ORIGINAL ARTICLE

Hypnotic Suggestion and the Modulation of Stroop Interference

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Background: Hypnosis has been used clinically for hundreds of years and is primarily a phenomenon involving attentive receptive concentration. Cognitive science has not fully exploited hypnosis and hypnotic suggestion as experimental tools. This study was designed to determine whether a hypnotic suggestion to hinder lexical processing could modulate the Stroop effect.

Methods: Behavioral Stroop data were collected from 16 highly suggestible and 16 less suggestible subjects; both naturally vigilant and under posthypnotic suggestion. Subjects were urged to only attend to the ink color and to impede reading the stimuli under posthypnotic suggestion.

Results: Whereas posthypnotic suggestion eliminated Stroop interference for highly suggestible subjects, less suggestible control subjects showed no significant reduction in the interference effect.

Conclusions: This outcome challenges the dominant view that word recognition is obligatory for proficient readers, and may provide insight into top-down influences of suggestion on cognition.

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IN THE CLASSIC Stroop task, experienced readers are asked to name the ink color of a colored word.[1] In responding to the ink color of an incompatible color word (eg, the word BLUE displayed in red ink), subjects are usually much slower and less accurate than in identifying the ink color of a control item (eg, XXXX or SHIP printed in red). This is called the Stroop Interference Effect (SIE), and it is one of the most robust and well-studied phenomena in attentional research.[2,3] Reading words is considered to be automatic; a proficient reader cannot withhold accessing a word's meaning, despite explicit instructions to attend only to the ink color. Indeed, the standard account in the word recognition and Stroop literature maintains that words are processed automatically to the semantic level[3,4] and that the SIE is therefore the "gold standard" of automated performance.[5]

There are 2 classic theoretical accounts of the Stroop effect.[2,3] First, the relative speed of processing or "horse race" hypothesis[6] suggests that word reading is faster than color naming.[7] A second account, the automaticity hypothesis,[8] postulates that word reading interferes with the more effortful, attention-demanding process of color naming. These 2 accounts are similar because the idea of automaticity is implicit in the relative speed of processing hypothesis. Both hypotheses assume that word reading occurs even though the meaning of the word is to be disregarded. Both place the locus of interference at the output stage and can be considered variants of "response competition" explanations.

These 2 accounts are complemented by additional versions. Semantic similarity between relevant and irrelevant stimulus dimensions has been shown to determine the amount of elicited interference.[9] Recent studies have also challenged the response-competition hypothesis.[10] In fact, experimental assays, which manipulated the stimulus onset asynchrony[11,12] and the speed of processing,[13] diverge from simple relative speed of processing explanations and make the parallel processing accounts of the Stroop effect seem more viable than the serial processing accounts.[2,3,14,15]

Hypnosis relates to other self-regulation techniques (eg, meditation and imagery) in that it evokes a form of highly concentrated attention. Hypnosis is primarily associated with attentive-receptive absorption and is characterized by extreme focused attention as well as by heightened compliance with suggestion.[16-18] Hypnotic susceptibility scales indicate the quantifiable rating of a sub-

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ject's response to suggestions under standard conditions. In the Stanford Hypnotic Susceptibility Scale Form C (SHSS-C),[19] one's hypnotic suggestibility can be classified as either "high" or "low." Some researchers prefer to use hypnotic "suggestibility" over "hypnotizability,"[20] but such terminological variations are often used interchangeably. Whereas there are no substantial correlates of hypnotic suggestibility with personality measures,[21] response expectancy does correlate reliably with hypnotic suggestibility.[22,23] Some clinicians practicing hypnosis suggest that when a highly suggestible person is hypnotized, attentional and perceptual changes may occur that would not have occurred had one been commonly vigilant.[24,25]

The Stroop paradigm provides a promising way to investigate the modulation of attentional networks and top-down control via hypnosis and suggestion.[18] Although neuroimaging data reported by Kosslyn et al[26] show that a neural process as low-level as color perception was successfully affected by hypnotic suggestion,[26] other recent data suggest that hypnotic instruction for color blindness did not inhibit the SIE[27] (note earlier attempts at hypnotic suggestions for color blindness,[28-31] negative visual hallucination, and agnosia,[32] or comparable efforts in the auditory modality[33,34]).

The current study is a "mirror image" of that by Kosslyn et al,[26] since in light of inconsistent data attempting to modulate the SIE through hypnotic manipulation of color perception,[27-31] we instead used a posthypnotic suggestion, which directed subjects not to read meaningful words (see "Methods" section). Based on previous research with hypnosis, we expected the highly suggestible subjects to be compliant with the suggestion made during the hypnotic experience following the hypnotic session, but not to remember the instruction.

The Stroop effect is not new to the hypnosis literature. Blum and Graef[35] first reported that under hypnosis (without suggestion), the SIE was bigger in highly suggestible as compared with less suggestible.[35] Sheehan et al also reported that the SIE was magnified under suggestion-free hypnosis.[36] On the other hand, using suggestion outside of hypnosis, Sun[37] found no difference in the SIE between highly and less suggestible subjects,[37] but Sheehan et al[36] found a bigger SIE for the highly suggestible. Thus, some highly suggestible individuals seem to display increased SIE compared with less suggestible subjects under suggestion-free hypnosis. Furthermore, SIE was reduced when subjects were instructed to shift their gaze away from the displayed word and to covertly attend to the bottom portion of the last letter of the word to be ignored.[36] Using a comparable strategy, Sun found that the SIE was significantly reduced for the highly suggestible, but not for the less suggestible.[37] Hence, hypnotic suggestions containing explicit attentional strategies seem to obviate the prepotent inclination to read in the highly suggestible. Lastly, Dixon and Laurence, extending their earlier study,[38] looked at highly vs less suggestible subjects outside of hypnosis and explored the interaction between automatic and controlled processing, using a "strategy free" modified Stroop procedure.[39] Both studies showed that when strategic influences were minimized, a reliable difference between highly suggestible and less suggestible subjects was apparent: the highly suggestible showed larger Stroop effects than the less suggestible. In general, these findings proposed that outside of the hypnotic context, the highly suggestible subjects processed words more automatically than the less suggestible.

In contrast to these studies of the SIE during hypnosis, the present study did not instruct subjects to follow a variation of a peripheral strategy such as looking away or blurring vision. Rather, the goal of the present study was to establish whether a simple strategy-free posthypnotic suggestion to circumvent reading could effectively modulate the SIE within a classical Stroop design. Our aim was to determine whether it would be possible to obviate the pervasiveness of word reading, using a subjective behavioral indicant and by recruiting hypnosis as an attentional manipulation.[18] Specifically, we hypothesized that if this instruction were effective, we would no longer observe the relative advantage (ie, faster reaction time [RT] and higher accuracy) commonly associated with congruent trials. Furthermore, we speculated that the specific suggestion would reduce or completely remove the SIE for highly suggestible subjects, but have no effect on the less suggestible.

METHODS

Subjects consisted of 32 proficient readers of English (mean age, 24.3 years) naïve to the Stroop task, who agreed to participate in this study in exchange for an average compensation of $30 per hour. Subjects were recruited from a pool of 75 volunteers (mostly medical students at the Weill Medical College of Cornell University, New York, NY) who had earlier been individually screened for suggestibility in a hypnotic context using the SHSS-C[19] (absent the anosmia to ammonia challenge). Sixteen hypnosis subjects (8 female, 8 male; 4 nonnative) scoring in the highly suggestible range (10-11 of a possible 11), and 16 control subjects (7 female, 9 male; 4 nonnative) scoring in the less-suggestible range (2-3 of a possible 11) on the SHSS-C were recruited for further participation.

MATERIALS

Subjects sat at a viewing distance of approximately 65 cm in front of a color computer monitor. Stimuli consisted of a single word written in one of 4 ink colors (red, blue, green, or yellow) appearing at the center of the computer screen, where a black fixation cross was visible. All characters were displayed in upper-case font against a white background, and the stimuli subtended visual angles of 0.5° vertically, and 1.3° to 1.9° horizontally (depending on word length). Two classes of words were used: color words (RED, BLUE, GREEN, and YELLOW) and neutral words (LOT, SHIP, KNIFE, and FLOWER), with the latter class being frequency-matched as well as length-matched to the color words.

Three experimental conditions were used: a congruent condition consisting of a color word inked in its own color; a neutral condition consisting of a neutral word inked in any one of the 4 colors; and an incongruent condition consisting of a color word inked in any of the 3 colors (eg, the color word BLUE inked in green) other than the one to which it referred. During each trial, subjects were asked to indicate the ink color in which a word was written by depressing one of 4 keys on a keyboard. Although button pressing reduces effect size relative to vocal naming, we opted for it because of its relative merit in a sequel neuroimaging assay. The color-labeled response keys were "V," "B,"

Table 1. Mean Reaction Times and Error*

Group	Posthypnotic Suggestion	Congruent		Neutral		Incongruent	
		RT, ms	Error, %	RT, ms	Error, %	RT, ms	Error, %
Highly suggestible subjects (n = 16)	Absent	703	2	748	2	860	6
	Present	664	2	671	2	669	2
Less suggestible subjects (n = 16)	Absent	694	3	719	4	798	6
	Present	687	3	721	6	808	7

*RT indicates reaction time.

"N," and "M" for the colors red, blue, green, and yellow, respectively. Two fingers of each hand were used to press these response keys (ie, left middle finger for V, right index finger for N, etc). Speed and accuracy were emphasized equally.

DESIGN AND PROCEDURE

The experimental design was a mixed factorial model with "group" (highly or less suggestible) and "order" (naturally alert→posthypnotized, posthypnotized→naturally alert) as between-subject factors, and with "posthypnotic-suggestion" (absent, present) and "congruency" (congruent, neutral, incongruent) as within-subject factors. Following a standard Stanford induction,[19] posthypnotic suggestion was a within-subject factor in the sense that all subjects participated in both a naturally alert (N) and a posthypnotized (PH) condition. No suggestion was made under N; posthypnotic suggestion was made under PH. Administration order (N→PH vs PH→N) was counterbalanced across groups.

Informed consent was obtained from all subjects in advance in the following manner: preceding the experiment, an experimenter notified the subjects that the purpose of the study was to investigate the effects of suggestion on cognitive performance. Subjects were told that hypnotic inductions and suggestions would be administered at certain points during the experiment and that they would be asked to play a computer game (ie, Stroop) with the experimenter present in the room.

Subjects were instructed to focus their eyes on a fixation cross at the center of the screen. A stimulus would then appear on the screen replacing the crosshair. The stimulus remained on the screen for a maximum of 2 seconds or until subjects responded. Following a response, veridical visual feedback was provided (ie, "CORRECT" or "INCORRECT" was flashed in black ink), and the fixation cross was redisplayed at the center for a variable duration contingent on the subject's RT. At this point, a new stimulus appeared on the screen, again replacing the fixation cross and beginning the next trial. The interstimulus interval was always 4 seconds (preparing for a follow-up neuroimaging design).

Thirty-two practice trials preceded the first session for each subject. This training session was used to confirm that subjects were able to understand the task, proficiently map the 4 colors to the appropriate response keys, and respond quickly and accurately. Following this brief training session, subjects took a short break and then completed 144 experimental trials. One-third of all trials were neutral, congruent, and incongruent, respectively. Trial order was randomized throughout the experiment.

The following posthypnotic suggestion was verbally presented to both highly suggestible and less-suggestible subjects subsequent to a standard hypnotic induction:[19]

> Very soon you will be playing the computer game. When I clap my hands, meaningless symbols will appear in the middle of the screen. They will feel like characters of a foreign language that you do not know, and you will not attempt to attribute any meaning to them. This gibberish will be printed in one of 4 ink colors: red, blue, green or yellow. Although you will only be able to attend to the symbols' ink color, you will look straight at the scrambled signs and crisply see all of them. Your job is to quickly and accurately depress the key that corresponds to the ink color shown. You will find that you can play this game easily and effortlessly.

The specific wording of this suggestion is significant because the particular phrasing was the result of a tedious piloting process of trial and repetition. Initially, we attempted to use variations on less specific instructions, telling highly suggestible subjects that they would see letters and not know that they formed meaningful words. This approach was not consistently successful, but introducing the concept of an unfamiliar foreign language seemed plausible to the subjects.

Subjects were randomly assigned to an administration order of the 2 experimental conditions. Half of the subjects in each group (ie, highly or less suggestible) were first run on the Stroop task following hypnosis induction with the previously mentioned posthypnotic suggestion and then (after a 15-minute break) when naturally alert in a common Stroop context. The remaining subjects experienced these 2 conditions in the reverse order. When not under the posthypnotic suggestion condition, subjects were simply instructed to foveate on the center fixation cross and respond (ie, depress the appropriate keys) as quickly and as accurately as possible in response to the ink color of the stimuli.

Interviews free of any hypnotic influence were conducted (and videotaped) immediately following the posthypnotic-suggestion sessions, when subjects regained their natural (nonhypnotic) attentiveness.

RESULTS

Table 1 presents the mean RT and mean error scores for the 2 attentional conditions (ie, naturally alert vs posthypnotized) as a function of the 3 Stroop conditions (ie, congruent, neutral, and incongruent) for the 2 subject groups. Incorrect responses were excluded from the analyses, as were RTs that were 3 SDs either above or below the mean. Approximately 1.5% of all the data were excluded owing to deviant RTs for both the highly suggestible and less-suggestible subjects, respectively.

Table 2 presents subtractions of the various data from Table 1 to indicate the overall SIE (I-C) as well as the breakdown into interference (I-N) and facilitation (N-C).

Table 3 summarizes the analysis of variance analyses of the data from Table 2, separately displaying RT and errors.

Table 2. Performance of the Stroop Congruency Subtractions*

Group	Posthypnotic Suggestion	I-C		I-N		N-C	
		Interference + Facilitation	Error	Interference	Error	Facilitation	Error
Highly suggestible subjects (n = 16)	Absent	157	4	112	4	45	0
	Present	5	0	−2	0	7	0
Less suggestible subjects (n = 16)	Absent	104	3	79	2	25	1
	Present	121	4	87	1	34	3

*Interference and/or facilitation values are in mean milliseconds; error values are percentages. I-C indicates incongruent-congruent; I-N, incongruent-neutral; and N-C, neutral-congruent.

Table 3. Analysis of Variance Main Effects and Interactions*

Effect	RT (I-C)	RT (I-N)	RT (N-C)	Error (I-C)	Error (I-N)	Error (N-C)
Order	F<1	F<1	$F_{1,28}$ = 6.42, *P*<.05	F<1	$F_{1,28}$ = 2.38, *P* = .134	$F_{1,28}$ = 1.46, *P* = .237
Group	$F_{1,28}$ = 1.67, *P* = .206	$F_{1,28}$ = 1.47, *P* = .235	F<1	$F_{1,28}$ = 2.51, *P* = .124	F<1	$F_{1,28}$ = 4.05, *P* = .054
Suggestion	**$F_{1,28}$ = 10.80, *P*<.005**	**$F_{1,28}$ = 6.84, *P*<.05**	$F_{1,28}$ = 2.36, *P* = .136	$F_{1,28}$ = 3.72, *P* = .064	**$F_{1,28}$ = 12.32, *P*<.005**	$F_{1,28}$ = 2.09, *P* = .159
Order × Group	F<1	F<1	F<1	F<1	F<1	F<1
Order × Suggestion	F<1	F<1	F<1	F<1	F<1	F<1
Group × Suggestion	**$F_{1,28}$ = 17.13, *P*<.001**	**$F_{1,28}$ = 9.36, *P*<.01**	**$F_{1,28}$ = 5.91, *P*<.05**	**$F_{1,28}$ = 5.56, *P*<.05**	$F_{1,28}$ = 1.37, *P* = .252	$F_{1,28}$ = 2.09, *P* = .159
Order × Group × Suggestion	F<1	F<1	F<1	$F_{1,28}$ = 1.84, *P* = .185	F<1	F<1

*Effects and interactions apply to the data in Table 2 under the experimental design. Statistically significant effects (ie, *P*<.05) appear in bold. RT indicates reaction time; I-C, incongruent-congruent; I-N, incongruent-neutral; and N-C, neutral-congruent.

RT ANALYSIS

Inspection of the main effects showed that posthypnotic suggestion caused a significant reduction in Stroop interference. (Note that the significant order main effect for Stroop facilitation has no interactions associated with it and constitutes a practice effect not related to posthypnotic suggestion.)

Since our hypotheses had been laid out *before* the experiment, planned comparisons were performed to further investigate the results. Considered with the data from Tables 2 and 3, these comparisons showed that whereas the SIE differential was highly significant when contrasting the highly suggestible subjects between the 2 hypnotic-suggestion conditions ($F_{1,30}$=29.35, *P*<.001) for I-C $F_{1,30}$=16.78, *P*<.001) for I-N), it was not significant for the less-suggestible group (F<1 for both). Additionally, in the absence of hypnotic suggestion there was no significant SIE difference between highly suggestible and less suggestible subjects ($F_{1,30}$=2.09, *P*=.16 for I-C; F<1 for I-N), but in the presence of hypnotic suggestion, a significant effect was found ($F_{1,30}$=21.20, *P*<.001 for I-C; $F_{1,30}$=16.66, *P*<.001 for I-N).

Tests of the RTs (Table 2) under posthypnotic suggestion in the highly suggestible group revealed that neither was significantly different from zero (F<1), indicating that interference and facilitation were completely removed by the posthypnotic suggestion.

ERROR ANALYSIS

Table 3 indicates how posthypnotic suggestion significantly reduced interference errors. Planned comparisons showed that the performance differential was significant for the high-suggestible group between the suggestion conditions for interference ($F_{1,30}$=11.50, *P*=.002). Conversely, the less suggestible did not differ significantly on error performance as a function of suggestion for interference ($F_{1,30}$=2.88, *P*=.10). In the absence of posthypnotic suggestion, the performance difference between the 2 groups was not significant for interference (F<1) as was the case in the presence of the posthypnotic suggestion ($F_{1,30}$=1.40, *P*=.24).

Postexperimental interviews showed that 12 highly suggestible subjects reported having seen only "colored images," "scrambled symbols," "gibberish," or "words in an unknown foreign language" on the computer screen. The remaining 4 highly suggestible subjects reported awareness that words were sometimes flashed on the screen, but that they could ignore reading them most of the time. Conversely, all control (less suggestible) subjects reported being cognizant of the word stimuli.

COMMENT

This article follows our effort to relate hypnosis to cognitive studies of attention.[18] Interference in the stroop effect has been considered a prime case of attentional control in processing sensory input. The data indicate that, for some subjects, the SIE can be removed, and performance significantly enhanced by means of an attentional manipulation (hypnosis) accompanied by a specific posthypnotic suggestion to thwart reading. Specifically, the reported data show that hypnosis plus a carefully crafted suggestion (containing no reference to a specific attentional strategy) can obviate the effect of automatic word reading and suffice to eliminate the SIE in operationally defined highly suggestible proficient English readers.

Experimental order (ie, whether subjects were first tested under posthypnotic suggestion or while naturally alert) did not significantly affect the experimental outcome. Analysis of the RT data showed that whereas responses were both collectively faster and comparable across the 3 Stroop conditions under posthypnotic suggestion for the highly suggestible (consistent with our hypothesis that lexical processing was impeded), this trend was not elicited from the less suggestible (see Table 1). Interestingly, nullifying the "relative advantage" (ie, faster RT and higher accuracy) of the congruent trials as a function of posthypnotic suggestion was also consistent with error performance. As expected, not only was the traditional SIE present for the less suggestible within the posthypnotic suggestion condition, it was not significantly different from the RT trend acquired while naturally alert. Performance analysis further showed that the highly suggestible made significantly fewer interference errors under posthypnotic suggestion. Similarly, although facilitation (N-C) is not always evident in color Stroop paradigms in which manual responses are used,[40] the present results show that as a consequence of the posthypnotic suggestion, not only was the SIE removed in the highly suggestible, but so was facilitation. Although performance accuracy was increased on all conditions under posthypnotic suggestion, only for the incongruent trials was a significant difference obtained. These results might hold important implications for neurocognitive investigations of the interaction between attentional resources and word recognition. Evidently, the involvement of attention in word reading warrants closer scrutiny.

Not only is attention known to modulate the activity of evoked visual stimuli within early brain areas,[41] recent functional imaging data indicate that attention can strikingly influence word reading as well. Rees et al[42] reported inattentional blindness (ie, utter failure to perceive words) even for highly familiar and meaningful stimuli when looked at directly at the center of gaze. By creating a situation in which subjects could look straight at a word without attending to it, Rees et al showed that brain activity in response to recognizable visual words vs random letters entirely depended on attention. Since hypnosis is likely to propel an attentional gradient, taken together with the present data, these findings seem to suggest that word reading was effectively prevented under the posthypnotic-suggestion condition.

In one parallel distributed processing model, Cohen et al[15] suggested a connectionist account of the Stroop effect using spreading activation along pathways of different strengths. A particularly attractive feature of this early model is that attention is realized as the modulation of the operation of processing units along a pathway, thus making attention inherent to the model, and not an external element applied to it. Indeed, attention may play a pivotal role in modulating the ballistic nature of word reading.

REDUCING AND REMOVING THE STROOP INTERFERENCE EFFECT

The traditional SIE is understood to indicate that one cannot screen perfectly for only what is relevant, and that concurrent processing of irrelevant information takes place even if this is unfavorable to the task at hand. Because the SIE is a vigorous attentional phenomenon and is difficult to reduce by practice, there is widespread accord in the Stroop literature that skilled readers obligatorily process printed stimuli presented to the fovea. Nonetheless, complementing the present results, recent reports have shown that within particular (hypnosis-free) contexts, the SIE can also be significantly reduced or eliminated.[43-54] Although critiqued on multiple aspects,[55-57] these reports suggest that a seemingly unconsciously controlled process can be derailed by relatively simple means. Such results put forth a challenge to the commonly accepted construct of automatic, involuntary activation of word representations, and suggest that these processes are perhaps malleable to the point of elimination. Indeed, current theories of the SIE are incompatible with such findings.

There is little disagreement that the role of attentional strategies[58,59] and mental set[60] is to serve as determinants in SIE elicitation. Additionally, it is well known that diverting gaze away from the stimuli, blurring vision, concentrating on a single letter within a word stimulus, speeding or slowing of response, and employing a particular congruent to incongruent trial ratio can all significantly affect the SIE.

POTENTIAL STRATEGIES

Sheehan et al[36] found the SIE to be increased in the highly suggestible under hypnosis unless special instructions were given to overcome the effect. In light of these data and the literature examining the effects of various strategies on the SIE, it may be that the hypnotized subjects still instigated some strategy while performing the present experimental task, even without instructions. During the postexperimental interviews, subjects reported that they had indeed observed all symbols within a stimulus and universally denied use of alternative strategies. Whereas the experimental instructions explicitly directed subjects to "look straight at" and "crisply see" *all* the symbols comprising the stimuli shown at the center of the screen, recruitment of covert strategies cannot be easily ruled out (ie, it is perhaps plausible that hypnotic subjects may be successful in deceiving themselves).

Attempting to reconstruct strategies that may have been covertly used by the subjects, 2 are most likely: focusing visual gaze away from the central target, and blurring of vision. The effects of changes in the distribution of spatial attention have largely been neglected in the Stroop literature; nonetheless, some reports strongly suggest that spatial attention may play a critical role in visual word recognition.[61] Besner and Stolz[46] reported that the SIE can be reduced in magnitude or removed when a single letter position in a colored word is precued (hence the importance that *all* letters are seen crisply as part of the posthypnotic suggestion). Videotaped recordings of the experimental sessions showed subjects unmistakably focusing on the central target. Furthermore, blurry vision is unlikely because subjects were unambiguously instructed to sharply see the stimuli. On ophthalmological grounds, it is theoretically possible to maintain either a spasm of accommodation or a relaxation of accommodation (ie, volitionally have the image fall either in front of or behind the retinae) for the duration of the experiment, but the intermittent presentation of the stimuli and fixation point makes this option improbable. An online technique (eg, ultrasound) to monitor the convexity of the lens can be used to determine this issue, but such technology is currently in a nascent stage.

We conclude that posthypnotic suggestion markedly reduces Stroop interference for the highly suggestible subjects as compared with controls, indicating that posthypnotic suggestion, when effective, must operate through a top-down mechanism that modifies the processing of input words through a means not voluntarily available. This outcome challenges the dominant view that word recognition is obligatory for all proficient readers and may allow insight into the top-down influences exerted by suggestion. Because it has been reported that highly suggestible people can respond to suggestions even without hypnosis,[20,62] it is not clear whether a hypnotic context is essential to the effect achieved. An appropriate study is currently underway to explore this question.

Finally, a related result using neuroimaging indicated that the hypnotic instruction not to see color prevented activation of prestriate areas related to processing color.[26] The processing of printed words involves areas of the prestriate visual system (visual word form), the temporoparietal junction (phonology), and prefrontal and posterior areas related to semantics. We already have initiated several imaging studies to find out where the instruction not to see the stimulus as a meaningful word influences this stream of information processing.

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REFERENCES

1. Stroop JR. Studies of interference in serial verbal reactions. *J Exp Psychol.* 1935;18:643-661.
2. MacLeod CM, MacDonald PA. Interdimensional interference in the Stroop effect: uncovering the cognitive and neural anatomy of attention. *Trends Cogn Sci.* 2000;4:383-391.
3. MacLeod CM. Half a century of research on the Stroop effect: an integrative review. *Psychol Bull.* 1991;109:163-203.
4. Neely JH. Semantic priming effects in visual word recognition: a selective review of current findings and theories. In: Besner D, Humphreys GW, eds. *Basic Processes in Reading: Visual Word Recognition.* Hillsdale, NJ: Erlbaum; 1991:264-336.
5. MacLeod CM. The Stroop task: the "gold standard" of attentional measures. *J Exp Psychol Gen.* 1992;121:12-14.
6. Posner MI, Snyder CRR. Attention and cognitive control. In: Solso RL, ed. *Information Processing and Cognition: The Loyola Symposium.* Hillsdale, NJ: Erlbaum; 1975:55-85.
7. Theios J, Amrhein PC. Theoretical analysis of the cognitive processing of lexical and pictorial stimuli: reading, naming, and visual and conceptual comparisons. *Psychol Rev.* 1989;96:5-24.
8. LaBerge D, Samuels SJ. Toward a theory of automatic information processing in reading. *Cognit Psychol.* 1974;6:293-323.
9. Klopfer DS. Stroop interference and color-word similarity. *Psychol Sci.* 1996;7:150-157.
10. Luo CR. Semantic competition as the basis of Stroop interference: evidence from color-word matching tasks. *Psychol Sci.* 1999;10:35-40.
11. Glaser MO, Glaser WR. Time course analysis of the Stroop phenomenon. *J Exp Psychol Hum Percept Perform.* 1982;8:875-894.
12. Glaser WR, Dungelhoff FJ. The time course of picture-word interference. *J Exp Psychol Hum Percept Perform.* 1984;10:640-654.
13. Dunbar KN, MacLeod CM. A horse race of a difference color: Stroop interference patterns with transformed words. *J Exp Psychol Hum Percept Perform.* 1984;10:622-639.
14. Phaf RH, Van der Heijden AH, Hudson PT. SLAM: a connectionist model for attention in visual selection tasks. *Cognit Psychol.* 1990;22:273-341.
15. Cohen JD, Dunbar K, McClelland JL. On the control of automatic processes: a parallel distributed processing model of the Stroop effect. *Psychol Rev.* 1990;97:332-361.
16. Hilgard ER. *Hypnotic Susceptibility.* New York, NY: Harcourt, Brace & World; 1965.
17. Spiegel H, Spiegel D. *Trance and Treatment: Clinical Uses of Hypnosis.* Washington, DC: American Psychiatric Press; 1987.
18. Raz A, Shapiro T. Hypnosis and neuroscience: a cross talk between clinical and cognitive research. *Arch Gen Psychiatry.* 2001;59:85-90.
19. Weitzenhoffer AM, Hilgard ER. *Stanford Hypnotic Susceptibility Scale: Form C.* Palo Alto, Calif: Consulting Psychologists Press; 1962.
20. Kirsch I, Braffman W. Imaginative suggestibility and hypnotizability. *Curr Dir Psychol Sci.* 2001;10:57-61.
21. Nash MR. The truth and the hype of hypnosis. *Sci Am.* 2001;285:46-49,52-55.
22. Braffman W, Kirsch I. Imaginative suggestibility and hypnotizability: an empirical analysis. *J Pers Soc Psychol.* 1999;77:578-587.
23. Kirsch I, Silva CE, Comey G, Reed S. A spectral analysis of cognitive and personality variables in hypnosis: empirical disconfirmation of the two-factor model of hypnotic responding. *J Pers Soc Psychol.* 1995;69:167-175.
24. Spiegel D, Cutcomb S, Ren C, Pibram K. Hypnotic hallucination alters evoked potentials. *J Abnorm Psychol.* 1985;94:249-255.
25. Spiegel D, Bierre P, Rootenberg J. Hypnotic alteration of somatosensory perception. *Am J Psychiatry.* 1989;146:749-754.
26. Kosslyn SM, Thompson WL, Costantini-Ferrando MF, Alpert NM, Spiegel D. Hypnotic visual illusion alters brain color processing. *Am J Psychiatry.* 2000;157:1279-1284.
27. Mallard D, Bryant RA. Hypnotic color blindness and the Stroop test. *Int J Clin Exp Hypn.* 2001;49:330-338.
28. Harvey MA, Sipprelle CN. Color blindness, perceptual interference, and hypnosis. *Am J Clin Hypn.* 1978;20:189-193.
29. Erickson MH. The induction of color blindness by a technique of hypnotic suggestion. *J Gen Psychol.* 1939;20:61-89.
30. Grether WF. A comment on "The Induction of Color Blindness by a Technique of Hypnotic Suggestion." *J Gen Psychol.* 1940;23:207-210.
31. Harriman PL. Hypnotic induction of color vision anomalies, I: the use of the Ishihara and the Jensen tests to verify the acceptance of suggested color blindness. *J Gen Psychol.* 1942;26:289-298.
32. Blum GS, Wiess F. Attenuation of symbol/word interference by posthypnotic negative hallucination and agnosia. *Exp Klin Hypn.* 1986:2:58-62.
33. 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 USA.* 1998;95:1956-1960.
34. Dierks T, Linden DE, Jandl M, Formisano E, Goebel R, Lanfermann H, Singer W. Activation of Heschl's gyrus during auditory hallucinations. *Neuron.* 1999;22:615-621.
35. Blum GS, Graef JR. The detection over time of subjects simulating hypnosis. *Int J Clin Exp Hypn.* 1971;19:211-224.

36. Sheenan PW, Donovan P, MacLeod CM. Startegy manipulation and the Stroop effect in hypnosis. *J Abnorm Psychol*. 1988;94:249-255.
37. Sun S. A comparative study of Stroop effect under hypnosis and in the normal waking state [in Chinese]. *Psychol Sci*. 1994;17:287-290.
38. Dixon M, Brunet A, Laurence JR. Hypnotic susceptibility and verbal automatic and strategic processing differences in the Stroop color-naming task. *J Abnorm Psychol*. 1990;99:336-343.
39. 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.
40. Keele SW. Attention demands of memory retrieval. *J Exp Psychol*. 1972;93:245-248.
41. Martínez A, Anllo-Vento L, Sereno MI, Frank LR, Buxton RB, Dubowitz DJ, Wong EC, Hinrichs H, Heinze HJ, Hillyard SA. Involvement of striate and extrastriate cortical areas in spatial selective attention: combined evidence from fMRI and event-related potentials. *Nat Neurosci*. 1999;2:364-369.
42. Rees G, Russell C, Frith CD, Driver J. Inattentional blindness versus inattentional amnesia for fixated but ignored words. *Science*. 1999;286:2504-2507.
43. Kuhl J, Kazén M. Volitional facilitation of difficult intentions: joint activation of intention memory and positive affect removes stroop interference. *J Exp Psychol Gen*. 1999;128;382-399.
44. De Jong R, Berendsen E, Cools R. Goal neglect and inhibitory limitations: dissociable causes of interference effects in conflict situations. *Acta Psychol (Amst)*. 1999;101:379-394.
45. Besner D, Stolz JA, Boutilier C. The Stroop effect and the myth of automaticity. *Psychon Bull Rev*. 1997;4:221-225.
46. Besner D. Stolz JA. What kind of attention modulates the Stroop effect? *Psychon Bull Rev*. 1999;6:99-104.
47. Melara RD, Algom D. A tectonic theory of Stroop effects. *Psychol Rev*. In press.
48. Besner D, Stolz JA. Unconsciously controlled processing: the Stroop effect reconsidered. *Psychon Bull Rev*. 1999;6:449-455.
49. Besner D. Stolz JA. Context dependency in Stroop's Paradigm: when are words treated as nonlinguistic objects? *Can J Exp Psychol*. 1999;53:374-380.
50. Besner D. The myth of ballistic processing: Evidence from Stroop's paradigm. *Psychon Bull Rev*. 2001;8:324-330.
51. Dishon-Berkovits M, Algom D. The Stroop effect: it is not the robust phenomenon that you have thought it to be. *Mem Cognit*. 2000;28:1437-1449.
52. Pansky A, Algom D. Stroop and Garner effects in comparative judgment of numerals: the role of attention. *J Exp Psychol Hum Percept Perform*. 1999:25:39-58.
53. Vivas AB, Fuentes LJ. Stroop interference is affected in inhibition of return. *Psychon Bull Rev*. 2001;8:315-323.
54. Arieh Y, Algom D. Processing picture-word stimuli: the contingent nature of picture and of word superiority. *J Exp Psychol Learn Mem Cogn*. 2002;28:221-232.
55. MacLeod CM. Putting automaticity in context: reducing the Stroop effect. Paper presented at: Joint Meeting of the Experimental Psychology Society and Canadian Society for Brain, Behaviour, and Cognitive Science; July 22, 2000; Cambridge, England.
56. Marmurek H. Response modality modulates single-letter effects in color-word interference. Poster presented at: 40th Annual Meeting of the Psychonomic Society; November 18-21, 1999; Los Angeles, Calif.
57. Neely JH, Kahan T. Is semantic activation automatic? a critical re-evaluation. In: Roediger HL, Nairne JS, Neath I, Surprenant AM, eds. *The Nature of Remembering: Essays in Honor of Robert G. Crowder*. Washington, DC: American Psychological Association; 2000.
58. Cheesman J, Merikle PM. Word recognition and consciousness. In: Besner D, Waller TG, McKinnon E, eds. *Reading Research: Advances in Theory and Practice*. San Diego, Calif: Academic Press; 1985:311-352.
59. Logan GD, Zbrodoff NJ, Williamson J. Strategies in the color-word Stroop task. *Bull Psychon Soc*. 1984;22:135-138.
60. Bauer B, Besner D. Mental set as a determinant of processing in the Stroop task. *Can J Exp Psychol*. 1997;51:61-68.
61. Kahneman D, Henik A. Perceptual organization and attention. In: Kubovy M, Pomerantz JR, eds. *Perceptual Organization*. Hillsdale, NJ: Erlbaum; 1981:181-211.
62. Braffman W, Kirsch I. Imaginative suggestibility and hypnotizability: an empirical analysis. *J Pers Soc Psychol*. 1999;77:578-587.