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Consciousness and Cognition 12 (2003) 332–346
Consciousness and Cognition
www.elsevier.com/locate/concog

Posthypnotic suggestion and the modulation of Stroop interference under cycloplegia

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Received 21 October 2002

Abstract

Recent data indicate that under a specific posthypnotic suggestion to circumvent reading, highly suggestible subjects successfully eliminated the Stroop interference effect. The present study examined whether an optical explanation (e.g., visual blurring or looking away) could account for this finding. Using cyclopentolate hydrochloride eye drops to pharmacologically prevent visual accommodation in all subjects, behavioral Stroop data were collected from six highly hypnotizables and six less suggestibles using an optical setup that guaranteed either sharply focused or blurred vision. The highly suggestibles performed the Stroop task when naturally vigilant, under posthypnotic suggestion not to read, and while visually blurred; the less suggestibles ran naturally vigilant, while looking away, and while visually blurred. Although visual accommodation was precluded for all subjects, posthypnotic suggestion effectively eliminated Stroop interference and was comparable to looking away in controls. These data strengthen the view that Stroop interference is neither robust nor inevitable and support the hypothesis that posthypnotic suggestion may exert a top-down influence on neural processing.

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doi:10.1016/S1053-8100(03)00024-2

1. Introduction

In accord with a theoretical framework relating hypnosis to attention (Raz & Shapiro, 2002), recent data demonstrated that highly suggestible individuals were able to eliminate the Stroop interference effect following a posthypnotic suggestion designed to avoid attributing meaning to the words (Raz, Shapiro, Fan, & Posner, 2002b). In the classic Stroop task experienced readers name the ink color of a displayed word (Stroop, 1935). Responding to the ink color of an incompatible color word (e.g., the word "RED" displayed in blue ink) subjects are usually slower and less accurate than identifying the ink color of a control item (e.g., "XXX" or "LOT" inked in red). This difference in performance is called the Stroop Interference Effect (SIE) and is one of the most robust and well-studied phenomena in attentional research (MacLeod, 1991; MacLeod & MacDonald, 2000). Reading words is largely considered to be automatic; according to this view a proficient reader cannot withhold accessing a word's meaning despite explicit instructions to attend only to its ink color. Indeed, the standard account in both the word recognition and Stroop literatures maintains that words are automatically processed to the semantic level (MacLeod, 1991; Neely, 1991) and that the SIE is therefore the "gold standard" to measure executive attention (MacLeod, 1992).

Some investigators, notably Daniel Algom and Derek Besner, have independently shown that within hypnosis-free contexts the SIE can be significantly reduced or even eliminated (e.g., Algom, Dekel, & Pansky, 1996; Arieh & Algom, 2002; Besner, 2001; Besner & Stolz, 1999a, 1999b, 1999c; Besner, Stolz, & Boutilier, 1997; De Jong, Berendsen, & Cools, 1999; Dishon-Berkovits & Algom, 2000; Kuhl & Kazén, 1999; Long & Prat, 2002; Pansky & Algom, 1999; Pansky & Algom, 2002; Shaki & Algom, 2002). Interpretation of these findings led some scholars (e.g., Algom & Besner) to challenge the automaticity account of the SIE and reason that the effect is neither vigorous nor ballistic. Construing the SIE as a phenomenon of attention, not automaticity, these researchers disagree with the notion that upon visual presentation skilled readers are obliged to extract the meaning of familiar words.

Although amply critiqued (e.g., MacLeod, 2000; Marmurek, 1999; Neely & Kahan, 2000), these reports collectively suggest that a seemingly unconsciously controlled process may be reduced by cognitive and attentional strategies without manipulating the stimulus. These results put forth a challenge to the commonly accepted construct of automatic, involuntary, activation of word representations. Specifically, attentional strategies (e.g., Cheesman & Merikle, 1985; Logan, Zbrodoff, & Williamson, 1984) and mental set (e.g., Bauer & Besner, 1997) serve as determinants in SIE elicitation. Thus, it has been possible to significantly affect the SIE by modulating either perceptual input (e.g., averting the eyes from the central stimuli, squinting or blurring vision), processing (e.g., slowing of response), or both (e.g., concentrating on a single letter within a word stimulus). In addition, it is also possible to modulate the SIE via design parameters (e.g., employing a particular congruent/incongruent trial ratio).

Supplementing earlier studies concerning Stroop and hypnosis (e.g., Blum & Graef, 1971; Blum & Wiess, 1986; Dixon, Brunet, & Laurence, 1990; Dixon & Laurence, 1992; Nordby, Hugdahl, Jasiukaitis, & Spiegel, 1999; Sheehan, Donovan, & MacLeod, 1988; Sun, 1994; cf., Spiegel, Cutcomb, Ren, & Pribram, 1985), Raz et al. (2002b) were successful in eliminating the SIE while explicitly instructing their subjects to neither look away nor blur their vision (for relevant historical accounts see MacLeod & Sheehan, 2003; Schatzman, 1980). In fact, Raz et al. exhorted subjects not to employ any method of changing or degrading the stimulus input. Instead, as part of their experimental posthypnotic suggestion, they explicitly instructed subjects to "look straight at" and "crisply see" all elements comprising the stimuli. Using event-related potentials Nordby et al. (1999) also reported SIE reduction using a paradigm demonstrating that hypnotic perceptual alteration was not due to optical defocusing because it was not associated with prolonged latency, which would normally occur upon defocused gaze (Spiegel et al., 1985).

Nonetheless, attempting to investigate potential strategies that subjects may have covertly employed, two are most likely: averting the eyes from the central target and blurring of vision. Whereas monitoring subject gaze is easy to control (e.g., videotaping and eye-tracking), visual blurring is more difficult to rule out because it is theoretically possible to maintain either a spasm or a relaxation of accommodation (i.e., have the image fall either in front of or behind the retinae). Since objective online monitoring of lens convexity is currently in a nascent technological stage, the present design precluded visual accommodation using a pharmacological agent known to ophthalmology as cyclopentolate hydrochloride solution (hereafter cyclopentolate).

This study set out to reproduce the finding of Raz et al. (2002b) while exploiting cyclopentolate to induce cycloplegia—loss of power in the ciliary muscle of the eye resulting in absence of visual accommodation. Data were collected under cycloplegia, both while using an individually tailored optical contrivance assuring crisp vision and without such optical correction; this design allowed for either accommodation-free in-focus vision or blurred eye-sight, respectively. In order to demonstrate that highly hypnotizable individuals did not blur their vision to diminish the SIE, we hypothesized that modulating the SIE would occur despite cycloplegia coupled with optical correction (i.e., on the basis of the posthypnotic suggestion to block reading). Postulating that visual blurring is not the primary mechanism circumventing the SIE, we hypothesized that highly suggestibles would be able to either completely remove or significantly reduce the SIE even while under cycloplegia. We further predicted that the performance of highly suggestibles under the experimental posthypnotic suggestion would be comparable to that of less hypnotizables when instructed to look away.

2. Method

2.1. Subjects

Six highly suggestible subjects and six (matched) less hypnotizables agreed to participate in this study for \$20 (28 ± 8 and 25 ± 5 years, respectively). They were recruited from a pool of 75 volunteers who had earlier been individually screened for suggestibility using the Stanford Hypnotic Susceptibility Scale (absent the anosmia to ammonia challenge) (Weitzenhoffer & Hilgard, 1962). The highly suggestible subjects (3 female, 3 male; 2 non-native to English: 1 female, 1 male) scored in the higher range of the susceptibility scale (8–11 out of a possible 11); the less suggestible (3 female, 3 male; 2 non-native to English: 1 female, 1 male) scored in the lower range (1–4 out of a possible 11). All had normal or corrected-to-normal vision and no history of color-blindness based on self-report as well as performance on the Ishihara color plate testing (Ishihara, 1951, 1994). All subjects were examined by an ophthalmologist to ensure that they did not have narrow angles (i.e., not at risk for acute angle closure glaucoma, induced by pharmacological dilation of the pupils). One volunteer was excluded on these grounds.

2.2. Materials and apparatus

This experiment closely followed the materials and procedures described by Raz et al. (2002b) with the addition of cycloplegia-related procedures. All subjects were cyclopleged throughout this experiment (see Section 2.3). Subjects sat at a video-monitored chinrest–forehead-support combination placed 66.67 cm in front of a flat color monitor. Every subject was fitted with the appropriate prescription lens for each eye to ensure sharp vision of word stimuli displayed on the screen (i.e., visual images were correctly focused on the subjects' retinae upon cycloplegia). Stimuli consisted of a single word written in one of four ink colors (red, blue, green, or yellow) appearing at the center of the computer screen where a black fixation cross was visible between stimuli presentations. 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°–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), the latter class being frequency- as well as length-matched to the color words.

Three Stroop conditions were employed: 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 four colors; and an incongruent condition consisting of a color word inked in any of the three colors other than the one to which it referred (e.g., the color word BLUE inked in green). During each trial, subjects were asked to indicate the ink color in which a word was written by pressing one of four keys on a keyboard. (Manual, rather than vocal, response was used due to both compatibility with a neuroimaging assay (Raz, Fan, Shapiro, & Posner, 2002; Raz, Shapiro, Fan, & Posner, 2002a; Raz, Shapiro, Fan, & Posner, 2002c) and evidence of elicited semantic processing (Brown & Besner, 2001; Brown, Roberts, & Besner, 2001; Sharma & McKenna, 1998)). The color-labeled response keys were V, B, N, M for the colors red, blue, green, and yellow, respectively. Two fingers of each hand were used to press these response keys (i.e., left middle finger for V, left index finger for B, right index finger for N, and right middle finger for M).

2.3. Design and procedure

Test 1, Test 2, and Test 3 correspond to the conditions of Naturally-alert, Posthypnotized (for the highly suggestibles) or Looking-away (for the low suggestibles), and Visually-blurred, respectively. The experimental design was a non-factorial model with Group (Highly Suggestibles, Less Suggestibles) as a between-subject factor, and with Test (Naturally-alert, Posthypnotized or Looking-away, and Visually-blurred), and Congruency (Congruent, Neutral, and Incongruent) as within-subject factors. In the second test (Test 2), the experimental condition was different for the two groups. Whereas the within-subjects factor in the second test for the highly suggestibles was a posthypnotic suggestion (following a standard induction (Weitzenhoffer & Hilgard, 1962)) to obviate reading of the Stroop words, for the less suggestibles it was an instruction to achieve the same goal by looking away. 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 (e.g., to change chairs, rise and stretch, or forget a fact) but does not usually remember being told to do so. The posthypnotic suggestion is usually summoned on a prearranged signal and can be effective in highly responsive individuals. It is experimentally advantageous to use posthypnotic suggestion (versus a hypnotic suggestion) because the subjects comply with the suggestion during normal wakefulness (as opposed to while under hypnosis).

The posthypnotic suggestion (see below) aimed to preclude reading by way of a top-down process while the instructions to look away (fixate at the corner of the computer screen) intended to enable identifying the stimuli's ink color without processing the word (i.e., using parafoveal or extrafoveal perception). The third condition, visual blurring, consisted of having all subjects perform without the trial frame (i.e., no optical correction was available). Every group ran a counterbalanced administration order consisting of three separate conditions.

Informed consent was obtained from all candidates in advance: preceding the experiment, an investigator notified the candidates that the purpose of the study was to investigate the effects of suggestion on cognitive performance absent the ability to use visual accommodation, and that a board-certified ophthalmologist with subspecialty in glaucoma (KSL) would perform all ophthalmic procedures. If cleared by the ophthalmologist, subjects agreed to have 2 drops of 1% cyclopentolate hydrochloride solution, dispensed 5 min apart, to be administered to each eye at the beginning of the experiment in order to induce cycloplegia. Then, about 30 min later, they would be optically refracted while cyclopleged and given glasses to allow them perfect vision (i.e., 6/6 or better) of visual objects appearing straight ahead on a flat screen at a distance of 2/3 m. The consent form as well as the hypnotic susceptibility screening made all subjects aware that hypnotic inductions and suggestions may be administered at certain points during the experiment. Finally, subjects were apprised that recovery from the experimental cycloplegia usually occurs within 24 h (and that no medication would be offered to reduce recovery time at the end of the experimental procedures). Under cycloplegia, visual accommodation is effectively impossible and visual perception is only sharp for viewing objects at visual infinity (i.e., farther than 6 m away from the retina). Residual accommodation despite cycloplegia is generally a function of age: the younger the individual, the greater the remaining accommodation (e.g., 60-year-old individuals are not likely to have any residual accommodation upon cycloplegia). Although using atropine would have completely abolished any residual accommodation for any age group, the aftereffects associated with such a powerful drug (e.g., dilated pupils and photophobia for a period of weeks) are not indicated. Instead, we opted for 2 drops of cyclopentolate, which is a potent cycloplegic agent entailing relatively mild and short-lived discomfort and used routinely in ophthalmological practice.

Before the experiment, the ophthalmologist checked all candidates using a gonioscopy lens to exclude those with anatomically narrow angles, a risk factor for acute angle closure glaucoma. Additionally, because one's corrective prescription may change as a function of cycloplegia (i.e., a subject not ordinarily using optical correction may require some), the ophthalmologist then refracted all viable subjects under full cycloplegia (i.e., 30 min post-cyclopentolate administration) at a distance of 6 m, determining each subject's cyclopleged refraction (CR) to be 6/6 or better.

Upon refraction, every subject was outfitted with a trial frame holding a pair of corrective lenses, positioned closely in front of each eye. Lens' strength was determined as +1.5-diopter (i.e., optical correction for 2/3 m, that is, the distance of the computer display from the eyes) plus one's CR. This scheme guaranteed that using the optical setup, all images fell exactly on one's retinae. With the exception of less suggestibles in Test 2 (i.e., averting gaze), all subjects were instructed to look straight at a fixation cross shown at the center of the screen. Then, a stimulus would appear on the screen replacing the crosshair. The stimulus remained on the screen either until subjects responded or for a maximum of two seconds—the shorter of the two. Subsequently, the fixation cross was redisplayed at the center for a variable duration contingent upon the subject's reaction time. At this point a new stimulus appeared on the screen again replacing the fixation cross and beginning the next trial. The inter-stimulus interval was always 4 s. Speed and accuracy were emphasized equally.

At least 32 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 four 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 congruent, neutral, and incongruent, respectively. Trial order was randomized throughout the experiment.

Since the Stroop effect profoundly relies on one's color vision, it is important to acknowledge that excluding visual accommodation influences the eye's ability to detect color and therefore impinges on color perception. Optically, different wavelengths (i.e., colors) result in a variation in the location of the end image relative to the retina. In particular, sulfur yellow (wavelength = 586 nm) falls right on the retina and is therefore the sharpest (i.e., requiring no visual adaptation). Blue and green fall slightly in front of the retina, while red falls correspondingly behind it. The normally accommodating eye unerringly compensates for these small differences. We were concerned that the induced cycloplegia would introduce a color bias that could sway our experimental design. Therefore, within the current context, we guaranteed that these wavelength variations were negligible (i.e., less than 1/3 of a diopter in the worst case).

Following Raz et al. (2002b), the following posthypnotic suggestion was verbally presented to all highly suggestibles at the end of a standard (Weitzenhoffer & Hilgard, 1962) hypnotic induction:

> 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 four 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.

Subjects were randomly assigned to a counterbalanced administration order of the three experimental conditions within each group. In Tests 1 and 3, subjects were conventionally instructed to focus on the center fixation cross and respond (i.e., depress the appropriate keys) as quickly and as accurately as possible in response to the ink color of the stimuli. However, in Test 2 while highly hypnotizables received a posthypnotic suggestion to prevent them from reading the stimuli, less suggestibles diverted their gaze and reported the Stroop words' ink color without reading them. Continuous video monitoring throughout the experimental sessions ascertained compliance with gaze orientation.

3. Results

Table 1 shows mean reaction time (RT) and mean error scores for the various experimental conditions as a function of the three Stroop conditions under cycloplegia. Incorrect responses

Table 1
Mean reaction times (ms) and error (%) under cycloplegia

Group	Condition	Congruent		Neutral		Incongruent	
		RT	Error	RT	Error	RT	Error
Highly suggestibles $N = 6$	Naturally Vigilant	641 (123.4)	2.1 (2.3)	674 (93.0)	6.6 (5.2)	776 (150.0)	6.2 (4.4)
	Posthypnotic Suggestion	685 (142.2)	3.5 (2.2)	688 (133.3)	4.2 (2.9)	707 (139.3)	4.9 (4.1)
	Blurred Vision	618 (85.9)	5.6 (3.4)	654 (81.5)	4.2 (3.2)	725 (167.4)	7.3 (4.5)
Less suggestibles $N = 6$	Naturally Vigilant	624 (82.5)	5.9 (4.0)	646 (95.3)	8.3 (7.2)	753 (214.3)	11.1 (4.1)
	Looking Away	610 (127.2)	8.3 (7.9)	656 (119.2)	9.0 (10.2)	644 (106.6)	8.7 (6.1)
	Blurred Vision	614 (87.6)	7.3 (6.4)	660 (112.2)	7.3 (7.5)	753 (258.9)	11.8 (8.9)

Standard deviations are shown in parentheses.

were excluded from the RT analyses, as were RTs that were 2 standard deviations either above or below the mean. About 5% of the data were excluded due to deviant RTs (5.2% for highly suggestibles and 4.9% for less suggestibles).

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

First, we established that there were no interactions with experimental order for either RT or accuracy ($F < 1$ on a global test). Next, a repeated measures omnibus analysis of variance (ANOVA) was carried out to investigate the RT effects across the 3 tests. Note that although formally speaking our design was not strictly factorial (i.e., Test 2 was different for the two groups), we opted for a factorial ANOVA because we had initially predicted that the separate group conditions of Test 2 would be comparable. We therefore performed the following ANOVA: Groups (Less Suggestible, Highly Suggestible) as a between-subject factor*Tests (Naturally-alert, Posthypnotized or Looking-away, and Visually Blurred), and Congruency (Congruent, Neutral, and Incongruent) as within-subject factors and then followed up with sets of simple effect tests (Bonferroni adjusted) to investigate the significant interactions. Finally, we repeated the whole analysis for the accuracy performance (i.e., error) data.

RT analysis. No significant difference was found between the two groups across all tests and conditions (Table 3). Bonferroni-adjusted tests of simple main effects were performed to further investigate the significant Stroop-Congruency and Test*Stroop-Congruency results. These tests demonstrated that whereas the SIE was significant for Test 1 ($F(1,10) = 11.99$, $p < .01$ for I–C; $F(1,10) = 10.94$, $p < .01$ for I–N; $F(1,10) = 4.48$, $p = .060$ for N–C) and Test 3 ($F(1,10) = 7.46$, $p < .05$ for I–C; $F(1,10) = 4.25$, $p = .066$ for I–N; $F(1,10) = 21.88$, $p < .005$ for N–C), it was not significant in the case of Test 2 for both less suggestibles ($F < 1$ for I–C, I–N, and N–C) and highly suggestibles ($F < 1$ for I–C and N–C; $F(1,10) = 1.38$, $p = .268$ for I–N). Thus, both posthypnotic suggestion and looking away yielded a significant and comparable reduction on Stroop interference.

Table 4 displays t test results illustrating those Stroop effects obtained for Test 2 and Test 3 which significantly deviated from zero (i.e., determining whether the Stroop effects were significantly reduced or practically eliminated). Whereas both averting gaze and posthypnotic suggestion convincingly eliminated the SIE, visual blurring significantly reduced it and altogether did away only with the interference effect (I–N).

Error analysis. Bonferroni-adjusted tests of simple main effects were performed to further investigate the only significant result: Stroop-Congruency (Table 3). Similar to the RT analysis, since Group was not significant the two groups were collapsed on Test 1 and Test 3. Although a performance gradient was significant for I–C in Test 1 ($F(1,10) = 22.09$, $p < .005$ for I–C; $F < 1$ for I–N; $F(1,10) = 5.24$, $p = .135$ for N–C), only I–N was significant in the case of Test 3 ($F(1,10) = 5.03$, $p = .146$ for I–C; $F(1,10) = 10.00$, $p < .05$ for I–N; $F(1,10) = 1.00$, $p = 1.000$ for N–C). Regardless of group, all Stroop contrasts were not significant in Test 2 ($F < 1$ for I–C, I–N, and N–C for both groups).

Subsequent to the experimental sessions, interviews were conducted with all the subjects. Information gleaned from these postexperimental interviews was revealing albeit based on subjective self-report. These informal exchanges showed that four highly suggestible subjects reported having seen only "colored squiggles," "scrambled symbols," "gobbledygook," or "text in a foreign language" on the computer screen. The remaining two highly hypnotizable subjects

Table 2
Mean values (with standard deviations shown in parentheses) for RT (ms) and error (%) under cycloplegia

Group	Condition	RT (I–C)	Error (I–C)	RT (I–N)	Error (I–N)	RT (N–C)	Error (N–C)
Highly suggestibles $N = 6$	Naturally Vigilant	135 (103.6)	4.2 (3.7)	103 (82.7)	−0.3 (4.6)	33 (47.0)	4.5 (3.6)
	Posthypnotic Suggestion	22 (61.7)	1.4 (4.9)	19 (41.7)	0.7 (3.1)	3 (27.1)	0.7 (3.9)
	Blurred Vision	107 (96.3)	1.7 (5.7)	71 (95.9)	3.1 (4.3)	36 (24.2)	−1.4 (2.5)
Less suggestibles $N = 6$	Naturally Vigilant	129 (155.5)	5.2 (3.2)	106 (131.1)	2.8 (8.9)	22 (42.8)	2.4 (6.5)
	Looking Away	34 (40.4)	0.3 (7.3)	−12 (35.9)	−0.3 (8.4)	46 (37.6)	0.7 (3.1)
	Blurred Vision	139 (198.0)	4.5 (3.8)	93 (169.4)	4.5 (4.0)	46 (35.3)	0 (2.3)

The Stroop effects are computed for Interference + Facilitation: I–C (incongruent–congruent); Interference: I–N (incongruent–neutral); and Facilitation: N–C (neutral–congruent).

Table 3
Results of the omnibus repeated measures ANOVA for the data shown in Table 2

RT		Error	
Groups	$F < 1$	Groups	$F(1, 10) = 2.24$
Tests	$F < 1$	Tests	$F < 1$
Stroop Congruency	**$F(2, 20) = 13.34$, $p < .001$**	Stroop Congruency	**$F(2, 20) = 8.72$, $p < .005$**
Tests*Stroop Congruency	**$F(4, 40) = 3.43$, $p < .05$**	Tests*Stroop Congruency	$F(4, 40) = 1.61$, $p = .191$
Groups*Stroop Congruency	$F < 1$	Groups*Stroop Congruency	$F < 1$
Groups*Tests	$F(2, 20) = 1.28$, $p = .301$	Groups*Tests	$F < 1$
Groups*Test*Stroop Congruency	$F < 1$	Groups*Test*Stroop Congruency	$F < 1$

Main effects and interactions are given for the 3 Stroop Congruency Conditions across the 3 Tests. Statistically significant effects (i.e., $p < .05$) appear in bold.

Table 4
T tests to determine whether the various Stroop subtractions were statistically different from zero

Group	Condition	Interference + Facilitation (I–C)	Interference (I–N)	Facilitation (N–C)
Highly Suggestibles $N = 6$	Posthypnotic Suggestion	**$t(5) = .867$, $p = .426$**	**$t(5) = 1.106$, $p = .319$**	**$t(5) = .272$, $p = .797$**
	Blurred Vision	$t(11) = 2.846$, $p < .05$	**$t(11) = 2.153$, $p = .054$**	$t(11) = 4.824$, $p < .005$
Less Suggestibles $N = 6$	Looking Away	**$t(5) = 2.050$, $p = .096$**	**$t(5) = -.814$, $p = .452$**	$t(5) = 2.982$, $p < .05$

Results that are not statistically significant (i.e., $p \geqslant .05$ to indicate that the effect was utterly removed) appear in bold.

reported partial awareness that words were sometimes flashed on the screen, but that they could ignore reading them. Conversely, all control (less suggestible) subjects reported being fully cognizant of the word stimuli.

The interviews confirmed that in Test 2 less hypnotizables were successful in looking away and not reading while highly suggestibles were directly gazing at and plainly viewing all the presented symbols under the impression that they were foreign writing (i.e., both groups reportedly responded to the ink color while the activation of the actual words in the internal lexicon was suppressed (cf., Neely & Kahan, 2000)). Subjects from both groups stated similar accounts concerning Test 1 and Test 3, namely that performing while visually blurred (Test 3) was generally easier than when seeing sharply (Test 1).

Having viewed the video sessions for variation in eye patterns, five independent judges could not discern highly suggestibles from less hypnotizables.

4. Discussion

The data indicate that despite physiological inability to blur vision, highly suggestibles successfully annulled the SIE under a specific posthypnotic suggestion designed to avoid attributing meaning to the words. The current data are in harmony with other evidence that hypnotically-induced alteration of perception is not mediated by blurring of gaze, since blurring is usually associated with increased latency of visual event-related potentials, and reduced amplitude was found not to be associated with increased latency (Spiegel et al., 1985). The current findings accord with our hypothesis, follow our efforts to employ hypnosis as a vehicle to illuminate cognitive studies of attention (Raz & Shapiro, 2002), and replicate our previous results signifying that highly suggestibles did not show the Stroop effect under the same posthypnotic suggestion (Raz et al., 2002b).

Experimental order (i.e., the particular testing sequence that subjects followed as they performed the Stroop task) did not significantly affect the experimental outcome. Analysis of the RT data indicated that responses were comparable across the 3 Stroop congruence conditions in Test 2 both under posthypnotic suggestion and while looking away. In addition, no significant differences were found between the two groups on Test 1 (of Dixon et al., 1990; Dixon & Laurence, 1992; Raz et al., 2002b) and Test 3 (i.e., when both groups performed identical tasks) as well as—most importantly—on Test 2 (i.e., when highly suggestibles adhered to a posthypnotic suggestion to hinder reading while less suggestibles focused their gaze away). In harmony with our hypothesis, the traditional SIE was conspicuously absent in Test 2 (and significantly reduced, indeed almost removed, in Test 3). Interpretation of these data suggests that under effective posthypnotic suggestion, activation of words in the internal lexicon is suppressed for highly suggestibles. In fact, their performance was similar to that of control subjects, who did not read the Stroop words by way of diverting their gaze.

Performance analysis revealed that there was no difference between the two groups on the various tests, although on Test 2 different processes were recruited to elicit the reduction in SIE (i.e., gaze aversion for the lows and altered central processing for the highs). Furthermore, both highly suggestibles and controls did not significantly alter their accuracy across the experimental conditions.

Using modified Stroop procedures, some researchers have examined highly versus less hypnotizable subjects outside of hypnosis (e.g., Dixon et al., 1990; Dixon & Laurence, 1992). They found reliable differences between the groups: SIE was significantly larger for the highly hypnotizables compared to the less hypnotizables. This finding suggests that outside of the hypnotic context highly hypnotizables processed words more automatically than less hypnotizables. However, it may also imply that the baseline efficiency of the executive attention network of highly hypnotizables deviates significantly from the baseline level of less hypnotizable controls. We hope to soon report our neuroimaging data exploring this baseline variation between highly and less hypnotizables.

Attention can modulate the activity of evoked visual stimuli along the neural hierarchy: from early processing (e.g., Martinez et al., 1999) all the way up to word reading (e.g., Rees, Russell, Frith, & Driver, 1999). To this end, Rees et al. (1999) reported inattentional blindness (i.e., utter failure to perceive words) even for decidedly familiar and meaningful stimuli when looked at directly within the center of gaze. By creating a situation in which subjects could look straight at a word without attending to it, they showed that brain activity in response to recognizable visual words, versus random letters, entirely depended on attention (Rees et al., 1999). Since hypnosis is considered an attentive-receptive concentration (Spiegel & Spiegel, 1987), and since visual blurring was not possible for subjects in our study, Rees et al.'s (1999) finding, together with the current data, provide converging evidence that word reading was effectively prevented under the posthypnotic suggestion condition. Furthermore, the current findings serve as a good complement to other related reports (e.g., Rainville, Hofbauer, Bushnell, Duncan, & Price, 2002) and seem to recommend hypnotic phenomena—which have not been the bailiwick of cognitive neuroscientists—as viable experimental probes for cognitive research (Kosslyn, Thompson, Costantini-Ferrando, Alpert, & Spiegel, 2000; Raz et al., 2002; Raz & Shapiro, 2002; Raz et al., 2002b).

One way to interpret the data, which seems to falsify at least some common notions concerning word reading as an automatic process, is to consider it as evidence that automaticity is a continuum (MacLeod & Dunbar, 1988). Besner and Algom challenge the automaticity account of the Stroop effect and claim that the effect is neither robust nor inevitable. For example, Algom et al. showed the effect to be malleable to the point of elimination without changing the physical stimulus (through correlation, discriminability and other factors of context) (e.g., Melara & Algom, in press). Thus, there are multiple accounts suggesting that the SIE is pliable and that atleast some processes may have the potential for variable automaticity, depending on such factors as practice, task circumstances, and the attentional profile of the subject. On the one hand, it is clear that factors such as the amount and type of practice can predict whether a particular task would qualify as controlled or automatic (Logan, 1988; Logan, Taylor, & Etherton, 1999; Shiffrin & Schneider, 1977). On the other hand, the plausibility of this argument remains theoretical when no factor is designated to determine whether a particular process is automatic.

There are data suggesting that spatial attention may play a critical role in visual word recognition (Kahneman & Henik, 1981; Shalev & Algom, 2000). Besner and Stolz (1999c) reported SIE reduction or removal when a single letter position in a colored word was precued (hence the insistence as part of the posthypnotic suggestion that *all* letters be crisply seen). Nonetheless, it may be that the hypnotized subjects still followed some ulterior strategy while performing the present Stroop task, despite the experimental instructions and the post-experimental accounts.

5. Conclusion

With the exception of the lack of faster RTs for the neutral condition, the result that effective posthypnotic suggestion under cycloplegia cancelled the SIE in highly suggestibles replicates our earlier findings (Raz et al., 2002b) and proposes that the effect must operate via a top-down cognitive mechanism that modifies the processing of input words through a means not entirely related to visual blurring. Notably, highly suggestibles' performance under posthypnotic suggestion to prevent reading was comparable to that of a control group's responding to the Stroop words' ink color without reading (by averting their eyes). Interpretation of these data therefore suggests that the highly suggestibles genuinely censored lexical word processing, and did not just inhibit the words' triggered activations (cf., Neely & Kahan, 2000).

Despite the SIE's role as the experimental benchmark of automaticity in word reading, there is mounting evidence from converging domains to clarify the role of top-down control in word reading. In particular, consistent reports suggest that the SIE was significantly modulated by such factors as the nature of the task, its experimental context, and the subject's mental state. Whereas other investigators have argued that word reading is not automatic by showing SIE malleability, the current results demonstrate that posthypnotic suggestion can also bypass customary automaticity. Further research is required to explore the differences and similarities between these hypnotic effects and other cognitive means of circumventing the SIE.

Thus, the current findings challenge the dominant view that word recognition is obligatory for all proficient readers, and may allow insight into the top-down influences exerted by suggestion at the neural level (cf., Dixon et al., 1990; Dixon & Laurence, 1992). In light of other recent accounts and because it was reported that highly suggestible individuals can respond to suggestions even without hypnosis (Braffman & Kirsch, 1999; Kirsch & Braffman, 2001), it is not clear whether a hypnotic context is essential to elicit the effect achieved. An appropriate study is currently underway to explore this question (Pollard, Raz, & Kirsch, 2003).

The present results suggest a strong top-down modulation of the word recognition processes. Albeit there is gradual appreciation that word reading can be mediated by attention, it is still largely considered automatic. Two general mechanisms to account for the data are equally plausible: one argues that the hypnotic manipulation resulted in an obstruction in the activation of the irrelevant words in the internal lexicon; the other purports that activation did occur, but was then inhibited and subsequently prevented from running its course. We are currently completing a report of our neuroimaging data to shed further light on this issue (cf., Raz et al., 2002; Raz, Fossella, McGuinness, Sommer, & Posner, in press; Raz et al., 2002a; Raz et al., 2002c).

Acknowledgments

We thank the Department of Ophthalmology at the New York Presbyterian Hospital–Weill Medical College of Cornell University in Manhattan for making their equipment and space available to us for this study. We are also grateful to Colin M. MacLeod, Ph.D., Derek Besner, Ph.D., and Heidi E. Sormaz, Ph.D. for constructive comments on this manuscript.

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