, while others generate high amplitude theta that is present in long, regular bursts and associated with better performance (Nakagawa, 1988). Not yet integrated into this body of literature are findings (e.g., Evans, 1992; Galin et al., 1992; Lubar, 1991) that individuals with brain-damage or attention-deficit disorders with hypothesized cortical-subcortical disruptions of attentional mechanisms may also exhibit enhanced theta (only 3 - 8 Hz range reported). We (Barabasz, Crawford, & Barabasz, 1993) found substantially more low theta, but not high theta, power present in attention-deficit children than in normal children.

One robust finding has related hypnotic susceptibility to enhanced theta power. Several early studies (e.g., Galbraith, London, Leibovitz, Cooper, & Hart, 1970; Tebecis, Provins, Farnbach, & Pentony, 1975; Ulett, Akpinar, & Itil, 1972; for reviews, see Crawford & Gruzelier, 1992; Schacter, 1977) reported that enhanced theta recorded in posterior regions (often occipital) was an important predictor of hypnotizability. More recent studies have evaluated various regions of the brain with multiple electrode placements. Sabourin, Cutcomb, Crawford, and Pribram (1990) reported substantial differences in mean theta power between extreme lows and highs who had been screened on three different measures of hypnotizability. Subjects had their EEG recorded while in waking rest, with eyes open and closed; in hypnotic rest, with eyes closed; and during certain hypnotic suggestions from the Stanford Hypnotic Susceptibility Scale, Form C (SHSS:C; Weitzenhoffer & Hilgard, 1962) test items. As seen in Figure 1, the major finding was that highs had substantially greater mean theta power than lows in both the left and right regions of the frontal (F3, F4), central (C3, C4), and occipital (01, 02) regions across conditions of waking rest, hypnotic rest, SHSS:C hypnotic suggestion items, and waking rest. Interestingly, during hypnosis there was a substantial increase of theta power in both lows and highs, but the difference between the two groups remained. Lows and highs did not differ in total alpha and beta power, although highs showed greater hemispheric asymmetry than lows in the beta power band.

In research carried out in Hungary, we (Crawford, 1989; Crawford, Mészáros, & Szabó, 1989; Mészáros, Crawford, Szabó, Nagy-Kovács, & Révész, 1989) found enhanced theta power in the right hemisphere among highs while engaged in eyes-closed arithmetic, visual discrimination, and imaginal tasks. In addition, we found hemispheric asymmetry differences for lows and highs in the anterior and posterior regions of the brain. Generalized functional changes were not evident throughout the entire hemisphere; rather, differential influences within hemispheres along an anterior-posterior axis were found (e.g., Gruzelier, 1987, 1990).

In a study of induced positive and negative emotional states during waking and hypnosis, we (Crawford, Clarke, & Kitner-Triolo, 1989; Crawford, Kitner-Triolo, Clarke, & Brown, 1988) found highs showed significantly more mean theta power than did lows. Highs showed significantly more theta power in the right than left hemisphere, while

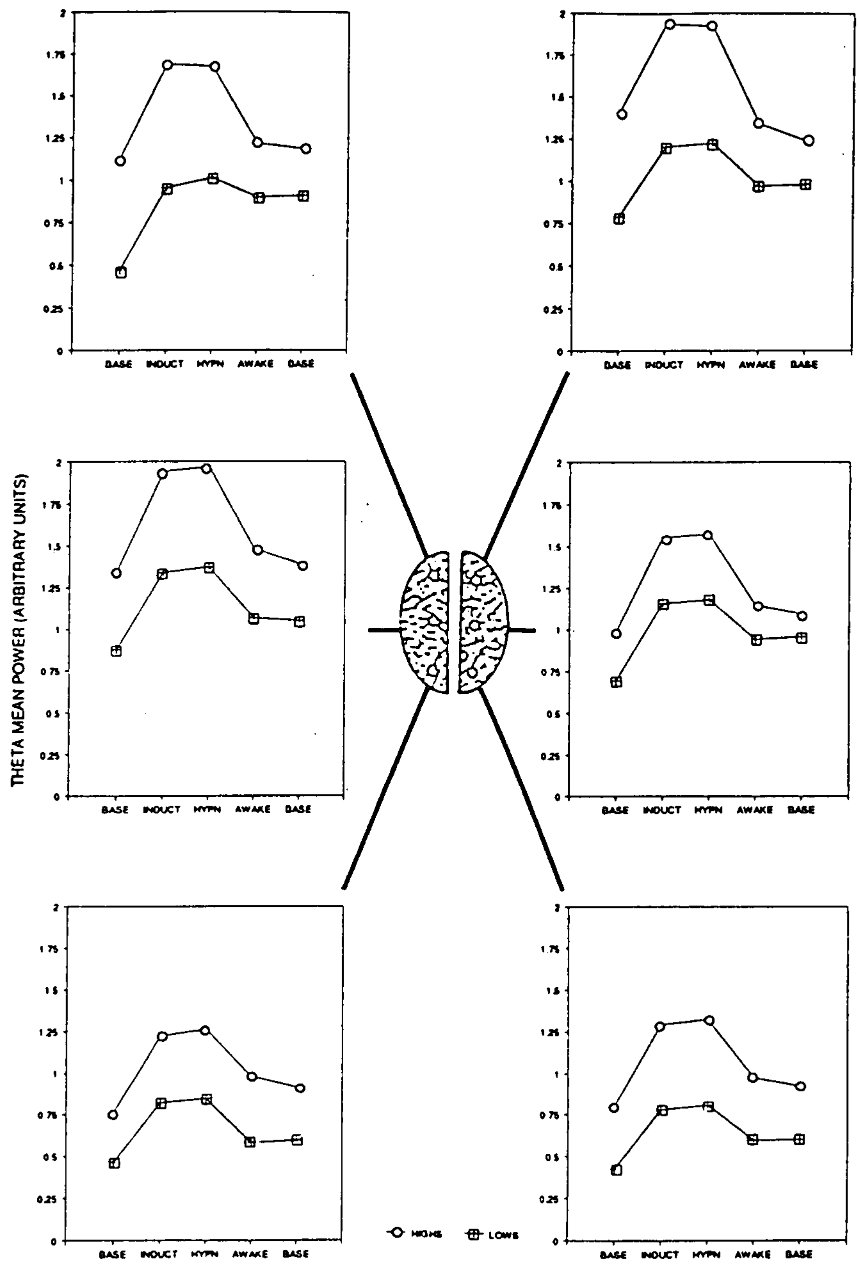


Figure 1. **Mean theta power differences across waking and hypnosis conditions at frontal (F3, F4), central (C3, C4), and occipital (01, 02) regions in low and high hypnotizables.**
Note. From "EEG Correlates of Hypnotic Susceptibility and Hypnotic Trance: Spectral Analysis and Coherence," by M. E. Sabourin, S. D. Cutcomb, H. J. Crawford, and K. Pribram, 1990, *International Journal of Psychophysiology, 10,* p. 132. Copyright 1990 by Elsevier. Reprinted by permission.

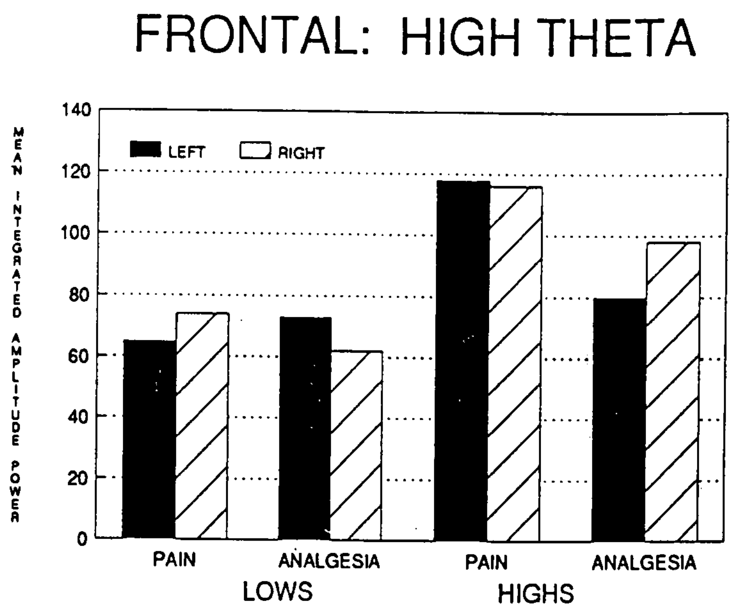
lows showed no significant hemispheric differences for either happy or sad emotional states.

During hypnosis when experiencing cold pressor pain and following suggested analgesia, highs were found to generate more high theta power (5.5 - 7.5) Hz in both hemispheres of the frontal (F3, F4), temporal (T3, T4), parietal (P3, P4), and occipital (01, 02) regions (Crawford, 1990a, 1990b) (see Figure 2). This study will be discussed in greater detail later in this article.

Increased theta power similar to that observed in hypnosis has been reported following restricted environmental stimulation (Barabasz, 1990), and during quiescent meditative states among experienced meditators (Banquet, 1973; Corby, Roth, Zarcone, & Kopell, 1978; Delmonte, 1984; Elson, Hauri, & Cunis, 1977; Hebert & Lehmann, 1979; Kasamatsu & Hirai, 1969; Saletu, 1987; Taneli & Krahne, 1987), autogenic training (Jacobs & Lubar, 1989), and a "self-regulation method" that is similar to self-hypnosis (Ikema, 1988; Ikema, Tomita, Kuroda, Hayashida, & Ikema, 1986). These related alternate states of awareness all involve the redistribution of attention, and are often accompanied by self-reports of enhanced focused attention.

Can theta recorded at the surface of the scalp reflect theta generators indigenous to the hippocampal system, a phylogenetically ancient cortex? Michel, Lehmann, Henggeler, and Brandeis (1992) reported the first dipole study evidence indicating that theta recorded at the cortical surface is of a bihemispheric origin from the hippocampal region of the human brain. A study (Arnolds, Lopes Da Silva, Aitink, Kamp, & Boeijinga, 1980) of an epileptic patient with electrodes implanted in the hippocampal area reinforced the relationships between theta in the hippocampus and focused attention. When the patient was concentrating on a task, there were enhanced theta bursts being generated in the hippocampal area.

There is strong evidence from animal studies (e.g, Isaacson, 1982; Isaacson & Pribram, 1986; R. Miller, 1991) that increased firing of theta generators (increased theta bursts) in the hippocampal region occurs when animals (e.g., cats, rats, rabbits, primates) are actively engaged in exploratory and other attentional behaviors. Pribram and his associates (Crowne, Konow, Drake, & Pribram, 1972; see also, Pribram, 1991) demonstrated that the hippocampus is "ordinarily involved in processing the nonreinforced rather than the reinforced aspects of a situation" (Pribram, 1991, p. 224). This implies that the hippocampus is assisting in processing the nonimportant stimuli in the environment that are to be subsequently ignored. R. Miller (1989, 1991) suggested that the hippocampus through a cortico-hippocampal relay transmits information by theta wave modulation and Hebbian synaptic modification so that there is selective disattention. Crowne et al. (1972) found theta electrical activity from the hippocampus while monkeys were performing discrimina-


FRONTAL: HIGH THETA
MEAN INTEGRATED AMPLITUDE POWER
LEFT
RIGHT
140
120
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60
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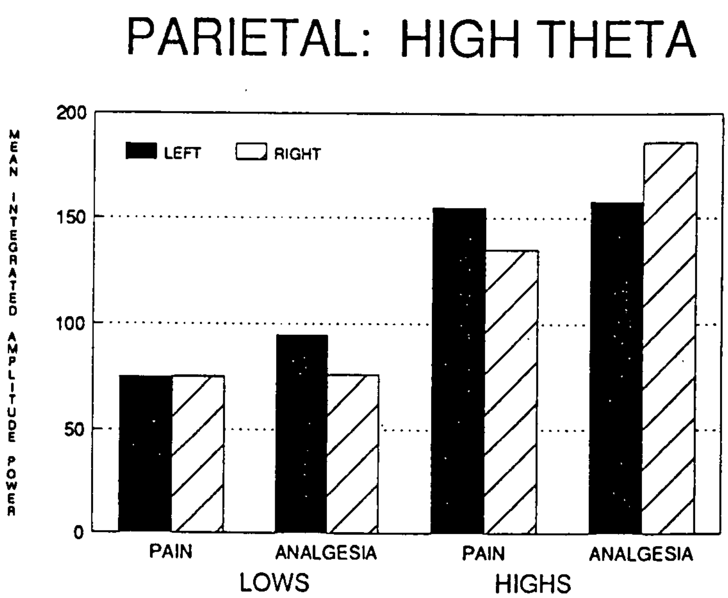
PARIETAL: HIGH THETA
MEAN INTEGRATED AMPLITUDE POWER
LEFT
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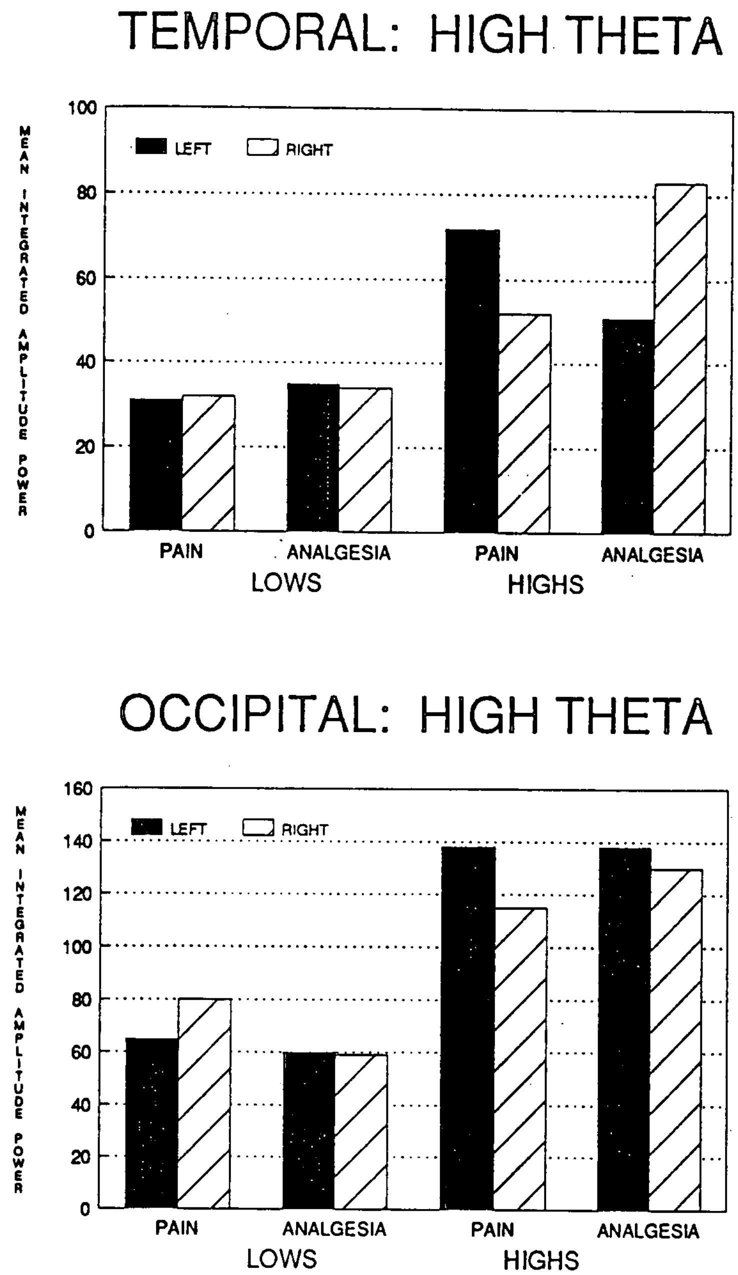

Figure 2. **Mean integrated theta power in the left and right hemispheres during hypnosis with and without suggested analgesia in low and high hypnotizables.**

Note. From "Cognitive and Psychophysiological Correlates of Hypnotic Responsiveness and Hypnosis," by H. J. Crawford, in M. L. Fass and D. Brown (Eds.), 1990, *Creative Mastery in Hypnosis and Hypnoanalysis: A Festschrift for Erika Fromm* (p. 53); Hillsdale, NJ: Lawrence Erlbaum. Copyright 1990 by Lawrence Erlbaum Associates. Reprinted by permission of the author.

tion tasks. When monkeys learned not to respond in no-go conditions, hippocampal theta was generated. As Pribram (1991) stated, "It is as if these systems were processing 'don't look there' rather than 'look-here' " (p. 224). This suggests that the willing of both attention and disattention may be correlated with theta activity.

De Benedittis and Sironi (1986, 1988) have directly examined hippocampal and amygdala electrical activity in epileptic patients with deeply implanted intracranial electrodes. During hypnosis, repeated stimulations of the left and right amygdala aroused a moderately hypnotizable patient from hypnosis, whereas stimulation of the temporal neocortices and the right Ammon's horn of the hippocampus did not. Unknown is whether any segment of the arousal system that includes the amygdala, when stimulated may bring an individual out of hypnosis. They postulated "that hypnotic behavior is mediated, at least in part, by a dynamic balance of antagonizing effects of discrete limbic structures—the amygdala and the hippocampus. In fact, the trance state is associated with the hippocampal activity, concomitant with a partial angdaloid [*sic*] complex functional inhibition" (p. 104).

What might this related physiological research say about the robust finding of greater theta power in high than low hypnotizable persons during task performance that requires focused and sustained attention? I would like to suggest that highly hypnotizable persons demonstrate greater efficiency in processing relevant and irrelevant environmental stimuli—the process of cognitive inhibition and ignoring stimuli requires first the recognition of it and then the decision to not look there. It is hypothesized that this disattending ability is related to greater theta power, a reflection of the fronto-limbic system of attention. If this is true, then to eliminate the perception of pain or to experience other positive or negative hallucinations, the highly hypnotizable person must have the ability to disattend and may generate substantial theta power during such attentive/disattentive states. Several hypnotic analgesia studies, reviewed in the next section, provide support for this hypothesis.

Finally, related neurophysiological work from Gruzelier's laboratory provides further support for our argument of greater fronto-limbic inhibitory processing found among highs. Gruzelier and Brow (1985) found that there were fewer orienting responses and increased habituation to relevant auditory clicks during hypnosis for highs, but not lows. Such changes reflect increased activity in fronto-limbic attentional systems having an inhibitory action (Gruzelier, 1990; Gruzelier & Venables, 1972).

Hypnotic Analgesia: Shifts in Attentional Processing

Pain and hypnotic analgesia is a particularly fertile ground to explore attentional and disattentional processes and their relationships to hypnotic susceptibility. The effectiveness of hypnosis in the relief of pain is a topic not in need of review here (for a review, see E. R. Hilgard & J. R. Hilgard, 1983). Typically, standardized measures of hypnotic susceptibility correlate about .50 with pain reduction during hypnotically suggested analgesia.

Neurophysiology of Pain

Pain is "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such pain" (Mersky, 1986, p. 215). First, there is the nociception or sensory aspect of pain. Second, there are the emotional-motivation and cognitive aspects of pain, often referred to as psychological distress. Much work (for a review, see Price, 1988) has been done to elucidate the complex interactions between primary sensory afferents and neuronal responses within the dorsal horn of the spinal cord and the subcortical structures, but much less is known about the cortical-subcortical involvement during pain.

Two processes present in pain and temperature are associated with different regions of the brain. The epicritic, sensory aspects of pain are more associated with the central and posterior regions of the brain, while the protocritic, distress, comfort-discomfort aspects of pain are associated with the fronto-limbic region (e.g., Pribram, 1991). The sensory experience that is critically located in space and time is sent to the posterior region of the brain, particularly the parietal cortex. Anatomical studies have linked the multisynaptic pain pathways from the thalamus not only to the posterior cortex but also to the amygdala and related limbic-cortical structures, as well as to the orbito-frontal cortex (e.g., Morin, Schwartz, & O'Leary, 1951; Pribram, 1991; Price, 1988; Roland, 1992). Electrical activity from the frontal cortex shows arousal when pain is experienced. As attention is directed away from pain, it is hypothesized that one should see changes in the activation of this anterior protocritic sensory process that may differ from changes observed in the posterior epicritic process.

Using magnetic resonance imaging and PET in humans, Talbot and her colleagues (Talbot et al., 1991) have demonstrated that the parietal and frontal cortical areas are involved in different aspects of heat perception (41-42° C; 48-49° C). Mild heat and pain are evaluated in terms of their temporal and spatial features in the posterior primary and secondary somatosensory cortex and in terms of emotional reactions of distress in the limbic regions of the frontal cortex, particularly the anterior cingulate cortex. The heterogeneous anterior cingulate cortex is activated during word association, recognition of visual material, and lactate-induced panic (for a review, see Raichle, 1990). Jones, Brown, Friston, Qi, and Frackowiak (1991) administered painful thermal stimuli (46-47° C) to the forearm. With PET subtractive techniques they found that the contralateral thalamus, anterior cingulate cortex, and lenticular nucleus are activated when strong pain is experienced. Removal of the frontal or cingulate cortex in patients with intractable pain leads to the amelioration of distress while not eliminating sensory pain (for a review, see Bouckoms, 1989). These diverse physiological studies suggest that the frontal cortex and the cingulate mediate thalamic pain input from the spinothalamic tract.

Neurophysiological Changes During Hypnotic Analgesia

Highly hypnotizable pain patients or laboratory subjects are more likely to learn to decrease or eliminate the perception of pain during suggested analgesia (for review, see E. R. Hilgard & J. R. Hilgard, 1983). Those who can eliminate the distress or emotional involvement but still experience some sensory pain give reports similar to frontal lobotomized patients (Bouckoms, 1989). The virtuoso hypnotic individual, whom we study after extensive screening and training, can eliminate absolutely all perception of sensory pain and distress. Brain dynamic changes accompanying hypnotic analgesia in such virtuoso highs have been observed in recent EEG, ERP, and CBF studies.

Electroencephalographic activity. In an earlier section was a discussion of enhanced theta being associated with focused attention. Recently I (Crawford, 1990a, 1990b) have initiated research to investigate EEG correlates of cold pressor pain during counterbalanced conditions of attend to and suggested analgesia in conditions of waking and hypnosis. Subjects were highs who had been able to reduce the perception of pain to absolutely no experience during cold pressor training sessions and lows who could not eliminate such pain perceptions, although their pain and distress perceptions were sometimes reduced during suggested hypnotic analgesia. Using the same recording technique as Sabourin et al. (1990), EEG was recorded monopolarly at frontal (F3, F4), temporal (T3, T4), parietal (P3, P4), and occipital (01, 02) regions while subjects had their left hand dipped into cold water for 60 seconds.

In all measured brain regions, highs showed significantly more high theta (5.5 - 7.5 Hz) power than did lows during pain and analgesia during hypnosis. Of the four regions of the brain (Figure 2), the anterior temporal region (T3, T4) showed the greatest differences between pain and analgesia conditions. In the anterior temporal region, during pain and analgesia, low hypnotizables showed no significant asymmetries between the left and right hemispheres. By contrast, the highs were significantly more left hemisphere dominant in the pain dip and showed a dramatic reversal in hemispheric dominance during analgesia. Left hemisphere theta power decreased significantly while right hemisphere theta power increased in the anterior temporal region (T3, T4).

Complementary support is provided by Larbig and his colleagues (Larbig et al., 1982) in a study of the EEG and evoked potentials in fakirs trained to hang from hooks or put needles through their skin or tongue without perception of pain. Substantially higher theta power was shown in the parietal, but not central, midline derivations in fakirs who demonstrated pain control, in comparison to controls who showed no change when asked to reduce pain perception but were unsuccessful. Chen, Dworkin, and Bloomquist (1981) reported shifts in EEG theta and alpha power during hypnotic analgesia in one dental patient undergoing surgery.

If cortically recorded theta is reflective of underlying theta generators in the hippocampal region as found by Michel et al. (1992), these data suggest the fronto-hippocampal attentional system may be involved during suggested analgesia. Shifts in theta power dominance, as seen in Crawford (1990a, 1990b), suggest possible shifts in hippocampal dominance during conditions of pain and analgesia. When pain is experienced, the subject—particularly the highly hypnotizable subject—is immersed in and focused on the external pain. This focusing of attention on the environment is suggestive of left hemisphere involvement. When hypnotic analgesia occurs, the subject may turn away from the pain and be immersed in and focused on ongoing self-generated imagery. While this imagery activity may be associated with right hemisphere functioning (e.g., Kosslyn, 1988), we must also consider more complex brain dynamics as the left hemisphere has also been implicated in self-generated visual imagery (e.g., Farah, 1988; for a review, see Crawford, in press). Research with topographical EEG is under way in my laboratory to explore further brain dynamics, both anterior-posterior and left-right, during cold pressor pain.

Somatosensory evoked potentials. The later components of pain-associated ERP amplitudes correlate positively with perceived pain level (e.g., Chen, Chapman, & Harkins, 1979; Stowell, 1984). When given successful suggestions of hypnotic analgesia or reduced feeling, the amplitudes of the early, sensory components of evoked potentials (less than 100 msec) to somatosensory electrical (e.g., Mészáros, Bányai, & Greguss, 1981; Spiegel, Bierre, & Rootenberg, 1989) and heat (e.g., Sharev & Tal, 1989) stimuli are apparently unaffected. But the latter components of the evoked potential are often, but not always (e.g., Barabasz & Lonsdale, 1983), reduced in amplitude. Mészáros et al. (1980) reported decreases in P200 somatosensory (SERP) amplitudes to short electrical impulses to the median nerve during hypnotic analgesia. Spiegel et al. (1989) demonstrated that there were greater reductions in the SERP components to mildly uncomfortable stimuli in the right hemisphere than in the left hemisphere, as early as P100. We (De Pascalis, Crawford, & Marucci, 1992a, 1992b) found reductions of the amplitude of the N150-P260, more so in the left hemisphere, to quite painful somatosensory stimuli administered to the median nerve during suggested hypnotic analgesia. Like

I. Mészáros (personal communication, July 1990), we found the P200 (which correlates with perceived pain level in other studies) contributed to this reduced amplitude.

In ongoing research, we (e.g., Crawford, Pribram et al., 1992, 1993; Crawford, Pribram, Xie, & Zhang, 1993a, 1993b) are evaluating topographical SERP brain maps of highs who can completely eliminate the perception of pain with lows during conditions of attend to and ignore noxious electrical stimulations. During hypnotic analgesia, in the far frontal region there is often a complete amelioration of the SERP at least as early as N100, while in the primary sensory central region, we observe dramatic decreases of the N100 and P200 often with no later components evident. At times we have seen contingent negative variations in the pre-500-msec period, associated with preparation to respond or inhibit responses (Birbaumer, Elbert, Canavan, & Rockstroh, 1990), occur during hypnotic analgesia mainly in the far frontal region. This ongoing research supports prior research (e.g., Jones et al., 1991; Talbot et al., 1991) suggesting two attentional systems associated with pain. During hypnotic analgesia, the far frontal cortex appears to be involved in a topographically specific inhibitory feedback circuit that cooperates in the regulation of thalamocortical activities (for a review, see Birbaumer et al., 1990). Thus we propose that during hypnotic analgesia the far frontal cortex "determines" that the incoming painful events are irrelevant and is involved in the inhibition of somatosensory information coming from the thalamic region.

Cerebral blood flow. Regional cerebral blood flow (CBF) provides a window on regional brain metabolism activity that is sensitive to the effects of cognitive tasks (e.g., Gur & Reivich, 1980; Risberg, 1986). In the first study to address CBF activation patterns by the 133-xenon inhalation method during hypnotic analgesia, Crawford, Gur, Skolnick, Gur, and Benson (1993) studied virtuoso highs who could completely eliminate the perception of pain with lows. Following an eyes-closed rest condition, they were administered ischemic pain to both arms under counterbalanced conditions of attend to pain and suggested analgesia in waking and hypnosis. Previously, they had been administered three standardized hypnotizability scales as well as training in both the typical cold pressor pain and ischemic pain experimental regimes.

Both low and highly hypnotizable men had essentially the same initial slope of regional blood flow metabolism during the waking condition, regardless of the presence or absence of pain. During hypnosis, the lows continued to show similar cerebral metabolism, while the highs showed a significant increase in overall CBF during hypnosis (see Figure 3). This finding of enhanced CBF during hypnosis has been substantiated elsewhere (De Benedittis & Longostreui, 1988; Halama, 1989; Meyer, Diehl, Ulrich, & Meinig, 1989; Walter, 1992). We believe this process may reflect increased cortical involvement in the focusing of attention and disatten-

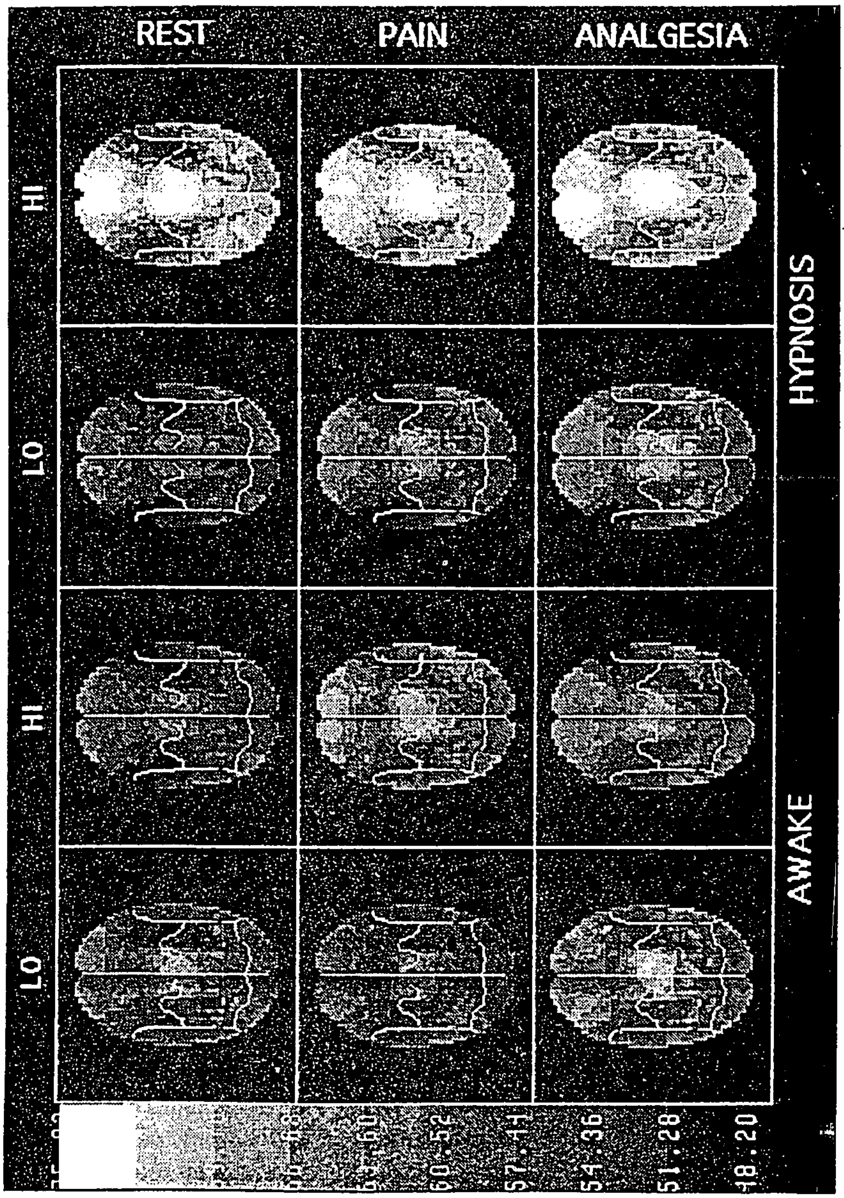

Figure 3. A topographical display of CBF grey-matter values in three conditions: Rest (Column 1), Pain (Column 2), Pain with Suggested Analgesia (Column 3). The waking, nonhypnosis state is the first two rows: low (bottom row) and highly (second row) hypnotizable subjects. The hypnosis state is the top two rows: Low (third row) and highly (fourth row) hypnotizable subjects. The lighter the color, the greater the CBF.

Note. From "Effects of Hypnosis on Regional Cerebral Blood Flow During Ischemic Pain With and Without Suggested Hypnotic Analgesia," by H. J. Crawford, R. C. Gur, B. Skolnick, R. E. Gur, and D. Benson, 1993, *International Journal of Psychophysiology, 15*, p. 189. Copyright 1993 by Elsevier. Reprinted by permission.

tion during hypnosis (e.g., E. R. Hilgard, 1965, 1986; Krippner & Bindler, 1974). While hypnosis may be experienced as being involuntary and effortless, at another level the cerebral metabolism increases suggest that hypnosis may be a state in which there is increased cognitive effort and activity occurring. Thus, in view of the consistent demonstrations of increased CBF during mental effort (for a review, see Frith, 1991), this research supports a growing belief (e.g., Crawford & Gruzelier, 1992; E. R. Hilgard, 1986) that hypnosis takes effort and is a cognitive task that demands attentional and disattentional allocations.

During ischemic pain there was the anticipated increased CBF in the somatosensory cortex, consistent with other neuroimaging studies. During hypnotic analgesia, there were significant CBF increases only among the highs, beyond that noted in the attend to pain condition, in the orbito-frontal cortex and the sensorimotor cortex. Crawford, Gur, et al. (1993) suggest "that the increased orbito-frontal CBF activation in highs is reflective of increased attentional effort during hypnotic analgesia by the 'executive control system' (E. R. Hilgard, 1986; Pribram, 1991) or 'supervisory attentional system' (Shallice, 1988). PET studies (for a review, see Frith, 1991) show an increase of activity in the frontal cortex during the performance of willed actions" (p. 192). They concluded that their data provide further support to the hypothesis that hypnotic analgesia activates a topographically specific inhibitory feedback circuit that cooperates in the regulation of thalamocortical activities (e.g., Birbaumer et al., 1990).

Such CBF data, in conjunction with previously reviewed SERP (Crawford, Pribram, et al., 1992, 1993; 1993a, 1993b) and habituation (Gruzelier & Brow, 1985) findings suggestive of enhanced frontal lobe inhibitory processing during hypnosis, fail to support Bowers' (1990; see also, Miller & Bowers, 1986, 1993) conclusion that "hypnotic analgesia does not seem to require executive initiative and/or the sustained effort of higher, conscious processes" (Bowers, 1990, p. 171) but rather unspecified "lower levels" (p. 171) of cognitive control. Rather, I would argue that "dissociated control" still requires higher order cognitive and attentional effort (even though experienced as effortless or out of awareness). Morton Prince (1910) argued that dissociated hypnotic phenomena were due to "consciousness occur(ing) without self-consciousness" (p. 29). While there may be a lack of self-concept (see Kihlstrom, 1987; Kunzendorf, 1989-90) and thus a dissociation during hypnosis, this does not negate processes still occurring during dissociated hypnotic phenomena that may involve higher cognitive processing and the executive control system. My laboratory is presently pursuing research that investigates the interplay between cortical-subcortical processes during hypnotic phenomena out of awareness to self-consciousness.

CONCLUSIONS

Experimental evidence has been provided that highly hypnotizable persons demonstrate greater cognitive flexibility, the ability to shift cognitive strategies and states of awareness, than do lows (e.g., Crawford, 1982a; 1989; Crawford & Allen, 1983; Crawford & Gruzelier, 1992; Crawford et al., 1986). Highs can shift from detail to holistic strategies with greater ease than lows (e.g., Crawford & Allen, 1983). Highs can also shift from left to right anterior functioning as demonstrated by neuropsychological tests (e.g., Gruzelier, 1990; Gruzelier & Warren, 1993). These cognitive strategy shifts appear to be accompanied by greater neurophysiological hemispheric specificity or dominance across tasks (e.g., Crawford, 1989, 1990a, 1990b, 1991; Crawford, Mészáros, & Szabó, 1989; for reviews, see Crawford & Gruzelier, 1992; Gruzelier, 1987, 1990).

In the present article, evidence was presented to suggest that highly hypnotizable persons possess stronger attentional filtering abilities that may be associated with the fronto-limbic attentional system. As shown in behavioral and cognitive studies, highly hypnotizable individuals have a greater ability to sustain focused attention on relevant activities and to disattend nonimportant stimuli in the environment than do low hypnotizable persons. The importance of the anterior fronto-limbic system in the control processes of attention is supported by independent studies of EEG, evoked potentials, cerebral blood flow, electrodermal, and neuropsychological functioning. These studies demonstrate individual differences in the brain dynamics of lows and highs in waking or hypnosis. Despite these propositions, much has still to be empirically demonstrated and explained. While an emphasis has been placed upon neurophysiological mechanisms associated with focused attention and disattention, we must also still consider other additionally important information processing abilities of highs and what neurophysiological correlates may be associated with them (e.g., Crawford, in press). These include the abilities to give up reality testing and become deeply involved in imaginative activities, to produce imagery (even of an hallucinatory nature) vividly and effortlessly, and the ability to shift to greater holistic information processing styles.

Most exciting then is that our field of hypnosis research can provide a unique window on individual differences in cognitive and attentional processing and their accompanying brain dynamics. As B. F. Skinner (1989) wrote just prior to his death:

> There are two unavoidable gaps in any behavioral account: one between the stimulating action of the environment and the response of the organism and one between consequences and the resulting change in behavior. Only brain science can fill those gaps. In doing so it completes the account; it does not give a different account of the same thing. (p. 18)

Thus brain research is validating and extending our behavioral observations—it is completing our account of how and why individuals differ in their abilities to attend and to disattend and helping us understand why there are individual differences in hypnotic susceptibility.

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Gehirnsdynamik und Hypnose: Aufmerksamkeits- und Unaufmerksamkeitsprozesse

Helen J. Crawford

Abstrakt: Diese Arbeit gibt einen Überblick über neuere Forschungsbefunde und damit ein entfaltendes, neuropsychophysiologisches Modell der Hypnose erweiternd (Crawford, 1989; Crawford & Gruzelier, 1992), das die Meinung unterstützt, daβ hoch hypnotisierbare Personen (die Hohen) stärkere aufmerksamkeitsfilternde Fähigkeiten besitzen als die schwach hypnotisierbaren Personen und daβ diese Unterschiede in der unterliegenden Gehirnsdynamik reflektiert werden. Der verhaltensmäβige, kognitive und neurophysiologische Nachweis wird untersucht, der andeutet, daβ die Hohen ihre Aufmerksamkeit besser fokussieren und aufrechterhalten können sowie auch unaufmerksamer auf irrelevante Stimuli in der Umgebung reagieren können. Es wird vorgeschlagen, daβ Hypnose ein Zustand der verstärkten Aufmerksamkeit ist, der ein Zwischenspiel zwischen kortikaler und subkortikaler Gehirnsdynamik während des Erlebens von dissoziierten, hypnotischen Phänomenen, wie hypnotische Analgesie, darstellt. Eine Sammlung von Forschungsbefunden ist untersucht, die andeutet, daβ Aufmerksamkeits- wie auch Unaufmerksamkeitsprozesse im Erleben der Hypnose und der hypnotischen Phänomene wichtig sind. Befunde aus Studien der elektrokortikalen Aktivität, geschehnisbezogen hervorgerufenen Potentialen und regionaler, zerebraler Blutzufuhr während des Wachzustandes und der Hypnose werden geboten, um anzudeuten, daβ diese Aufmerksamkeitsunterschiede in unterliegenden, neurophysiologischen Unterschieden im weiten fronto-limbischen Aufmerksamkeitssystem reflektiert sind.

Dynamiques cérébrales et hypnose: processus attentionnels et désattentionnels

Helen J. Crawford

Résumé: Cette étude examine les récentes découvertes, mettant de l'avant un modèle neuropsychophysiologique de l'hypnose (Crawford, 1989; Crawford &

Gruzelier, 1992), qui soutient le point vue que les individus à suggestibilité élevée possèdent des capacités de filtrage attentionnel plus élevées que n'en possèdent les individus à suggestibilité faible, et que ces différences sont reflétées dans les dynamiques cérébrales sous-jacentes. Les évidences béhaviorales, cognitives et neurophysiologiques revues suggèrent que les sujets fortement hypnotisables peuvent tout à la fois mieux se concentrer et maintenir leur attention aussi bien que de ne pas prêter attention aux stimuli non pertinents de l'environnement. Il est proposé que l'hypnose est un état d'attention accru qui active un processus interactionnel entre les dynamiques cérébrales corticales et sous-corticales durant l'expérience du phénomène de dissociation hypnotique telle l'analgésie hypnotique. Les nombreuses études recensées suggèrent que les deux processus, attentionel et désattentionel, sont importants dans l'expérience de l'hypnose et du phénomène hypnotique. Les résultats des études sur l'activité électrocorticale, les potentiels évoqués et le flot cérébral régional durant l'éveil et l'hypnose sont présentés pour suggérer que ces différences attentionelles sont reflétées dans les différences neurophysiologiques sous-jacentes au niveau du système d'attention fronto-limbique.

Dinámica cerebral e hipnosis:
procesos de atención y distracción

Helen J. Crawford

Resumen: Este trabajo revisa recientes hallazgos de investigaciones que despliegan un modelo neurofisiológico desarrollado de la hipnosis (Crawford, 1989; Crawford y Gruzelier, 1992). Este modelo sostiene la idea que personas altamente hipnotizables poseen capacidades de filtrado de la atención más fuertes que aquellas personas de baja hipnotizabilidad, y que estas diferencias están reflejadas en la dinámica cerebral subyacente. Se revisaron evidencias conductuales, cognitivas y neurofisiológicas que sugieren que los sujetos altamente hipnotizables pueden focalizar y sostener su atención así como desatender estímulos irrelevantes del medio ambiente. Se propone que la hipnosis es un estado de atención incrementada que activa un interjuego entre la dinámica cerebral del fenómeno hipnótico, tal como la analgesia hipnótica. Se revisó un cuerpo de investigación que sugiere que los procesos de atención y de distracción son importantes en la experiencia del fenómeno hipnótico y de la hipnosis. Hallazgos provenientes de estudios de actividad electrocortical, de potenciales evocados y de flujo sanguíneo cerebral regional durante la vigilia y la hipnosis fueron presentados para indicar que estas diferencias atencionales están reflejadas en las diferencias neurofisiológicas subyacentes en el lejano sistema fronto-límbico de la atención.