

HYPNOSIS AND IMAGINATION

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CHAPTER 13

*Cerebral Brain Dynamics
of Mental Imagery:
Evidence and
Issues for Hypnosis*

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There is good evidence for the age-old belief that the brain has something to do with . . . mind. Or, to use less dualistic terms, when behavioral phenomena are carved at their joints, there will be some sense in which the analysis will correspond to the way the brain is put together. . . . In any case each time there is a new idea in psychology, it suggests a corresponding insight in neurophysiology, and vice versa. The procedure of looking back and forth between the two fields is not only ancient and honorable—it is always fun and occasionally useful [1, p. 196], as quoted in Pribram [2, p. 1].

INTRODUCTION

Perceptual alterations and suggested hallucinations are the core phenomena of hypnosis [3]. Commonly given hypnotic suggestions ask persons to “image” or “imagine” an arm getting stiff, regressing to an earlier age, seeing something that is not present (e.g., hallucinating a person not present), or not seeing or feeling or smelling something that is actually present (e.g., not experiencing pain, hypnotic analgesia). These imaginal processes, whose roots are found in the Latin word *imitari*, to imitate, refer to the development of a mental representation of anything not actually in the senses. These mental images may or may not occur in conjunction with incoming sensory stimuli (e.g., hypnotic analgesia). Such complex, higher order cognitive processes involve various neurophysiological systems (e.g., [4, 5]) yet little attention has been given to integrating hypnosis findings into more recent neurophysiological studies of perceptually- and mentally-based imaging (e.g., [2, 6-10]).

Within the domain of hypnosis, these imaginal processes are variously hypothesized to draw on abilities such as imagery (e.g., [11-14]), imaginative involvement [15], absorption (e.g., [16, 17]), sustained attention [18], giving up reality testing

[19], and topographic regression [20]. A massive literature has examined the relationships between these individual cognitive abilities and hypnotizability, reporting at most moderate correlations in the .40s. Enhancements in imaginal processing during hypnosis for highly hypnotizable persons (subsequently referred to as highs) but not low hypnotizable persons (lows) have also been reported (e.g., [21, 22]; for review, see [11]).

No longer can one hypothesize hypnosis to be a right-hemisphere task, a commonly espoused theory (e.g., [23, 24]) popular since the 1970s, or that highly hypnotizable individuals exhibit greater right hemisphericity [25]. Rather, there is growing evidence (for reviews, see [4, 26-28]) that hypnotic phenomena selectively involve cortical and subcortical processes of either hemisphere, dependent upon the nature of the task, as well as shifts in attention and "disattention" processes. Highs apparently exhibit greater cognitive flexibility [21, 29], physiological hemispheric specificity [29, 30], and sustained attentional and disattentional processing [18] possibly due to differences in the prefronto-limbic attentional system [18, 26, 27, 31]. Thus, hypnosis instructions "can be seen to trigger a process that alters brain functional organization—a process that at the same time is dependent on individual differences in existing functional dynamics of the central nervous system" [4, p. 265]. The lack of "self-consciousness" so that hypnotic hallucinations become "unmonitored" images (e.g., [32, 33]) or dissociated (e.g., [34]) suggests possible greater involvement of prefrontal, disattentional brain systems. Thus, hypnotic phenomena may differentially involve left and right hemispheres, anteriorly and posteriorly, in different cortical and subcortical subsystems. Such differences may depend upon the type of imagery generated, the strategies employed, the accompanying emotional affect, the degree of effortful or willful attention involved, and the imagery or attentional skills of the individual. This chapter is directed toward reevaluating psychophysiological studies of imaginal processing during waking and hypnosis, as moderated by hypnotic level, in light of recent shifts in theoretical thinking about the neuropsychophysiological substrates of mental imagery.

IMAGINAL PROCESSING AND HYPNOSIS

Correlates of Hypnotic Susceptibility

Relationships between hypnotic susceptibility level and self reports of imaginal processing or performance on perceptual and cognitive tasks involving imagery have been reported, albeit not consistently, by a number of researchers (e.g., for reviews, see [11-14, 35-37]). While imagery is most commonly assessed by Marks' [38] Vividness of Visual Imagery Questionnaire or Sheehan's [39] imagery questionnaire, such self-report questionnaires may be affected by potential demand characteristics, subject expectations and social desirability [40, 41]. Work by Barrett suggests that there are two subgroups of highs: those who are

high on absorption and describe their hypnotic experiences as being much like their waking fantasy life; and the others who are lower in absorption and more likely to exhibit dissociative-like experiences in waking and hypnosis [42]. Kunzendorf and Boisvert provided some fascinating auditory brainstem evoked potential data that discriminates between these two groups of highs [43]. Hypnotic responsiveness is typically seen as being multidimensional, involving both multiple enduring abilities and situational influences (e.g., [37]). Thus, multivariate studies potentially provide more understanding about attentional [18] and imaginal [44] ability correlates. As seen below, a preference for and ease with imaginal-associated processing strategies may be more important than vividness per se in the imagery/hypnotizability relationship.

Gestalt closure tasks require subjects to organize fragmented stimuli into identifiable objects or scenes via gestalt processes of closure. Crawford found highs performed better, possibly because of their greater ability to be imaginal, holistic, and associational in strategies [45]. Wallace (Experiment 1) replicated these findings and additionally found that "the greatest number of correct closures was reported by those who were both high in hypnotic susceptibility and vivid in imaging ability" [46, p. 354].

Hypnotic susceptibility has been found to be associated with superior performance on visual search tasks [47, 48], and searches for an object embedded within a pictorial scene [49, 50]. It is thought that perceptual judgments of visual figural reversals require sustained concentration without distraction. Thus, hypnotizability has been shown to correlate with frequency of reversals of the Necker Cube as well as other visual illusions [18, 51-53]. Highs also report significantly more autokinetic movement in a dark environment [54, 55]. Consistently, these researchers have proposed that such relationships, as well as findings that highs perform better on sustained attentional tasks, are due to highs possessing greater sustained attentional and disattentional abilities [27]. Like research previously discussed, Wallace (Experiment 2) found that highs who also are vivid imagers report significantly longer after-images than either highs who are poor imagers or lows who are either vivid or poor imagers [46]. Thus, Wallace's innovative work provides new evidence of the importance of vivid imagery abilities moderating cognitive performance.

Shifts in Imaginal Processing during Hypnosis

Phenomenologically, imagery is often experienced as being more intense and hallucinatory during hypnosis [32]. Whether this is due to increased activation of imaging systems, shifts in thinking strategies, enhanced focused attention, expectations, or other cognitive factors is open to debate. From a clinical perspective, imagery

constitutes a very powerful uncovering technique because it is a symbolic representation of the activity of the patient's internal world, of unconscious

feelings, thoughts, and conflict [56, 57]. Imagery reveals these undercurrents more clearly than logical, reality-oriented, rational thinking . . . hypnotic imagery has often been found to represent problem-solving activity . . . [58, pp. 216-217].

In addition, imagery has been used within hypnotic and nonhypnotic contexts to influence bodily (e.g., psychoneuroimmunological) functioning with quite mixed results (for reviews, see [59-63]). The employment of imagery during hypnotically suggested analgesia is quite useful for pain control (for review, see [64]).

The enhancing effects of hypnosis upon self-reports of imagery vividness and/or controllability have been found in some studies but not others (e.g., [21, 65-67]). Bizarreness of imagery may also be increased (e.g., [68]). Encouraging, but mixed results have been reported on the facilitative effect of hypnosis upon creative task performance (for reviews, see [69, 70]).

Enhanced imaginal processing of information, particularly when the information to be remembered is literal or untransformed representations, has been shown to occur more consistently during hypnosis among hypnotically responsive individuals. Crawford and Allen examined performance on a sequential visual discrimination task that required detecting differences between successively presented picture pairs during waking and hypnosis [21]. While lows and highs did not differ significantly from one another in waking, highs showed enhanced performance in number correct during hypnosis but lows did not. Subjects reported two major strategies: 1) detail strategy, which involves the examination and rehearsal of individual details for memory, and 2) holistic strategy, which involves the examination and remembrance imaginally of whole pictures. Highs reported shifting to a more holistic, imagery-oriented strategy during hypnosis, while lows reported a preponderance of detail-oriented strategies in both conditions. In another study, Crawford, Nomura, and Slater found that subjects (both lows and highs) who reported during hypnosis experiencing significant shifts from a more detail-oriented strategy to a more holistic-oriented strategy, with reports of accompanying enhanced imagery, performed significantly better on a spatial memory for abstract forms test [71]. An alternative hypothesis to be considered is that hypnosis instructions facilitated a more focused and sustained attentional condition that led to enhanced performance.

A small percentage of high hypnotizables can produce eidetic-like visual memory imagery (remembering a random set of dots and superimposing this memory image upon a second set of dots in order to perceive a pattern of an object) during hypnosis [22, 72, 73] (for negative results, see [74]). Studies in the laboratories of Crawford and Wallace suggest that "this enhanced processing may be accompanied by reports of shifts in cognitive processing modes from a more verbal, detail-oriented style during waking to a more imaginal, holistic style during hypnosis" [29, p. 156]. In theoretically related research, longer sustaining of after-images during hypnosis by highs but not lows was reported by Atkinson [75].

Inspired by Paivio's dual-coding theory which proposes there are functionally separate but interactive imaginal and verbal processing systems, other research has examined the remembrance of more complex stimuli [76, 77]. The learning of high imagery, concrete words for subsequent recall is substantially easier than the learning of low imagery, abstract words. Traditionally, it is thought that imaginal processes are used for the processing of high imagery words (e.g., [76, 77]), although an alternate interpretation would suggest ease of verbal elaboration might also contribute. In light of this, several studies have examined paired-associate learning of high and low imagery words during hypnosis and waking with mixed results [78-81]. Positive relationships between hypnotizability and imagery-mediated learning was reported by 'T Hoen [81] but were not found by Sweeney, Lynn, and Bellezza [80]. By contrast, Crawford found lows recalled more low and high imagery words than did highs [78]. The facilitative effects of hypnosis on paired-associated learning was reported by Smith and Weene [79], but this study is limited by the lack of an assessment of the hypnotizability level of their subjects. Sweeney et al. reported no facilitative effect of hypnosis [80]. Crawford found highs recalled more words during hypnosis than waking, but the finding was not robust in all experimental orders [78].

Several studies by Friedman et al. found no hypnotizability-performance relationships for a speed of visual information processing, backward-masking task, but did find that subjects in the hypnosis condition performed significantly faster [82, 83]. Of interest to this chapter is that Friedman et al. found imagery suggestions had no influence on performance either in hypnotized or waking conditions [83].

Friedman, Taub, Sturr, and Monty suggested that imaginal differences between lows and highs after that favor highs may be more observable in more basic perceptual processes than in complex cognitive tasks [84]. The literature (for review, see [60]) reports enhanced performance during hypnosis more consistently for information to be remembered that is literal or untransformed representations. As Holroyd concluded, "The associated changes in imagery processing are more complex than simply changes in vividness, which heretofore was the principal attribute of interest" [60, p. 207]. Most certainly the observation of Friedman et al. [84] is an intriguing one that needs further systematic investigation in conjunction with the simultaneous evaluation of attentional and disattentional processes (e.g., [4, 26, 27]). Consideration of the rich literature on the neurophysiological correlates of imagery and hypnosis (discussed in subsequent sections) will also help guide future studies.

IMAGERY AND NEUROPHYSIOLOGICAL PROCESSING: GENERAL OVERVIEW

When the neurophysiology of perception is considered, a set of processes emerges, each served by a separate neural system. These systems are shown

to act in concert with other neural systems anatomically and/or biochemically related to them [2, p. 2].

... neither hemisphere can be said to be the seat of mental imagery; imagery is carried out by multiple processes, not all of which are implemented equally effectively in the same part of the brain [85, p. 1626].

Any mental thought is not an island unto itself. Rather, it is involved in a complexly orchestrated interplay—a reciprocal connectivity of top-down and bottom-up processing both within and between brain systems. Imagery involves an accessing of long-term memories about sensory experiences—visual as well as auditory and kinesthetic—so that at a phenomenological level it is experienced as if it were a perception. Whether imagery is a quasi-perceptual experience which shares some of its generational processes with perception has been the subject of a long-standing debate. There are two major sides with different models: top-down activation of perceptual representations models (e.g., [9, 86, 87]) and models maintaining that the representations imagery uses are distinct from actual perceptual representations (e.g., [88]). It is my working thesis that the creation of a mental image requires cognition, “an input independent of direct, current sensory stimulation” [2, p. 165] that reactivates downstream stored memory and perceptual systems—previously laden associative schemata—that then act in a similar manner to the percept imaging of external stimuli. If so, one may see certain similar brain systems activated during mental imagery and actual perception within the same sensory modality, if they have been equated in (among other additional dimensions) three distinguishable brain systems: the image, the object and the category [2].

Traditionally, mental imagery processing has often been assumed to be associated with the right hemisphere in the cerebral laterality literature. This was largely based upon a false formulation of a verbal/non-verbal split between the two hemispheres. One of the first challenges was a review of the neuropsychological literature by Paivio and te Linde [89]. They concluded that both hemispheres were involved with the right posterior hemisphere being more involved in image generation and manipulation processes. After a massive review of studies of lateral eye movement, EEG, and behavioral evaluations of brain damaged, commissurotomed, and normal subjects, Ehrlichman and Barrett concluded that there was insufficient empirical data for considering imagery as a right hemisphere function [90]. These challenging reviews subsequently led researchers to evaluate further how the various brain systems orchestrate together mental imagery.

There is growing evidence that specific components of imagery tasks can involve the left hemisphere, the right hemisphere, or bilaterally shared functioning of both hemispheres (e.g., [6-9, 91-93]). Not only is there differential hemispheric organization, but also there are important distinctions between the frontal and more posterior systems, with intimate interconnections, evident in both primates and humans [94]; (for review, see [2]). Thus, imagery processing can, like any

other mental process, be "decomposed into multicomponent information-processing systems" [85, p. 1621]. In addition, individual differences in mental imagery and other cognitive abilities may modulate how the brain processes mental imagery (e.g., [29, 38, 94, 95]). Hypotheses about the multicomponent imaginal systems, and the degree to which higher thought processes involved in mental imagery activate direct perceptual systems, in reciprocal connections between brain systems, can be tested by an increased availability of physiological neuroimaging methods such as computerized electroencephalographic (EEG) frequency analysis, EEG topographic brain mapping, evoked potential (EP) analysis, regional cerebral blood flow (rCBF), positron emission tomography (PET), and single photon emission computer tomography (SPECT).

In a landmark review, Farah [7] demonstrated how neurophysiological evidence on the relation between imagery and perception may eventually answer the long-debated question among cognitive psychologists: "Does visual imagery engage some of the same representations used in visual perception?" Earlier, Farah [6, 8] had demonstrated that for brain-damaged patients with a loss of imagery the posterior left hemisphere is critical for the imagery generation process, while right posterior damaged patients may demonstrate hemi-inattention to the left visual fields of actual and imagined perceptions [96]. The left hemisphere of split-brain patients is better than the right hemisphere in generating mental images [97, 98], apparently when multipart images are involved [98]. Whereas Farah [99] found the left hemisphere to be better at using imagery to prime perceptual recognition in a visual-field paradigm, a methodologically improved replication [100] found no evidence for a preferential locus of simple mental image generation in either hemisphere. A left hemisphere advantage was found for an imaginal scanning strategy with simple dot patterns [101]. By contrast, during more complex mental imaging of the spatial rotation, utilizing Shepard and Metzler's [102] paradigm, right hemispheric specialization was found in both normal and brain-damaged (left vs. right parietal) subjects [103]. Sergent's scathing review of research advocating the exclusive left hemisphere involvement in image generation makes us pause and reevaluate even further the contribution of the two hemispheres to the generation of mental images [104]. Sergent's conclusion is that both hemispheres house processing structures involved in generating multipart images. Deficit object or part-object imagery appears to be usually a consequence of left posterior damage [6, 8], whereas loss of spatial imagery (topographical memory) is a result of right posterior damage (e.g., [105]).

The contributions of the two hemispheres during imagery have emerged not only in Farah's work but also in Kosslyn's [9, 10, 85] multicomponent model that involves low-level and high-level processing by an image analysis system, and Marks' [106] model that views imagery as resulting from the "triggering of the relevant associative schemata" similar to Hebb's [107, 108] cell assemblies. Recently, Tippett [109] provided a comparative review of the theoretical "houses" of Farah, Kosslyn, Goldenberg, and Corballis. Pribram's seminal works on

holonomy and structure in figural processing [2] and the languages of the brain [110] have yet to be integrated into mental imagery research.

Pribram has provided an eloquent theory of brain and perception that should resonate to mental imagery researchers [2]. Unlike many neurophysiological theories of perception that only emphasize bottom-up, forward propagation of stimuli from the sensory organs to higher order "associative" cortex areas, Pribram reviews additional evidence for the likewise important top-down, higher-order influences on sensory cortex and demonstrates there are corticofugal connections even to the spinal reflex level (e.g., [1]) and the retinal processing stages [111, 112]. Dependent upon the imagery mode called upon, activation differences could be evident in the posterior convexity of the cerebrum if the mode is visual or auditory, the frontolimbic forebrain if olfactory/gustatory or pain/temperature, or the midarea around the central (Rolandic) fissure if tactile. Additional "computational spaces" may be activated within reciprocal brain systems when object-form or categorization is involved, or when there are multi-sensory mental images.

Kosslyn's still evolving theory of visual perception, drawn from a rich neurophysiological literature (e.g., [2]), has been applied more recently to mental imagery [10] with a rather successful attempt to explain individual differences in imaging visuospatial and imaginal information. Kosslyn [9, 85] proposed that low-level processing involves two cortical visual systems: the shape pathway, leading from the occipital lobe down to the inferior temporal lobe, and the location pathway, leading from the occipital lobe up to the parietal lobe [9, 85]. They connect via fibers to the frontal lobe. The subsystems of the high-level visual system are a visual buffer and an attention window that routes to the ventral system for shapes and the dorsal system for locations. The ventral system is involved in preprocessing or extracting "stable features of the stimulus that do not change when viewpoint or visual angle change" [10, p. 46], pattern activation and matching of shapes, and feature detection of properties (e.g., texture, color, location, simple shape features) that do require focal attention. The dorsal, location-encoding system involves spatiotopic mapping, encoding of categorical relations, and encoding of coordinate relations. In the hypothesis-testing system, subsystems of coordinate lookup, categorical lookup, categorical-coordinate conversion, attentional shifting, and transformation shifts are described. Kosslyn et al. [10] assumed "that the connections between the frontal lobe and the parietal lobe are involved" in the hypothesis-testing system, but have yet to elaborate upon these processes (see below).

Thus, Kosslyn has demonstrated that

the act of generating a visual mental image involves at least two classes of processes—ones that activate stored shapes and ones that use stored spatial relations to arrange shapes into an image. The discovery that the left hemisphere is better at arranging shapes when categorical information is appropriate, whereas the right hemisphere is better when coordinate information is

necessary, suggests that the processes that arrange parts can be further decomposed into two classes that operate on different sorts of information [85, p. 1626].

The left hemisphere is the "speech output controller," whereas the right hemisphere is the "search controller across the entire visual field" [9]. Similarly, the right hemisphere focuses more on the entire auditory field [113]. Thus, attention is also lateralized: the right hemisphere apparently is more dominant in the maintenance of attention over time and in vigilant, "preattentive focusing" (e.g., [114]), whereas the left hemisphere is superior at focusing on specific aspects of something (for review, see [92]).

Negative and positive affective states often accompany mental imagery and affect psychophysiological organization (for a review, see [115]). Langhinrichsen and Tucker's suggestion of an additional potential factor is worthy of noting:

Perhaps the right hemisphere and the left hemisphere have qualitatively different modes of experiencing and elaborating imagery. For example, consistent with notions of left hemisphere function, left hemisphere imagery might be detail-oriented, subvocally or verbally mediated, and connect to motor systems. Perhaps this left hemisphere imagery is related to the anxiety-relaxation dimension. In contrast, right hemisphere imagery may appear as a holistic or global display. It may well be past-oriented and unconnected to any perception of threat or anxiety. Right hemisphere imagery may be aligned with the mood dimension ranging from elation to depression. The right hemisphere may use imagery to facilitate access to affectively valenced long term memory [91, pp. 171-172].

Finally, the importance of the prefrontal executive control system [2, 34] or supervisory attentional system [116, 117] that directs and allocates the resources of the rest of the brain is deemphasized or often missing from mental imagery models. Petsche, Lacroix, Lindner, Rappelsberger, and Schmidt-Henrich suggest that sustained and elaborated verbal or imaginal thinking involves strongly the frontal regions as well as other neuroanatomical regions [93]. The three prefrontal subsystems direct the what, when, and how of processing:

The orbital cortex becomes involved when the question is what to do; the lateral frontal cortex becomes active when the question is how something is to be done and the dorsal portions of the lobe mediate when to do it. With regard to perceptual processing . . . "what" translates into propriety; "how" into practicality and "when" into priority. But . . . envisioning what to do when also involves where" [2, p. 242].

Thus, the type of mental thought processes involved may well activate different divisions of the prefrontal system.

These three major prefrontal subsystems have both cortical and subcortical connections, yet the probable additional involvement of the limbic system (e.g., amygdala, hippocampus, thalamus (see [2]) in imagery processes is not addressed adequately by mental imagery theories. Specifically, neuroanatomical evidence

(for reviews, see [2, 118, 119]) shows the orbital system to be reciprocally connected with the amygdala and other parts of the basal ganglia, augmenting and enhancing sensitivities based on episodic processing (and thus involved in *deja* and *jamais vu* phenomena). The dorsolateral system connects with the hippocampal system (including the limbic medial fronto-cingulate cortex), augmenting and enhancing both efficiency (hippocampus) and "the ordering of priorities to ensure effective action" [2, p. 242]. The third system, a ventrolaterally located system, has "strong reciprocal connections with the posterior cerebral convexity . . . [and] involves the far frontal cortex in a variety of sensory-motor modalities when sensory input from the consequences of action incompletely specifies the situation. In such situations practical inference becomes necessary" [2, p. 243].

With this as a background, mental imagery and hypnosis researchers need to be more cognizant of cortical and subcortical involvement in the what, when, and how of perceptual, cognitive, and neurophysiological processing underlying their various experimental manipulations and tasks. Such neurophysiological knowledge will assist in the development of hypotheses about the activation of specific brain systems dependent upon the type of imagery task. The imaging of simple and complex perceptual stimuli may call upon different processes. The imaging of concrete words may call upon verbal processing, while spontaneous daydreaming or imaging a walk in the woods may call upon other processes. Imaging animals may call upon the object system, while imaging the locations of things ("imagine your living room") may call upon the location and object systems. When effortful strategies are imposed or stimuli are still novel and unhabituated, frontal lobe activation is likely (e.g., [117]). Individual differences in imagery and other cognitive abilities and the experienced state of consciousness may well be additional moderators.

Preliminary experimental research supporting such differentiations accompanying imaginal processing in nonhypnosis and hypnosis studies are discussed in the next section. Past psychophysiological reviews have explored possible relationships between imagery and electrocortical activity, eye movements, pupillary reactions, electrodermal activity, and visceral activity. The reader is referred to Crawford and Gruzelier's in-depth review of the hypnosis literature and their neuropsychophysiological model of hypnosis [4]. Other, more specialized reviews address evoked potentials [5] and EEG alpha band production [120]. Because of the newness of the field and the exciting implications of such research, as well as imposed page limitations, this review limits itself mainly to "neuroimaging" studies of cerebral blood flow.

NEUROIMAGING STUDIES OF IMAGINAL PROCESSING: NONHYPNOTIC STUDIES

Not very long ago, the feasibility of mapping the distinguishable regions of the human brain in relation to their functional roles seemed remote. With the

tremendous advances in neurosciences in the past two decades, however, the opportunity now exists to approach the integrated understanding of brain structure and functioning necessary to clarify the neurobiological basis of human thought and emotion and to discern the mechanisms that underlie sensory perception and locomotor functions [121, p. 25].

Recent neuroimaging techniques (fMRI, PET, SPECT, rCBF) that assess regional brain metabolism offer a sensitive and reliable evaluation of brain function and cerebral organization during cognitive task activity. Changes in regional CBF accompany local changes in neuronal activity in the brain and been shown to be a valid marker of cerebral activation (e.g., for a review, see [122]). There are consistent increases in metabolic activity, with regional specificity often present, during cognitive tasks compared to resting baseline (e.g., [123-125]). The research provides us now with partial localization of language (e.g., [126]), memory (e.g., [127]), and attentional (e.g., [128, 129]) processing.

The prefrontal lobe that subserves the "executive processor" [2, 34] or the "supervisory attentional system" [SAS; 116, 117] becomes activated particularly when cognitive tasks are not routine but rather involved with novelty and attentional effort. Certainly, it does not act alone but in concert with other parts of the brain. As Frith summarized:

It is not that frontal cortex solves difficult problems, while temporal cortex solves easy ones. The frontal cortex solves difficult problems by interacting with other parts of the brain. Thus Goldman-Rakic proposes that visuo-spatial problems involve parietal-prefrontal connections, while problems that entail use of memory involve limbic-prefrontal connections [131]. Shallice proposes that the SAS (frontal cortex) modulates lower-level systems (other parts of the brain) by activating or inhibiting particular schemata [117]. PET scanning techniques are particularly suitable for studying interactions between prefrontal cortex and other parts of the brain [130, pp. 185-186].

As we turn our attention now to the activation of brain structures and processes after imagery instructions and during imaginal processing during nonhypnotic and hypnotic conditions, it is important to separate spontaneous imagining (e.g., daydreams or visualizations without an external source) from imagining that accompanies external stimuli (e.g., paired associate words), as well as object-form imagery from spatial imagery, as they may activate different associate schemas or memory systems.

Spontaneous Imagining

Roland and Friberg showed that visualizing a walk through one's neighborhood increased cerebral metabolism in the occipital lobe, the posterior superior parietal area and the posterior inferior temporal area; mental arithmetic and recalling sequential verbal aspects of a musical piece did not [132]. When asked to imagine their living room and describe all the furniture in it, subjects showed the greatest prefrontal activation of all the purely mental tasks studied. In a

SPECT study those subjects reporting spontaneous imagery during the rest condition had significantly higher flow indices in both orbitofrontal regions and lower flow indices in the left middle frontal and left inferior parietal regions [133]. Effortful organizing and controlling of cognitive processing is a function of the far frontal cortex, as demonstrated in other CBF studies (e.g., [134, 135]).

Finally, Goldenberg found that when he himself was experiencing spontaneous visual daydreaming there was an activation of the whole occipital lobe, the hippocampus, the left lateral inferior temporal region, and most strongly the left inferior occipital region [136].

Imaginal Processing Accompanying External Stimuli

Paivio's [76, 77] conceptual framework of a dual-coding theory has led him to argue that the two symbolic systems, verbal and nonverbal, are dependent on different brain systems (e.g., [137]). When referential processing activates an interconnectiveness between the two systems, Paivio hypothesized that the left hemisphere "dominates" [137, p. 210], such as during the imaginal processing of words and sentences. Goldenberg et al., in a series of studies reviewed below, have found somewhat consistent evidence that the left occipital brain region plays a prominent role in visual imagery, with interindividual variance having an effect on such cerebral activation patterns.

Goldenberg, Podreka, Steiner, and Willmes found that only in the resting condition and when subjects were asked to memorize concrete words without imagery were there large hemispheric asymmetries in favor of the right hemisphere [138]. Instructions to image concrete words led to leftward shifts of blood flow in the inferior occipital region, as well as in both superior frontal lobes and the left middle frontal lobe. Goldenberg, Podreka, Steiner, Willems, Suess, and Deecke (Experiment 1) found that imagery questions were accompanied by greater left inferior occipital blood flow than were low imagery questions when given to different groups of subjects [139]. In addition, the posterior temporal and posterior parietal visual processing areas were implicated only during imagery questions. Right anterior frontal flow rate was higher during low imagery conditions than during visual imagery, suggesting greater effort was expended (a confound was that more errors occurred with low imagery sentences). More recently, Goldberg et al. replicated the association of verifying high imagery sentences with higher flow rates in the left inferior occipital region and lower flow rates in the right anterior frontal region [140]. The decrease in right anterior frontal flow during imagery was replicated. When asked to use mental imagery strategies to memorize word lists, an increase of left middle frontal CBF was observed in another study [141]. Thus, differential involvement of the frontal lobes may occur with strategy differences. While Goldberg et al. [139] reported an unexplained

bilateral increase of thalamic flow rates with imagery, another study [140] did not replicate it.

Spatial and topographical imagery is thought to involve the right hemisphere to a greater extent. In another SPECT study, three kinds of images—colors, faces, and a spatial map—were investigated in a between-subjects design [133]. In comparison to rest, color imaging led to a decrease in the left inferior occipital region. Face imaging led to increases in the left hippocampus and right inferior temporal region, as well as decreases in the left central region. Map imaging led to a decrease of the left superior medial frontal region. Like other neuropsychological research, this study suggests neuroanatomical differences for the activation of color, face, and map image processing. The amount of willful effort required for each may also have contributed to CBF differences.

Goldenberg et al. (Experiment 2) examined changes in CBF during the solution of a visuospatial task [133]. Subjects had to maintain an image of a capital letter for periods of eight to fifteen seconds before indicating the number of corners of the letter by flashing a light for each corner. For the control they had to count the number of letters between two earlier presented letters of the alphabet. Strategies were subsequently assessed. Significant increases in both inferior frontal regions were observed during the alphabet condition. Of most interest was the finding that as vividness of imagery increased in the corners condition, there were accompanying “decreasing flow-rates in regions of the frontal convexity and with increasing flow rates in the inferior temporal regions.”

Different patterns of CBF may be associated with different strategies used in processing information. This is evident in activation studies of patients with specific strategy deficits, as well as normals (for reviews, see [125, 142]). In a PET study, Reivich, Alavi, Gur et al. (1985, as cited by [142]) reported that subjects who recalled tones during a tonal memory test by employing an analytical strategy activated the left hemisphere, whereas those employing a nonanalytical, holistic strategy activated the right hemisphere. Gender may also moderate CBF. For instance, Erwin, Mawhinney-Hee, Gur, and Gur reported that women, for unknown reasons (possibly strategy differences?), had greater hemispheric asymmetry of activation for verbal and spatial tasks [143].

Different patterns of CBF are also found in individuals differing in cognitive abilities. Gur and Reivich found increased CBF with the Xenon-133 technique in the left hemisphere with a verbal analogies task in comparison to rest [123]. Of particular interest to us is the finding that greater right hemispheric CBF increases correlated with better performance on a gestalt closure task, although for the whole sample it showed bilateral activation. Crawford found that highly hypnotizable persons perceived correctly more gestalt closure figures than did lows [45]. Thus, the blood flow research supports Crawford's earlier conclusion that highs may possess skills that permit greater right hemisphere involvement or preference for holistic processing.

High and low imagers while performing silent verb conjugation and mental imagery tasks, as well as rest, were studied by Charlot, Tzourio, Zilbovicius, Mazoyer, and Denis [144]. The left visual association and left frontal cortices showed increased CBF during the imagery task in both groups. Low imagers showed CBF increases over the whole cortex in both tasks, while high imagers were more region specific in their activation. Specifically, high imagers showed a right dominance in the visual association cortex in all conditions, and in the parietal association cortex at rest.

NEUROIMAGING STUDIES OF IMAGINAL PROCESSING: HYPNOSIS STUDIES

The importance of individual differences in cognitive abilities and strategies as moderators of cerebral blood flow during tasks has been documented in a few of the above reviewed studies. We may now turn to hypnosis studies which have used rCBF, PET, and SPECT techniques to ask whether 1) hypnosis has an effect upon CBF, and 2) individuals differing in hypnotic level have differing CBF patterns either in waking or hypnosis. Will the hypothesized focused state of hypnosis be accompanied by increased cerebral metabolism? Will lows and highs exhibit different cerebral activation patterns due to possible underlying cognitive strategy, ability, and/or neurophysiological differences in nonhypnotic conditions as well as hypnosis?

Substantial global increases in cerebral blood flow during hypnosis among hypnotically responsive subjects, both normally healthy [31, 145-148] and psychiatric [148-150], have been consistently reported. When included, lows do not demonstrate such global increases during hypnosis [31, 145, 148]. In light of consistent demonstrations of increased CBF during mental effort, these results support a growing belief (e.g., [14, 26, 27, 31, 34]) that hypnosis takes cognitive effort. Thus, there may be increased cortical involvement in the focusing of attention and disattention during hypnosis among hypnotically responsive individuals.

Regional CBF pattern differences between eyes closed waking and hypnotic rest (no specific instructions indicated) have been reported by Walter [148]. She examined SPECTs during counterbalanced waking and hypnosis rest, eyes closed conditions, in low and high hypnotic groups, as screened by the Stanford Hypnotic Susceptibility Scale, Form C [151]. Analyses were limited to men and women separately within the hypnotic groups. During hypnosis, highly hypnotizable women showed significant increases in the left superior frontal region as well as both left and right inferior frontal regions. They also showed significant decreases in the central region and both the left and right thalamus, possibly suggestive of less involvement in the screening of external stimuli. Male highs showed a significant CBF increase in the left basal ganglia and a decrease in the left inferior occipital region. Low women showed a CBF increase in the right inferior temporal

region, whereas low men showed a CBF increase in the right superior parietal region and a decrease in the left superior occipital. This well conducted study documents excellently the increased involvement of the frontal cortex during hypnosis (see also [31]). Gender differences have once again cropped up, like in some other CBF studies (e.g., [143]). Whether the men and women were equally hypnotizable was not ascertainable, but remains a possible confound.

Halama used SPECT to study changes before and during hypnosis in seventeen patients (16 neurotic depression, 1 epileptic) [149]. Both before and during hypnosis there was a greater right than left CBF. There was a global blood flow increase during hypnosis. Of the seventeen patients, the eleven more deeply hypnotized patients showed greater CBF increases than those six patients who reported being distracted by noises and showed less hypnotic responsiveness. In hypnosis ten minutes after the induction, he found (in comparison to a rest waking control) "a cortical 'frontalization,' takes place particularly in the right hemisphere and in higher areas (7 cm above the meato-orbital-level) more than in the deeper ones (4 cm above the meato-orbital-level)" [149, p. 19]. These frontal regional increases included the gyrus frontal, medial and inferior, as well as the superior and precentral gyrus regions. By contrast, there was a significant decrease in brain metabolism in the left hemisphere in the gyrus temporalis and inferior region, as well as in areas 39 and 40.

Crawford, Gur, Skolnick, Gur, and Benson found substantial increases in CBF, as measured by the xenon inhalation method, during hypnosis in highs but not lows [31]. CBF increases for highs during hypnotic conditions of rest, and ischemic pain with and without suggested analgesia are evident in Figure 1. In this study healthy male subjects had been screened on three well known hypnotic scales [151-153] to ensure they represented the extremes of hypnotic susceptibility: lows ($N = 6$) who could not eliminate pain perception, and "virtuoso" highs ($N = 5$) who could eliminate all perception of cold pressor and ischemic pain. Lows and highs did not differ significantly on the Mark's [38] Vividness of Visual Imagery Questionnaire, but highs reported more absorption on the Tellegen Absorption Scale [154].

During eyes closed rest conditions in waking and hypnosis their subjects were asked to let their thoughts come and go, thinking of a past trip they had taken. No CBF differences between lows and highs were noted during waking. During hypnosis, only the highs showed significant regional enhancements (left and right hemispheres collapsed due to the lack of regional hemispheric differences), ranging from 13 percent to 28 percent, with the largest being in the temporal region, an area associated with long-term memory processing [unpublished data]. For the resting imagery conditions CBF values in waking and hypnosis, there was a significant State X Hemisphere interaction ($p < .05$), but no further interaction with hypnotic level. This interaction reflected higher left hemispheric values during hypnosis than waking for both low and highs. Attention paid to external stimuli results in a right hemisphere CBF increase [155]. It may have been that

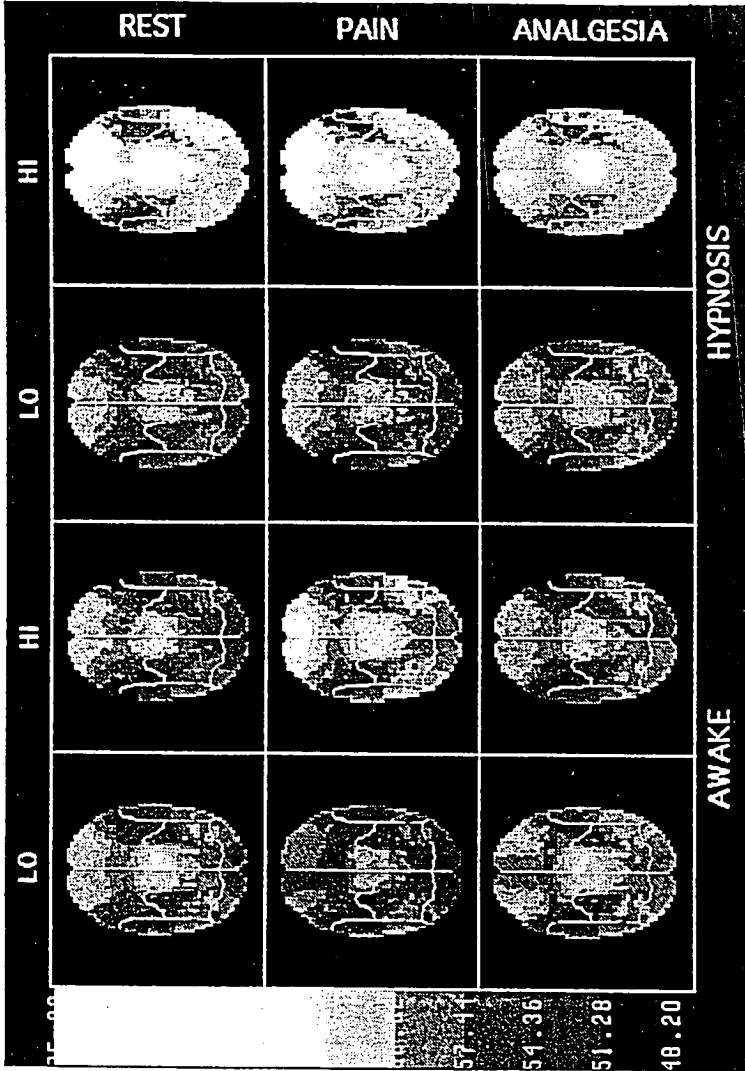


Figure 1. A topographic display of CBF gray-matter (IS) values in three conditions: Rest (top row), pain (middle row), and Pain with Suggested Analgesia (bottom row). The waking, nonhypnosis state is the first two columns: low (column one) and high (column two) hypnotizable healthy male subjects. The hypnosis state is the last two columns: low (column three) and highly (column four) hypnotizable subjects. The lighter the shading the greater the values. From "effects of hypnosis on regional cerebral blood flow during ischemic pain with and without suggested hypnotic analgesia" (p. 189) by H. J. Crawford, R. C. Gur, B. Skolnick, R. E. Gur, and D. M. Benson, *International Journal of Psychophysiology*, 15, pp. 181-195, 1993. Copyright 1993 by Elsevier Science Publishers. Reprinted by permission.

more attention was allocated to external activities in the room (sounds, although no talking occurring during the measurements) during waking while more attention was allocated to internal imaginal processing during hypnosis. Of further interest was a significant Hemisphere X Region X State interaction ($p < .0001$). In the temporal region there was a striking left greater than right CBF during waking, but this disappeared during hypnosis.

Crawford, Gur et al. examined CBF while experiencing ischemic pain to both arms under two counterbalanced conditions in waking and hypnosis: attend to pain and suggested analgesia [31] (Figure 1). Both lows and highs reported using similar imagery techniques to control pain, but only the highs were successful in eliminating all perception of pain. As anticipated, ischemic pain produced CBF increases in the somatosensory region. Of major theoretical interest was the finding that only the highs during hypnotic analgesia showed even further CBF increases: first, in the somatosensory region, and second, a bilateral CBF activation of the orbito-frontal cortex (Figure 2). Since PET studies (for a review, see [130]) show increased activity in the frontal cortex during the performance of willed actions, we [31] hypothesized that the mental effort involved in inhibiting painful stimuli was accompanied by increased cerebral blood flow in the frontal cortex. The increased CBF of the somatosensory cortex may be reflective of this inhibitory process since fibers do lead from the frontal lobes to more posterior regions, both cortico-cortical and cortico-subcortico-cortical [2].

Further support that changes in brain dynamics accompany hypnotically suggested analgesia is provided by recent somatosensory evoked potential [SEP; 26, 156, 157] and EEG Hz band [26, 158, 159] research conducted in my laboratory with collaborators. The SEP research demonstrated dramatic decreases in SEP in the prefrontal region during hypnotic analgesia, accompanied by decreases in SEPs in the more posterior regions of a different pattern [156, 157]. We have suggested that hypnotic analgesia involves the executive control system of the prefrontal cortex in a topographically specific inhibitory feedback circuit that cooperates in the regulation of thalamocortical activities, such as that discussed by Birbaumer, Elbert, Canavan, and Rockstroh [160].

Additional support for attentional shifts during hypnotic analgesia is found in Crawford's [26, 27, 158, 159] EEG research. Like Sabourin, Cutcomb, Crawford, and Pribram [161] and others ([62], for reviews, see [4, 163]), highs were found to generate more EEG theta power, hypothesized to be associated with focused attention, than lows. In addition, Crawford reported that highs showed asymmetrical EEG theta shifts during cold pressor pain focusing and disattention conditions, whereas lows did not [26, 158, 159]. Specifically, highs showed a left hemisphere (more anterior than posterior) dominance while focusing upon pain and a right hemisphere dominance while disattending the pain. In concert, these CBF, SEP, and EEG studies support the hypothesis that highly hypnotizable individuals have a more efficient and flexible fronto-limbic attentional-disattentional system [4, 26, 27, 164].

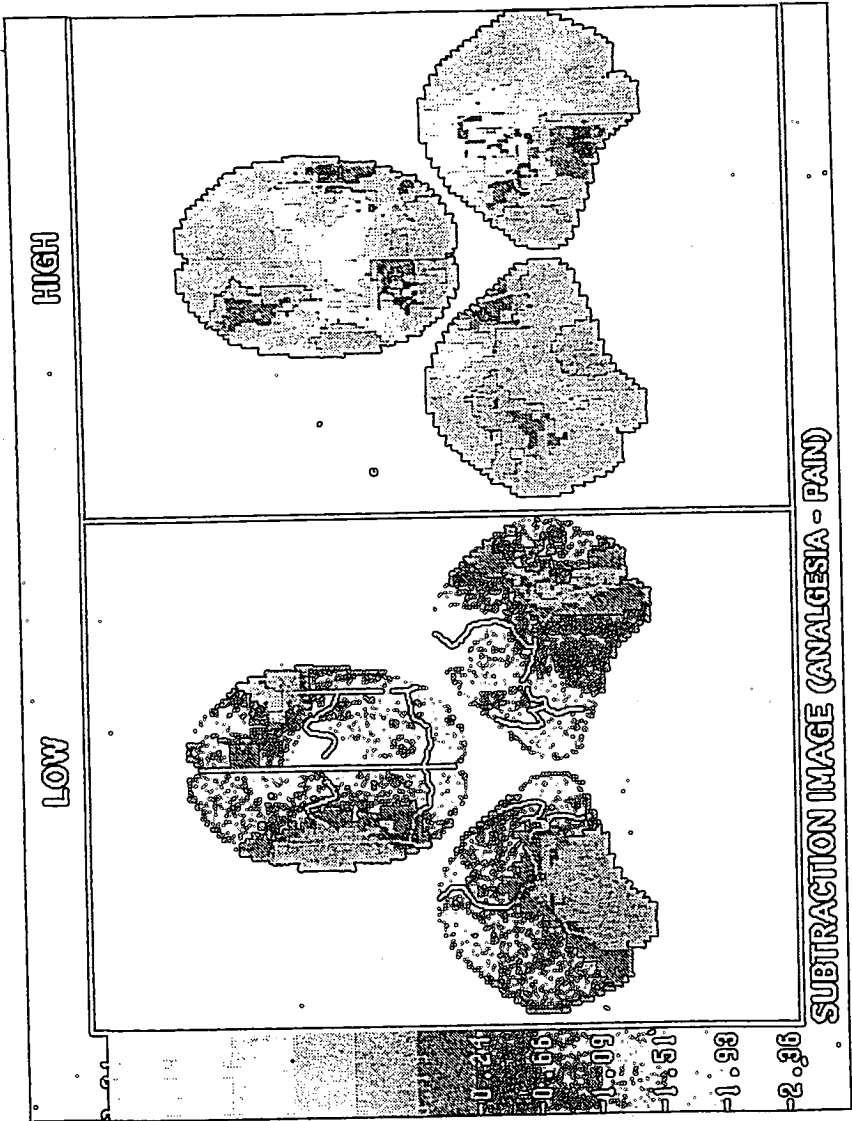


Figure 2. Blood flow activity unique to hypnotic analgesia: A topographic display reflection hypnosis analgesia after subtraction of pain condition during hypnosis. Low hypnotizables are on the left and high hypnotizables are on the right. The lighter the shading the greater the difference is. From "effects of hypnosis on regional cerebral blood flow during ischemic pain with and without suggested hypnotic analgesia" (p. 190) by H. J. Crawford, R. C. Gur, B. Skolnick, R. E. Gur, and D. M. Benson, *International Journal of Psychophysiology*, 15, pp. 181-195, 1993. Copyright 1993 by Elsevier Science Publishers. Reprinted by permission.

A SPECT comparison of seventeen psychotic patients who experienced auditory hallucinations was made with ten healthy, hypnotically responsive subjects experiencing music hallucinations by hypnotic suggestion by Walter et al. [148, 165]. In comparison to rest, during hallucinated music the healthy subjects experienced increased CBF in the left superior and mesio-frontal regions, whereas in the right superior occipital and superior temporal regions they demonstrated significant CBF decreases. The comparisons between the patients and healthy subjects is methodologically problematic for this reviewer because of their non-equivalence of phenomenological experiences and other potentially important dimensions.

In summary, this blood flow research is encouraging although it is still in its early infancy. Unlike EEG studies (e.g., [156-159]) which have reported greater theta power during waking among highs than lows, the CBF studies did not report differences in cerebral activation patterns between lows and highs in waking. The results of these CBF studies provide evidence that there are significant shifts in brain dynamics during hypnosis that varies dependent upon the task imposed. A rather consistent finding is an increase in CBF during hypnosis only among highly hypnotically responsive individuals. In view of the consistent findings of increased CBF during mental effort (reviewed previously), this research suggests that although a hypnotized person is often extremely relaxed at the physical level, at a cognitive level there is effort occurring that demands attentional and disattentional allocations. Thus, "dissociated" hypnotic phenomena may only be effortless and lack self-consciousness at a phenomenological level, yet they may still require directed, willful attention out of self-conscious awareness [27].

The differential involvement of the frontal and posterior regions of the brain during hypnosis was evident in several studies. Rather consistently there is increased involvement of regions within the frontal cortex during hypnotic suggestions [31, 147, 163]. This suggests the greater activation of the executive control system during imaginal activities, be they hypnotic or nonhypnotic. Alternate shifts in the posterior regions of the brain point out the importance of not only considering left and right hemisphere dynamics, but also anterior/posterior dynamics (e.g., [4]). Unexplained decreased activations found in the temporal regions during acoustic focused attention [146], music hallucinations [163], and sometimes hypnotic rest [148], need replication in order to verify their presence.

SUMMARY

It is now fairly well established that both hemispheres have the capacity for imagery, but they differ in the way they approach the material. The left hemisphere is more involved in object perception and the ordering of cognitive operations sequentially, whereas the right hemisphere is more involved in spatial perception and parallel, global processing. This chapter reviewed several theories of visual perception [2, 10] and their applicability to the understanding of mental

imagery. Evidence for the neural basis of the generation and maintenance of mental imagery, with an emphasis upon cerebral blood flow studies, was evaluated. There is no single substrate of imagery, even within sensory modalities. Rather, dependent upon what kind of information is being depicted by the mental image (e.g., verbal vs. spatial) and the cognitive strategies employed, different brain systems are activated in a reciprocal interplay between cortical and sub-cortical systems. The occipital and temporal-parietal cortices were differentially activated during visual imagery, suggesting the reactivation of long-term memories and percept-like processes. The involvement of the far frontal cortex in the executive or attentional control of thought processes involving mental imagery was evident.

A review of the literature suggested that hypothesized enhanced imaginal processing during hypnosis occurs more consistently with information to be remembered or imaged that is more literal or untransformed representations: eidetic-like imagery [22, 72, 73]; sustaining of after-images [75]; remembrance of complex pictures for subsequent comparison to new ones that differ slightly [21]; and memory for spatial abstract forms [71]. By contrast, reports of enhanced memory performance during hypnosis may or may not be reported for more complex, verbally-mediated processing such as paired associate words [78-81].

Given the review of cerebral blood flow activation patterns accompanying mental processing, and differences in individuals differing in hypothesized mental imagery skills, one might expect CBF differences between lows and highs during waking. Not one reviewed hypnosis CBF study reported waking differences, although EEG differences for lows and highs have been reported (for review, see [41]). In addition, one might anticipate increases in CBF during hypnosis when there is more focused attention on suggestions and tasks. A robust finding is that highs do show increases in CBF during hypnosis [31, 146-150, 165]. Such increases may reflect greater focused attention and disattention involving the fronto-limbic attentional system during hypnosis among the highs [31]. The enhanced CBF involvement of the fronto-orbital region during hypnotic analgesia attests to the possible greater involvement of the executive processor "deciding" to dis-attend pain and attend to internally produced mental imagery instead. Open to subsequent research is the hypothesis that such inhibitory processes may also activate other cortical and subcortical regions, as in our CBF study of hypnotic analgesia [31], due to feedback inhibitory fibers from the frontal lobes to these regions [2].

As reviewed here and elsewhere [4, 26-28], there is growing evidence that hypnotic phenomena selectively involve cortical and subcortical processes of either hemisphere, dependent upon the nature of the task, as well as shifts in attention and dis-attention processes. To help refine hypotheses and theoretical thinking, hypnosis researchers interested in cognitive and/or neuropsychophysiological functioning can find guidance from general neurophysiological theories of visual functioning [2, 10] and hypnosis [4].

Future research using new neuroimaging techniques such as fMRI, rCBF, PET, and SPECT holds exciting opportunities to map the brain areas that constitute different types of cognitive and perceptual processing in individuals with varying cognitive abilities both in hypnotic and nonhypnotic conditions. rCBF with 133-xenon restricts one's view to cortical dynamics, whereas the use of three-dimensional physiological neuro-imaging techniques such as PET and SPECT provides much more detailed maps of cortical-subcortical brain dynamics. The much safer and less expensive SPECT should become more accessible to researchers desiring to pursue this exciting and challenging field of research.

As the "Decade of the Brain" progresses through the 1990s and we enter the twenty-first century, we shall learn more at a neurophysiological level how hypnosis, and other alternate states of awareness, lead to sometimes rather dramatic perceptual alterations and even hallucinations experienced at the phenomenological level. Perhaps we will discover, like Miller et al. [1], that there is much truth in the age-old belief that "the brain has something to do with . . . mind."

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CHAPTER 14

Hypnosis and the Brain: The Relationship between Subclinical Complex Partial Epileptic-Like Symptoms, Imagination, Suggestibility, and Changes in Self-Identity

MICHAEL A. PERSINGER

INTRODUCTION

The principles of modern neuroscience predict that all phenomenological and subjective experiences are determined by brain activity. At any given moment of psychological time, the content of the person's stream of consciousness is a function of the themes of those spatial regions that are most metabolically active [1, 2]. From this perspective the brain can be viewed as a matrix and subjective experiences correspond to the relative dominance of activity between the elements of this matrix. If we can isolate those portions of the brain that are most associated with a behavior, then it can be more effectively controlled and predicted.

The capacity to be hypnotized (suggestibility) is assumed to be a normal correlate of brain function. Because of the strong cognitive component that is involved with hypnotizability, the role of cerebral structures would be primary. If this assumption is valid then hypnotizability should be associated with specific differences in psychological function both within and between the cerebral hemispheres. These patterns must be evident qualitatively in clinical populations (or in extreme cases) but only discernible *quantitatively* (assuming the restricted range problem is accommodated) within the normal population.

This chapter reviews the recent work of the Laurentian University Neuroscience Research Group. We have pursued the hypothesis that overt displays of hypnotizability are derived from neurocognitive processes that are very similar to those associated with synchronous electrical activity within the deep structures of the ventral cerebrum. If this hypothesis is correct, then there should be convergence