Hypnosis and Neuroscience: A Cross Talk Between Clinical and Cognitive Research

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Hypnosis and Neuroscience

A Cross Talk Between Clinical and Cognitive Research

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Despite its long use in clinical settings, the checkered reputation of hypnosis has dimmed its promise as a research instrument. Whereas cognitive neuroscience has scantily fostered hypnosis as a manipulation, neuroimaging techniques offer new opportunities to use hypnosis and posthypnotic suggestion as probes into brain mechanisms and, reciprocally, provide a means of studying hypnosis itself. We outline how the hypnotic state can serve as a way to tap neurocognitive questions and how cognitive assays can in turn shed new light on the neural bases of hypnosis. This cross talk should enhance research and clinical applications.

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Hypnosis has been used clinically for hundreds of years and is primarily a phenomenon involving attentive receptive concentration.[1,2] Historically, hypnosis was defined as an altered state of consciousness, characterized by heightened compliance with suggestion and extreme focused attention. Whereas this definition presumes a specific theoretical view, over the years this characterization of hypnosis was gradually refined and amended to reflect a more theoretically neutral approach.[3,4] Nonetheless, one persistent barrier to the scientific use of hypnosis has been the idea that it involves a special and "mysterious" state of consciousness, often referred to as *trance*. Although trance phenomena have been long used in initiation rites and other ceremonies in many cultures,[5] research inspired by this approach has not supported the trance hypothesis. Moreover, the idea of trance has impeded serious consideration by investigators. However, the rejection of the concept of trance in no way impugns the reality of subjects' responses evoked by hypnotic inductions and suggestions. These procedures generate changes in the way in which people experience themselves and the environment, and these alterations have been shown to affect cognitive processing.

Hypnosis and *hypnotherapy* must be distinguished. Hypnotherapy conveys the misimpression that hypnosis is a type of therapy, perhaps because it is a treatment modality in which the patient is in the hypnotic state at least part of the time. However, there is widespread accord that hypnosis, in itself, is not a treatment but rather an adjunct to therapy.[4] Whereas a patient who achieves the hypnotic state may experience reduced tension and other benefits, further goal-related interventions, such as suggestions about pain relief or cessation of smoking, are necessary to make it hypnotherapy.

Hypnosis has largely remained an elusive concept for science, because it is contaminated by folk beliefs and shrouded in layers of misconception. Recent investigative techniques have done little to demystify hypnotic phenomena. In this brief overview, we present an agenda for research based on modern neuroscientific applications and recent data to delineate how hypnosis and cognitive neuroscience can be wed into a successful relationship. Imaging techniques of the living brain may illuminate the anatomical and functional nature of hypnosis. Moreover, hypnosis can also be used as a tool to study cognitive phenomena, as we unravel some of the neural mechanisms subserving hypnotic expression.

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HISTORY

Hypnosis was notably driven into the realm of the mysterious by Franz Anton Mesmer,[6] whose 18th-century theory held that all objects in the universe were connected by and filled with a fluidlike substance possessing magnetic properties. Mesmer used eye gaze, accompanied by dramatic hand gestures, to apply his own "magnetic influence" to restore his patients' magnetic fluid to proper balance.[7] Although the French-appointed Benjamin Franklin Commission[8] flayed Mesmer's animal magnetism theory in 1784, contention between his doctrinaires and skeptics persisted.

Within the medical establishment, Jean-Martin Charcot and then his student Pierre Janet believed that hypnosis was related to hysteria and described various stages of the phenomenon in relation to a concept of pathology. A critical point in the history of hypnosis came in 1880, when Josef Breuer and young Freud treated a "hysterical" patient in self-induced hypnoid trances. The treatment was effective, and both men later wrote *Studies in Hysteria*.[9] Freud subsequently gave up hypnosis and continued the relaxation focus through free association. Now, 121 years later, data emanating from single-patient case studies using brain imaging suggest that hypnosis and hysteria indeed may share common neurophysiological mechanisms involving prefrontal regions.[10-12] Albeit this evidential base is meager, the common anatomy suggests that treating symptoms of conversion hysteria may be illuminated by hypnosis.

Common false theories continue to associate hypnosis with mysticism, loss of autonomy, and mind control. As popularly depicted in cartoons and films, many incorrectly believe that hypnosis is a variant of sleep, permitting a loss of will and submission to the hypnotic coach. The term *hypnosis* is a misnomer, associating the phenomenon with sleep (and death). Hypnos, who in Greek mythology is the god of sleep and dream (and brother of Thanatos, god of death), was misleadingly chosen as the designator of this state. Whereas exaggerated claims and blatant displays by lay and stage hypnotists continue to captivate the public, approximately 150 articles on hypnosis annually appear in mainstream medical and scientific journals.[13] Moreover, the American Medical Association, Chicago, Ill, and other medical associations formally recognize hypnosis as a valid adjunct for medical treatment.

Although some countries (eg, Israel) require hypnotists to be formally trained and licensed by a supervising board, many countries (eg, the United States) pose no such legal demands. The professional using hypnosis is a "hypnotic operator,"[14] who determines the subject's hypnotic capacity, then teaches the subject to achieve the meditative state, and, if the subject is willing, stimulates his or her imagination.

One of the most interesting feats of hypnosis is the observed alteration in volitional control over behavior. Individuals who are highly hypnotizable may either perform movements that they report as having occurred without volitional control or be unable to execute simple motor acts in response to challenge suggestions. Historically, such phenomena were taken at face value, supposing that hypnotic behavior was unintentional. In later years, however, the volitional status of suggested behavior has become a source of passionate argument.[15]

Therapists may well be practicing hypnosis (or hypnosislike work) when they engage children and adults alike in conversation during which participants appear absorbed or seem to be paying close attention.[16] Indeed, hypnosis is sometimes indistinguishable from the simple physical or mental repose of focused attention encountered in daily activities. For example, sports figures describe "being in the zone" when they achieve their best-focused performances. In fact, there is a kinship between hypnosis and attentive play, prayer, study, or rumination. The striking similarity between relaxation training, meditation, and typical hypnotic induction is easily recognized. Yet, hypnosis is not identical to imagery and relaxation training, because suggestion need not entail requests for imagery and, albeit not common, hypnosis can be induced without relaxation.[17,18]

MEASURING HYPNOSISLIKE STATES

The introduction of imaging techniques of the living brain has opened new avenues to study hypnosis. A few studies have explored the role of imagination in cognition[19] and imaged brain activity under meditation,[20,21] concluding that characteristic patterns of neural activity support this state. A comparison of the resting state of normal consciousness with meditation in a positron emission tomography study[22] showed differential activity mainly in prefrontal structures (eg, the dorsolateral, orbitofrontal, and anterior cingulate gyri) but also in other areas thought to be involved in executive attention (eg, the left parietal and inferior parietal lobule, striatal and thalamic regions, and cerebellar hemispheres and vermis).

Although based on scanty references,[23,24] clinicians practicing hypnosis suggest that, when one is in a hypnotic state, attentional and perceptual changes may occur that would not have occurred had one been in a more usual state of awareness. Hypnotic perceptual alteration in a responsive subject is usually accompanied by changes in brain activation.[23-26] Recent data[27,28] support the claim that the state of hypnosis is associated with distinct neural correlates and therefore is more than role playing[29] or social compliance.[30] One study[28] showed that whereas activity in the right anterior cingulate cortex was comparable when subjects were either hallucinating or actually hearing auditory stimuli, a marked decrease in anterior cingulate activity followed when subjects were imagining that they heard the sounds. Another study[27] showed that hypnosis affected low-level brain processes, such as color perception. Subjects under hypnosis were able to see color in black-and-white photographs and perceive only shades of gray when looking at a color image upon suggestion. Variations in the subjective experience of these highly responsive subjects under hypnosis were associated with positron emission tomography measure ments of changes in brain function typical of veridical perceptual alterations.

Several standardized measures, with good psychometric characteristics, are available to reliably assess hypnotizability. For example, the Stanford Hypnotic Susceptibility scales,[31,32] 2 variations of which have been developed for use with children and adolescents,[33] have excellent test-retest reliability after long intervals. Although such terms as *hypnotic susceptibility*, *responsiveness*, *suggestibility*, and *depth* embrace some subtle nuances, they are typically used interchangeably to indicate the quantifiable rating of a subject's response to hypnotic suggestions under standard conditions. It is common to classify people as either *low* or *highly* hypnotizables, depending on their performance on a particular scale. However, some researchers have attempted to change hypnotic susceptibility using programs that enhance hypnotic suggestibility.[34] These techniques, which often include elements of self-deception, are usually used to make hypnotherapy available to a wider group of clients in clinical settings.[35]

Posthypnotic suggestion refers to a condition following termination of the hypnotic experience, wherein a subject is compliant to a suggestion made during the hypnotic episode (eg, to change chairs, rise and stretch, or forget a fact) but does not remember being told to do so. The posthypnotic suggestion is usually summoned on a prearranged signal and can be effective in highly responsive individuals.

Hilgard[1] compared some of the better known scales for hypnotizability that had been described in the literature during the 19th and 20th centuries.[36-39] Of the modern measures available,[2,3,40,41] the Stanford Hypnotic Susceptibility Scale: Form C[32] stands out, because it includes items that more fully assess the subject's ability to experience hypnotic distortions of perception and memory and allows for a finer discrimination of hypnotizability. The Stanford scales, which typically require about 75 minutes to administer, have been effective because of their superior psychometric characteristics. Whereas these scales were primarily designed for academic research, permitting a decision regarding experimental participation, clinical constraints (eg, time, population, or posture) have forced most practitioners to profile patients using briefer clinical scales (eg, the Stanford Hypnotic Clinical Scale, Stanford Profile Scales of Hypnotic Ability, or Hypnotic Induction Profile).[2,41]

The introduction of functional brain scans offers a new research opportunity to study hypnosis and to use it as an experimental condition measured against a nonhypnotic state. Increasingly sophisticated imaging techniques of the living brain (eg, functional magnetic resonance imaging, positron emission tomography, and optical imaging) have made it possible to observe activation of neural regions when people perform complex cognitive tasks (eg, involving attention, language, or perception).[42,43] A review of the literature reveals that a small number of neuroimaging studies[10,25,27,28,44-49] have examined hypnotized subjects. These studies usually endeavor to capture a specific hemodynamic pattern underlying the multiple cognitive processes involved in the hypnotic state.

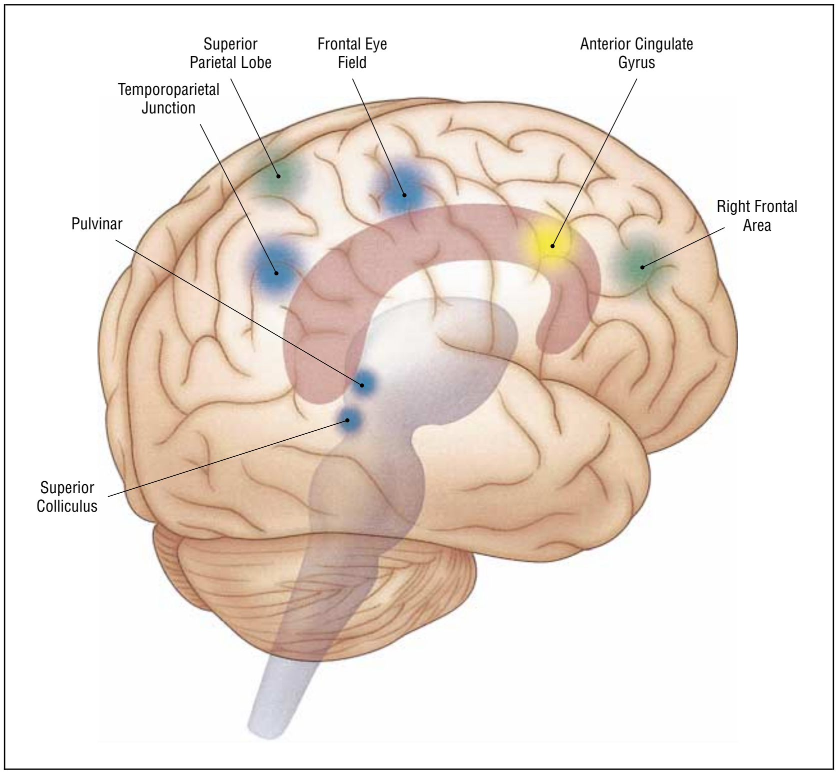
Traditionally, hypnosis was studied as one of the most effective behavioral interventions for acute and chronic pain. Hypnotic analgesia[50] is regarded as an active process requiring inhibitory effort,[51] albeit this effort may be dissociated from consciousness.[52] Imaging technology has fostered this line of investigation.[25,44,47-49] These studies report significant signal changes in areas associated with sensation and perception (eg, the primary somatosensory cortex, thalamus, and insula) and sensorimotor integration pain systems (eg, the supplementary motor cortex). However, pain control represents only a narrow area of inquiry, considering the panoply treasured by hypnosis.

Although it has been shown that pain and attention activate similar brain areas (eg, the frontal and anterior cingulate cortices)[53,54] and that hypnosis is a powerful attentional manipulation,[55-59] there are too few studies focusing on the effects hypnosis may have on such basic attentional processes as inhibition and facilitation, relative to current information in the cognitive neuroscience literature. In fact, new positron emission tomography data[49] suggest that hypnosis modulates activity in cerebral structures involved in arousal and attention. Blood flow in the brainstem was correlated negatively with relaxation and positively with absorption. This suggests the invocation of thalamocortical arousal and attentional networks in the instigation of hypnosis. Furthermore, congruent with research supporting frontal lobe activity and the role of the neurotransmitter dopamine in attentional processing[60,61] and hypnosis,[62] a positive correlation between measured hypnotizability and the activity of the dopaminergic system (as measured in cerebrospinal fluid by looking at homovanillic acid, a metabolite of dopamine) was reported.[63] Hence, a programmatic plan that integrates hypnosis into attentional and genetic research seems worthwhile.

HYPNOSIS AND ATTENTIONAL NETWORKS

Since the late 19th century, attention in general and selective visual attention in particular have been important areas of study. How attention relates to the brain has remained controversial. Modern cognitive assays have suggested that attention is neither a property of a single brain area nor that of the entire brain.[64] Attention can be viewed as involving a system of anatomical areas, consisting of 3 more specialized networks. These networks carry out the functions of alerting, orienting, and executive control.[42] Whereas the idea of separate locations of attention has often been discussed,[64-66] only with the aid of neuroimaging—as the field of cognitive neuroscience approaches its 20th birthday—has it been indicated that distinct brain areas mediate different attentional processes.[67,68]

Pharmacological studies on alert monkeys have related each of the attentional networks with specific chemical neuromodulators.[69] Alerting is thought to involve the cortical distribution of the brain's norepinephrine system arising in the locus coeruleus of the midbrain; cholinergic systems arising in the basal



A sketch of the functional anatomy of the attentional networks. The pulvinar, superior colliculus, superior parietal lobe, and frontal eye fields are often activated in studies of the orienting network. The temporoparietal junction is active when a target occurs at a novel location. The anterior cingulate gyrus is an important part of the executive network. Right frontal and parietal areas are active when people maintain the alert state.

forebrain play an important role in orienting; and the anterior cingulate and lateral frontal cortex are target areas of the ventral tegmental dopamine system (**Figure**).

Regrettably, to date most scientists studying the attentional system have not used hypnosis as a variable manipulation. This reluctance may be the result of the negative social history associated with this oneiric state, as well as the misguided view in classifying it as a clinical technique of only anecdotal research merit. Nonetheless, there are nascent efforts to measure these separate attentional networks.[70,71] It is intriguing to investigate which attentional networks, if any, can be modulated by hypnosis and posthypnotic suggestion. Notably, such information will have important clinical and scientific merits as we begin to segregate and relate the executive, alerting, and orienting components of the attentional system to separate anatomical sites.

Hypnosis, however, could be used to study additional function systems, as it offers attractive prospects to many fields of cognitive research (eg, mental imagery, memory, and perception). It is a singular noninvasive technique that can incite a dramatic effect on attentional and cognitive processing via verbal exhortation. Furthermore, highly responsive individuals can be induced in an expeditious, impromptu fashion, without elaborate technical preparation.

Because subjects may vary in the levels of depth during the hypnotic session, posthypnotic suggestion can also be used to facilitate a "cleaner" experimental manipulation.[72] For example, as part of the induction of subjects involved in a reading experiment, a specific instruction can be included suggesting that they will only consider the vertical lines of the symbols showing on the screen on each trial. This active blocking instruction may be effective to prevent the subjects from processing words as lexical units with semantic significance. There already is evidence in the literature suggesting that such manipulations can be performed.[58,73] However, few paradigms take advantage of such potentially important data. Furthermore, because posthypnotic suggestion can be triggered and disengaged on a specific cue (eg, auditory or visual), it is possible to alternately explore effects within a subject in natural and manipulated states.

In addition, hypnosis is experimentally appropriate for investigating developmental neurocognition. Pediatric hypnosis and hypnotherapy have been studied scientifically and documented for more than 200 years.[74,75] Most children are highly hypnotizable, and hypnosis is more easily induced with them than with adults.[16,76,77] Yet, there is no evidence that hypnosis in children is a different phenomenon from that studied in adults.[78]

In conclusion, clinicians practicing hypnosis and cognitive neuroscientists could benefit by using their expertise to exploit hypnosis as a probe into the neural bases of cognition. Such an endeavor can only increase our understanding of these phenomena. Too few higher-order manipulations are as experimentally advantageous as hypnosis and posthypnotic suggestion. Whereas the clinical effectiveness of hypnosis is documented, little has been done to harness this special phenomenon as a means of illuminating cognitive questions, despite its obvious relationship to attention, perception, memory, and consciousness, in light of recent progress in the field of cognitive neuroscience. Neuroimaging technology renders hypnosis particularly enticing not only as a potent cognitive manipulation but also as an effective meditative means to lower tension, alleviate anxiety, and reduce movement for the duration of imaging scans.[79,80] Furthermore, recent neuroimaging data suggest a potential anatomical (morphological and volumetric) basis for hypnotizability,[81] linking variations in the rostrum of the corpus callosum to differences in attentional and inhibitory processing.[82] Hypnosis is also particularly apt for developmental studies, as most children are highly responsive to hypnotic induction. Further inquiries into the developmental correlates of the phenomenon, as they relate to the stage of cognitive and social capacities, seem promising. Finally, in the aftermath of the Human Genome Project, wherein genotyping is increasingly possible, hypnotic responsiveness can be studied in the context of behavioral genetics,[83] thereby opening the way to discover a genetic basis for hypnotizability and associated cognitive capacities.[84] On the flip side, new information to be derived from the marriage of these assays may provide better scientific descriptions of the phenomenological correlates of hypnosis, and allow us to demystify a chthonic trait of human consciousness.

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REFERENCES

1. Hilgard ER. *Hypnotic Susceptibility*. New York, NY: Harcourt Brace & World; 1965.
2. Spiegel H, Spiegel D. *Trance and Treatment: Clinical Uses of Hypnosis*. Washington, DC: American Psychiatric Press; 1987.
3. Barber TX. *Hypnosis: A Scientific Approach*. New York, NY: Jason Aronson Inc; 1995.
4. Kirsch I. APA definition and description of hypnosis: defining hypnosis for the public. *Contemp Hypn*. 1994;11:142-143.
5. Mead M. *Coming of Age in Samoa: A Psychological Study of Primitive Youth for Western Civilization*. New York, NY: New American Library; 1949.
6. Mesmer FA. *Aphorismes de M. Mesmer, Dictes a l'Assemblee de ses Eleves, & Dans Lesquels on Trouve ses Principes, sa Theorie & les Moyens de Magnetizer*. Rev 3rd ed. Paris, France: Compiegne, de l'Imprimerie de Bertrand; 1785.
7. Bloch G. *Mesmerism: A Translation of the Original Medical and Scientific Writings of F. A. Mesmer*. Los Altos, Calif: Kaufman; 1980.
8. Tinterow M. *Foundations of Hypnosis, From Mesmer to Freud*. Springfield, Ill: Charles C Thomas; 1970.
9. Breuer J, Freud S. In: Brill AA, trans-ed. *Studies in Hysteria*. New York, NY: Nervous & Mental Disease Publishing Co; 1936.
10. Halligan PW, Athwal BS, Oakley DA, Frackowiak RS. Imaging hypnotic paralysis: implications for conversion hysteria. *Lancet*. 2000;355:986-987.
11. Marshall JC, Halligan PW, Fink GR, Wade DT, Frackowiak RS. The functional anatomy of a hysterical paralysis. *Cognition*. 1997;64:BI-B8.
12. Oakley D. Hypnosis and conversion hysteria: a unifying model. *Cognit Neuropsychiatry*. 1999;4:243-265.
13. Larkin M. Hypnosis makes headway in the clinic [news]. *Lancet*. 1999;353:386.
14. Elman D. *Hypnotherapy*. Glendale, Calif: Westwood; 1964.
15. Kirsch I, Lynn SJ. Hypnotic involuntariness and the automaticity of everyday life. *Am J Clin Hypn*. 1997;40:329-348.
16. Olness K, Kohen DP. *Hypnosis and Hypnotherapy With Children*. 3rd ed. New York, NY: Guilford Press; 1996.
17. Bányai ÉI, Hilgard ER. A comparison of active-alert hypnotic induction with traditional relaxation induction. *J Abnorm Psychol*. 1976;85:218-224.
18. Cardeña E, Alarcón A, Capafons A, Bayot A. Effects and suggestibility of a new method of active-alert hypnosis. *Int J Clin Exp Hypn*. 1998;3:280-294.
19. Overton JA. Neurocognitive foundations of the shamanic perspective: a brief exploration into the role of imagination in cognition and in the creation of experience. *Shaman*. 2000;8:35-88.
20. Kjaer TW, Lou HC, Nowak M, Holm S, Wildschiodtz G, Friberg L. Meditation induced dissociation between consciousness level and content: a PET study. *Neuroimaging*. 1997;5:123.
21. Stigsby B, Rodenberg JC, Moth HB. EEG findings during mantra meditation: a controlled, quantitative study of experienced meditators. *Electroencephalogy Clin Neurophysiol*. 1981;51:434-442.
22. Lou HC, Kjaer TW, Friberg L, Wildschiodtz G, Holm S, Nowak M. A ^{15}O-H_2O PET study of meditation and the resting state of normal consciousness. *Hum Brain Mapp*. 1999;7:98-105.
23. Spiegel D, Cutcomb S, Ren C, Pibram K. Hypnotic hallucination alters evoked potentials. *J Abnorm Psychol*. 1985;94:249-255.
24. Spiegel D, Bierre P, Rootenberg J. Hypnotic alteration of somatosensory perception. *Am J Psychiatry*. 1989;146:749-754.
25. Rainville P, Hofbauer RK, Paus T, Duncan GH, Bushnell MC, Price DD. Cerebral mechanisms of hypnotic induction and suggestion. *J Cogn Neurosci*. 1999;11:110-125.
26. Barabasz AF, Lonsdale C. Effects of hypnosis on P_{300} olfactory-evoked potential amplitudes. *J Abnorm Psychol*. 1983;92:520-523.
27. Kosslyn SM, Thompson WL, Costantini-Ferrando MF, Alpert NM, Spiegel D. Hypnotic visual illusion alters color processing in the brain. *Am J Psychiatry*. 2000;157:1279-1284.
28. Szechtman H, Woody E, Bowers KS, Nahmias C. Where the imaginal appears real: a positron emission tomography study of auditory hallucinations. *Proc Natl Acad Sci U S A*. 1998;95:1956-1960.
29. Barber TX. Physiological effects of "hypnosis." *Psychol Bull*. 1961;58:390-419.
30. Spanos NP. Hypnotic behavior: a social-psychological interpretation of amnesia, analgesia, and "trance logic." *Behav Brain Sci*. 1986;9:449-502.
31. Weitzenhoffer AM, Hilgard ER. *Stanford Hypnotic Susceptibility Scale: Forms A and B*. Palo Alto, Calif: Consulting Psychologists Press; 1959.
32. Weitzenhoffer AM, Hilgard ER. *Stanford Hypnotic Susceptibility Scale: Form C*. Palo Alto, Calif: Consulting Psychologists Press; 1962.
33. Morgan AH, Hilgard JR. The Stanford Hypnotic Clinical Scale for Children. *Am J Clin Hypn*. 1979;21:148-169.
34. Gorassini DR, Spanos NP. A cognitive–social skills approach to the successful modification of hypnotic susceptibility. *J Pers Soc Psychol*. 1986;50:1004-1012.
35. Gorassini DR, Spanos NP. The Carleton skill training program for modifying hypnotic suggestibility: original version and variations. In: Kirsch I, Capafons A, Cardeña -Buelna E, Amigó S, eds. *Clinical Hypnosis and Self-Regulation*. Washington, DC: American Psychological Association; 1999:141-177, i.
36. Liebeault AA. *Concerning Sleep and Related States* [in French]. Vienna, Austria: Duetricke; 1892.
37. Bernheim H. *Suggestive Therapeutics*. New York, NY: Putnam; 1895.
38. Davis LW, Husband RW. A study of hypnotic susceptibility in relation to personality traits. *J Abnorm Soc Psychol*. 1931;26:175-182.
39. LeCron LM, Bordeaux J. *Hypnotism Today*. New York, NY: Grune & Stratton; 1949.
40. Shor RE, Orne EC. *Harvard Group Scale of Hypnotic Susceptibility*. Palo Alto, Calif: Consulting Psychologists Press; 1962.
41. Spiegel H. An eye-roll test for hypnotic susceptibility. *Am J Clin Hypn*. 1972;15:25-28.
42. Posner MI, Raichle ME. *Images of Mind*. New York, NY: Scientific American Library; 1997.
43. Gazzaniga MS. *The New Cognitive Neurosciences*. 2nd ed. Cambridge, Mass: MIT Press; 2000.
44. Rainville P, Duncan GH, Price DD, Carrier B, Bushnell MC. Pain affect encoded in human anterior cingulate but not somatosensory cortex. *Science*. 1997;277:968-971.
45. Maquet P, Faymonville ME, Degueldre C, Delfiore G, Franck G, Luxen A, Lamy M. Functional neuroanatomy of hypnotic state. *Biol Psychiatry*. 1999;45:327-333.
46. Baer L, Ackerman R, Surman O, Correia J, Griffith J, Alpert N, Hackett T. PET studies during hypnosis and hypnotic suggestion. In: Berner P, ed. *Psychiatry: The State of the Art, Vol 2: Biological Psychiatry, Higher Nervous Activity*. New York, NY: Plenum Press; 1990.
47. Crawford HJ, Horton JE, Harrington GC, Vendemia JMC, Plantec MB, Jung S, Shamro C, Downs JH III. Hypnotic analgesia (disattending pain) impacts neuronal network activation: an fMRI study of noxious somatosensory TENS stimuli. *Neuroimage*. 1998;7(4):S436.
48. Crawford HJ, Horton JE, Harrington GS, Hirsch Downs T, Fox K, Daugherty S, Downs JH III. Attention and disattention (hypnotic analgesia) to noxious somatosensory TENS stimuli: fMRI differences in low and highly hypnotizable individuals. Poster presented at: Sixth Annual Meeting of the Organization for Human Brain Mapping; June 15, 2000; San Antonio, Tex.
49. Rainville P, Hofbauer RK, Bushnell, MC, Duncan GH, Price DD. Hypnosis modulates the activity in cerebral structures involved in arousal and attention. Poster presented at: Cognitive Neuroscience Society; April 10, 2000; San Francisco, Calif.
50. Price DD. Hypnotic analgesia: psychological and neural mechanisms. In: Barber J, ed. *Hypnosis and Suggestion in the Treatment of Pain*. New York, NY: WW Norton Co Inc; 1996:67-84.
51. Gruzelier JH. A working model of the neurophysiology of hypnosis: a review of the evidence. *Contemp Hypn*. 1998;15:3-21.
52. Crawford HJ. Brain dynamics and hypnosis: attentional and disattentional processes. *Int J Clin Exp Hypn*. 1994;52:204-232.

53. Davis KD, Taylor SJ, Crawley AP, Wood ML, Mikulis DJ. Functional MRI of pain- and attention-related activations in the human cingulate cortex. *Neurophysiology*. 1997;77:3370-3380.
54. Davis KD, Hutchison WD, Lozano AM, Tasker RR, Dostrovsky JO. Human anterior cingulate cortex neurons modulated by attention-demanding tasks. *J Neurophysiol*. 2000;83:3575-3577.
55. Sheenan PW, Donovan P, MacLeod CM. Strategy manipulation and the Stroop effect in hypnosis. *J Abnorm Psychol*. 1988;94:249-255.
56. Blum GS, Graef JR. The detection over time of subjects simulating hypnosis. *Int J Clin Exp Hypn*. 1971;19:211-224.
57. Dolby RM, Sheehan PW. Cognitive processing and expectancy behavior in hypnosis. *J Abnorm Psychol*. 1977;86:334-345.
58. Nordby H, Hugdahl K, Jasiukaitis P, Spiegel D. Effects of hypnotizability on performance of a Stroop task and event-related potentials. *Percept Mot Skills*. 1999;88:819-830.
59. Dixon M, Laurence JR. Hypnotic susceptibility and verbal automaticity: automatic and strategic processing differences in the Stroop color-naming task. *J Abnorm Psychol*. 1992;101:344-347.
60. Paterson AD, Sunohara GA, Kennedy JL. Dopamine D4 receptor gene: novelty or nonsense? *Neuropsychopharmacology*. 1999;21:3-16.
61. Swanson JM, Flodman P, Kennedy J, Spence MA, Moyzis R, Schuck S, Murias M, Moriarity J, Barr C, Smith M, Posner M. Dopamine, genes and ADHD. *Neurosci Biobehav Rev*. 2000;24:21-25.
62. Migály P. Integrated approach of hypnotic theories and hallucinatory states (pts 1-3). Presented at: 4th European Congress of Hypnosis in Psychotherapy and Psychosomatic Medicine; July 11-17,1987; Oxford, England.
63. Spiegel D, King R. Hypnotizability and CSF HVA levels among psychiatric patients. *Biol Psychiatry*. 1992;31:95-98.
64. Posner MI, Dahaene S. Attentional networks. *Trends Neurosci*. 1994;17:75-79.
65. Posner MI, Petersen SE. The attention system of the human brain. *Ann Rev Neurosci*. 1990;13:25-42.
66. Corbetta M, Miezin FM, Shulman GL, Peterson SE. A PET study of visuospatial attention. *J Neurosci*. 1993;13:1202-1226.
67. Hopfinger JB, Buonocore MH, Mangun GR. The neural mechanisms of top-down attentional control. *Nature Neurosci*. 2000;3:284-291.
68. Corbetta M, Kincade JM, Ollinger JM, McAvoy MP, Shulman GL. Voluntary orienting is dissociated from target detection in human posterior parietal cortex. *Nature Neurosci*. 2000;3:292-297.
69. Marrocco RT, Davidson MC. Neurochemistry of attention. In: Parasuraman R, ed. *The Attentive Brain*. Cambridge, Mass: MIT Press; 1998.
70. Fan J, McCandliss BD, Sommer T, Raz A, Posner MI. Testing the efficiency and independence of attentional networks. *J Cogn Neurosci*. In press.
71. Fan J, Raz A, Posner MI. Attentional mechanisms. *Encyclopedia Neurol Sci*. In press.
72. Van Denburg E, Kurtz R. Changes in body attitude as a function of posthypnotic suggestions. *Int J Clin Hypn*. 1989;37:15-30.
73. Shijin S. A comparative study of Stroop effect under hypnosis and in the normal waking state [in Chinese]. *Chin Psychol Sci*. 1994;17:287-290.
74. Weitzenhoffer AM. A bibliography of hypnotism in pediatrics. *Am J Clin Hypn*. 1959;2:92-95.
75. Gardner GG. Hypnosis with children: selected readings. *Int J Clin Exp Hypn*. 1980;28:289-293.
76. Cowles RS. The magic of hypnosis: is it child's play? *J Psychol*. 1998;132:356-366.
77. Gardner G, Olness K. *Hypnosis and Hypnotherapy With Children*. New York, NY: Grune & Stratton; 1981.
78. Plotnick A, Payne P, O'Grady D. Correlates of hypnotizability in children: absorption, vividness of imagery, fantasy play, and social desirability. *Am J Clin Hypn*. 1991;34:51-58.
79. Steggles S. The use of cognitive-behavioral treatment including hypnosis for claustrophobia in cancer patients. *Am J Clin Hypn*. 1999;41:319-326.
80. Lang EV, Benotsch EG, Fink LJ, Lutgendorf S, Berbaum ML, Berbaum KS, Logan H, Spiegel D. Adjunctive non-pharmacological analgesia for invasive medical procedures: a randomised trial. *Lancet*. 2000;355:1486-1490.
81. Horton JE, Crawford HJ, Downs JH III. Corpus callosum morphology differences in low and highly hypnotizable adults: attentional and inhibitory processing differences? Poster presented at: Sixth Annual Meeting of the Organization for Human Brain Mapping; June 15, 2000; San Antonio, Tex.
82. Crawford HJ, Gruzelier JH. A midstream view of the neuropsychophysiology of hypnosis: recent research and future directions. In: Fromm E, Nash MR, eds. *Contemporary Hypnosis Research*. New York, NY: Guilford Press; 1992:227-266.
83. Terwilliger JD, Goring HHH. Gene mapping in the 20th and 21st centuries: statistical methods, data analysis, and experimental design. *Hum Biol*. 2000; 72:63-132.
84. Swanson J, Oosterlaan J, Murias M, Schuck S, Flodman P, Spence MA, Wasdell M, Ding Y, Chi HC, Smith M, Mann M, Carlson C, Kennedy JL, Sergeant JA, Leung P, Zhang YP, Sadeh A, Chen C, Whalen CK, Babb KA, Moyzis R, Posner MI. Attention deficit/hyperactivity disorder children with a 7-repeat allele of the dopamine receptor D4 gene have extreme behavior but normal performance on critical neuropsychological tests of attention. *Proc Natl Acad Sci U S A*. 2000;97:4754-4759.