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Neurophysiological correlates of post-hypnotic alexia: A controlled study with Stroop test

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Abstract

To clarify whether hypnotically-induced alexia was able to reduce the Stroop effect due to color/word interference, 12 volunteers (6 with high and 6 with low hypnotizability according to Stanford Hypnotic Susceptibility Scale Form C) underwent a Stroop test consisting of measuring, both in basal conditions and during post-hypnotic alexia, the reaction times (RT) at appearance of a colored word indicating a color. In basal conditions, RT were greater in case of incongruence. In highly hypnotizable participants, the interference was less pronounced during post-hypnotic alexia (-34%, $p = 0.03$). During alexia, late positive complexamplitude was also greater for congruent than incongruent conditions ($p < 0.03$), and cardiovascular response to stress was less pronounced as well. In participants showing low hypnotizability, no reduction of Stroop effect was detected during post-hypnotic alexia. Post-hypnotic alexia is therefore a real and measurable phenomenon, capable of reducing the color-word interference and the haemodynamic effects of the Stroop test.

Keywords: Hypnosis, alexia,post-hypnotic conditioning, Stroop test, interference, color, word, experimental.

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Neurophysiological correlates of post-hypnotic alexia

Pathological alexia

Alexia is a condition which causes the incapacity to read. Although alexia is transiently or permanently present in many diseases involving the Wernicke area (Pyun, Sohn, Jung, & 2007; Michel, 2008), pathological alexia is not a good experimental tool. In fact, alexic patients often have concomitant or accompanying neurological defects due to the primary disease (stroke, tumor, trauma), making test results unreliable. The best experimental condition would be to have subjects with isolated alexia without any other confounding defects.

Hypnotic alexia

Phenomenology of hypnosis is multifaceted (Faymonville, Boly, & Laureys, 2006) and can mimic many pathological conditions. An expert hypnotist can easily suggest to highly hypnotizable subjects to experience alexia during hypnotic trance and after de-hypnotization (through a post-hypnotic command, i. e. a suggestion made during hypnosis indicating that a particular experience will occur on cue following termination of the hypnotic session) (Raz, 2005). In this special condition of modified consciousness, it is often sufficient to give a command like "you are incapable of reading, written language makes no sense to you, written words appear to you as a series of X or as a foreign language" to reduce or abolish the ability to read (Raz, Moreno-Iniguez, Martin, & Zhu, 2007). Hypnotically or post-hypnotically-induced alexia is probably due to distraction of attention rather than to a functional lesion of the Wernicke area.

How to demonstrate alexia

Unfortunately, hypnotic/ post-hypnotic alexia is difficult to demonstrate experimentally. The Stroop test could be of help for this aim. In the Stroop test (Stroop, 1935; Glaser & Glaser, 1982; MacLeod, 1991) the mental reactive is represented by words identifying a color or – alternatively - a series of X. Watching words on a black background, a subject can undergo these distinct conditions: *congruent* when the color of the ink and the color name correspond (e.g. the word "green" is written in green ink) and *incongruent* when color and word do not correspond. Getting out of this situation of congruence/incongruence constitutes the Stroop test. The performance is evaluated by measuring (in ms) the reaction times (RT) and the event-related potentials (ERP): the difference between times measured in congruent and incongruent conditions, if any, represents (in ms) the Stroop effect.

The Stroop test is a good model for studying word-color interference. Raz, Moreno-Iniguez, Martin, & Zhu (2007) recently demonstrated that, in highly hypnotizable participants receiving the hypnotic suggestion of being unable to read written words, incongruence has a less pronounced effect in the frame of the Stroop test. We therefore decided to use the Stroop test to demonstrate that post-hypnotic alexia is a real, repeatable and measurable phenomenon rather than a merely subjective inner experience. The hypothesis at the basis of this project was if participants experiencing post-hypnotic alexia really becomes alexic, the word-color interference will be reduced and the Stroop effect will be less pronounced. In fact, in conditions of alexia, when the semantic value of words is blinded, the semantic-perceptional incongruence should become negligible.

As a consequence, reduction of the Stroop effect after suggestion of alexia could demonstrate that alexia is real, and the measure of reduction of the Stroop effect could be a measure of alexia. A secondary target of this study was to clarify whether or not alexia is able in turn to modify the reflex haemodynamic response to a Stroop test considered as a stressor. If so, the hypothesis that alexia is a real phenomenon could be made stronger.

Participants, materials and methods

Study participants

Twelve young healthy volunteers, whose general characteristics are summarized in Table 1, were studied. They were recruited among the medical and psychological staff of the University of Padova, and previously defined as eligible for hypnosis on the basis of a historical questionnaire, a personal interview with the staff and a Minnesota Multiphasic Personality Inventory 2 procedure. This was aimed at screening out and excluding from the study participants with a borderline personality, prone to show unwanted effects during hypnotic dissociation.

As the aim of the study was to compare subjects showing higher and lower hypnotizability, this characteristic was individually determined in a set of possible participants by means of the Stanford Hypnotic Susceptibility Scale Form C (Weitzenhoffer & Hilgard, 1982). Participants ranging ≥ 9 were considered as highly hypnotizable, those ranging ≤ 4 were considered to show low hypnotizability, while those showing intermediate scores were not taken into consideration for the study. As power analysis indicated that 10 participants were sufficient for the aim of the study (see below), 12 subjects divided in two groups according to hypnotizability were identified and recruited.

Table 1: General characteristics of study participants, stratified according to hypnotizability. No significant difference between groups.

	All Subjects (n=12)	High Hypnotizability (n=6)	Low Hypnotizability (n=6)
Age (years)	28.6 ± 3.8	28.7 ± 3.5	28.2 ± 3.7
Men/Women ratio	4/12	2/6	2/6
Basal reaction time[1] (ms)			
- in neural conditions	632 ± 59	631 ± 62	633 ± 57
- in congruent conditions	597.5 ± 59	599 ± 60	595 ± 58
- in incongruent conditions	704 ± 102	703 ± 101	705 ± 103
Body surface area (m^2)	1.7 ± 0.7	1.7 ± 0.5	1.7 ± 0.8
Body mass index ($kg \times m^{-2}$)	20.7 ± 3.7	20.9 ± 3.5	20.6 ± 3.8
Systolic blood pressure (mmHg)	121.4 ± 11.0	121.5 ± 8.9	121.4 ± 8.7
Diastolic blood pressure (mmHg)	76.2 ± 13.5	76.2 ± 13.4	76.3 ± 11.2
Heart rate (bpm)	85.75 ± 14.3	85.7 ± 14.4	85.85 ± 14.1
Stroke volume (ml)	60.7 ± 15.7	60.6 ± 15.8	60.8 ± 15.6
Cardiac index ($1 \times min^{-1} \times m^{-2}$)	3.4 ± 1.3	3.4 ± 1.2	3.4 ± 1.3

[1]before hypnotic induction

Ethical aspects

Before recruitment, any potential participant was informed about the study and was acquainted with the fact that the aim was to make him/her incapable to read through post-hypnotic suggestions. The research adhered to the principles of the Declaration of Helsinki. All participants gave written informed consent to the procedure. Each one was preliminary and personally informed about methods and possible risks of the procedure, and had the opportunity to ask all questions that he/she considered necessary. The Ethics Committee of the University Hospital of Padova approved the protocol.

Preliminary setting

In a preliminary setting, all participants in turn individually underwent hypnotic induction through verbal suggestions with cues of relaxing and well-being, a method which had already been used with success in previous experiments carried out by our research group (Casiglia et al., 1997, 2006, 2007). Through the voice of an expert hypnotist, each participant was guided towards focusing his/her attention on a single idea, excluding any other external or internal stimuli. Hypnotic induction consisted of a brief enumeration coupled with suggestions of general well-being, eyelid heaviness, regular deep breathing, and staring at a point. After spontaneous eyelid closure was obtained, participants were invited to concentrate on their own body from head to foot, while a feeling of heaviness and muscular relaxation was being suggested (Casiglia et al., 1997, 2006, 2007). The verification of hypnosis was based on some signals, such as arm levitation, the easing of facial tension, a dropped lower jaw with a slight opening of the mouth, and slowing down of breathing rate. The analysis of these signals enabled the hypnotist to verify the participants were really hypnotized and to maintain or modify this condition by means of continuous appropriate suggestions. The aim of this preparatory procedure was to establish a valid interpersonal relationship between the operator and the participant, in order to favor rapid and valid mono-ideism on the occasion of the following experimental setting. To reduce the time needed for further inductions, post-hypnotic conditioning was predisposed in all participants during this first phase.

Experimental setting

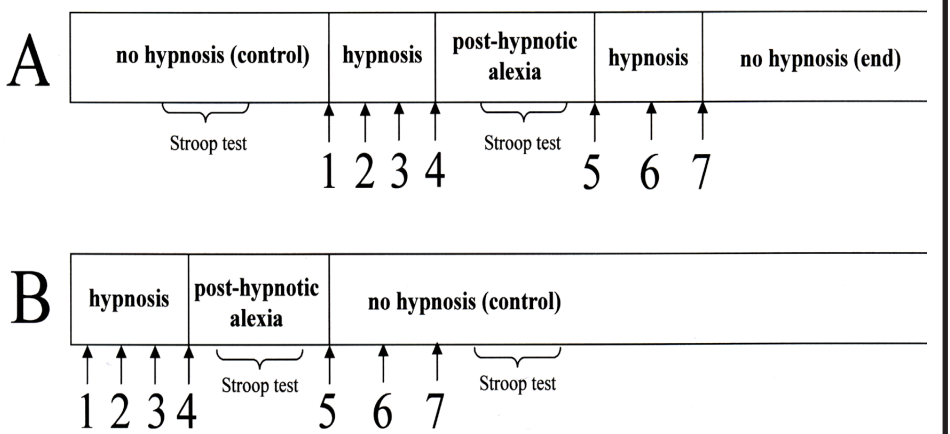
Study procedure

The study was performed according to the procedure summarized in Figure 1. Participants were randomly assigned to protocol A or B, receiving first the Stroop test in waking condition (control) and then in hypnosis, or vice versa. The variables to be recorded were RT after visual stimulus as a measure of the Stroop effect, total arteriolar resistance as a measure of the stressor effect of the test, and electroencephalographically-detected ERP.

The Stroop test was performed in a semi-darkened room. The participant were seated in front of a 15-inch VGA color screen placed at a distance of 87 cm from their nose. The screen was connected to a personal computer able to manage the order of presentation of stimuli and to record the RT and the accuracy of answers (software E-PRIME, Psychological Software Tools, Princeton, USA).

Each stimulus consisted of a single word-color (red, green, yellow or blue) written in one of the four colors (red, green, yellow or blue), appearing on the center of the screen. The color of words was congruent (word = color) or incongruent (word ≠ color). Participants were instructed to keep glancing at a cross in the middle of the screen during the whole experiment. Words were shown on a black background with a visual field of 6 degrees on horizontal axis. Each session started with a training block of 23 trials.

Figure 1: Study design. Participants were randomly allocated to protocol A or B. The Stroop test was performed both in normal conditions (control) and in post-hypnotic command of alexia. 1: hypnotic induction leading to neutral hypnosis; 2: suggestion of alexia; 3: suggestion of the post-ipnotic command of alexia; 4: de-hypnotization leading to post-hypnotic alexia; 5: hypnotic induction; 6: post-hypnotic alexia removed; 7) final de-hypnotization and end of study.



Each participant underwent two sessions of 7 blocks: one in basal conditions (without any hypnotic suggestions) and one in post-hypnotic conditioning of alexia. The order of the two sessions was balanced between participants. Each block consisted of 72 trials (47 congruent and 25 incongruent). The task consisted in promptly pressing one of 4 buttons associated to the 4 colored stimuli. Answers were acquired through a response box (Psychological Software Tools, Princeton, USA).

Suggestion of post-hypnotic alexia

After inducing hypnosis, alexia was suggested. The following suggestion was administered: "I want you to become unable to read. When you try to read, you will see meaningless symbols. They will seem like characters of a foreign language that you do not know, and you will not attempt to attribute any meaning to them. As a matter of fact, you are unable to attribute any meaning to them, and you will be unable until I give you a different order. You will be unable to read also after I de-hypnotize you by counting from 3 to 1." After this suggestion was administered, the participant was de-hypnotized. The protocol was performed in conditions of post-hypnotic rather than of hypnotic alexia, in order to have an experimental setting more similar to that performed in basal conditions. Immediately after de-hypnotization and before starting the Stroop test, each participant was asked to read a brief text. All participants referred to feel unable to read, therefore showing that alexia had really been reached at a subjective level.

At the end of the session, any participant was induced once more to deep hypnosis, then the post-hypnotic command of alexia was removed and the participant was definitively de-hypnotized through a brief enumeration from 3 to 1, and debriefed. Before sending the participant away, he was checked for his/her ability to read.

EEG recording and ERP analysis

EEG was digitalized with a 0.05-20 Hz feed through band and recorded by means of a pre-wired 19-electrode cuff (10/20 international system) (Jasper, 1958). Recording was performed using the System Plus software coupled to a 31-channel BQ132S head. Ocular movement artifact were monitored with two electrodes placed 1 cm to the left and 1 cm below the left rima palpebralis. During recording, all the electrodes referred to a further one placed on the nose. Analysis of ERP was made by extracting off line between 100 and 900 ms after the stimulus.

ERP were obtained in 4 conditions (congruent basal, incongruent basal, congruent suggestion and incongruent suggestion). After extracting ERP, baseline correction was made by subtracting from each post-stimulus sample of each electrode the average signal obtained in the pre-stimulus interval. Latency and amplitude of the late positive complex (LPC) by congruence and by session were then automatically obtained from parietal, central and frontal electrodes (P3, Pz, P4, C3, Cz, C4, F3, Fz and F4). The component was identified as a peak of maximum amplitude between 300 and 700 ms after the presentation of the stimulus. Wrong proofs (deflection > ±100 μ V) were automatically deleted before calculating the average values. LPC amplitude was analyzed using as between-participants factors the degree of hypnotizability (lower, higher), and within-participant factors post-hypnotic conditioning and congruence.

Localization of sources of cerebral activity

To localize the presumptive sources of cerebral electrical activity recorded on the scalp, an inverse method based on LORETA (Low-Resolution Electromagnetic Tomography) software was used (Pasqual-Marqui et al., 1999). This method is conceived to obtain a normalized minimal weighted solution aimed at minimizing the Laplace transformation by derivation of reference-free source. Localization was obtained in relation to 3D coordinates: X for activities recorded from left to right, Y for those recorded in the postero-anterior sense, and Z for those recorded from depth to surface, after correction for the normalized coordinates of a neuro-imaging anatomic atlas (Brett, Johnsrude, & Owen, 2002). Data were calculated in the frame of a grid ordered in 1,152 points localized inside a half-sphere. When compared to the dipole leads, LORETA has the advantage to detect the generators of cerebral electric activity without considering any *a priori* assumptions about the number and localization of the sources. Calculation of re-organization of all parameters was performed by a special algorithm by derivation of common mean reference.

Cardiovascular monitoring

The Stroop test as a stressor was evaluated by monitoring total peripheral resistance (TPR) before and during the test, both in basal non-hypnotic conditions and during post-hypnotic alexia. The aim was to ascertain whether the Stroop test was accompanied by a sympathetic drive discharge leading to systemic haemodynamic variations (particularly an increase in TRP), and to clarify whether or not this response, if any, was reduced during alexia.

Blood pressure was measured (in mmHg) by an automatic Omron 705 IT device (Omron Europe, Hoofddorp, The Netherlands). Pulse pressure (in mmHg) was calculated as systolic minus diastolic, and mean blood pressure (in mmHg) as diastolic + 1/3 pulse pressure. The amount of blood ejected from the left ventricle at each systole (stroke volume, in ml) and in one minute (cardiac output, in $l \times min^{-1}$) were measured with an impedance cardiograph featuring enhanced bio-impedance signal morphology analysis (PhysioFlow TM-Lab-1, Manatec Biomedical, Ebersviller, France) (Richard et al., 2001). Cardiac index (in $l \times min^{-1} \times m^{-2}$)

was calculated as usual from mean blood pressure/cardiac output ratio. These methods have been validated and largely tested by our research group in many experimental conditions (Casiglia et al., 1997, 1998, 1998a, 1999, 2000, 2006, 2007).

Electrocardiographic recordings were obtained by two arm leads and preliminarily examined in order to detect artifacts and checked for reliability. Spectral analysis was performed with sampling rate 256 Hz and filter 4-40 Hz by a dedicated software (Micromed, Mogliano, Italy) using non-parametric methods of analysis (rapid non-uniform Fourier transformation). From spectral analysis, distribution of total spectral power was obtained in ms^2 in the three components VLF (0.003-0.04 Hz), LF (0.04-0.15 Hz) and HF (0.15-0.4). The values of LF and HF components (in normalized units), the LF/HF ratio, and the average of frequency distribution were also calculated.

Statistical analysis

A priori power analysis indicated that 10 participants were sufficient to show effects, if any, avoiding β error (Pearson & Hartley, 1957). Linearity assumption was ascertained for each variable by the method of the residuals, and normality assumption by the Kolmogorov-Smirnov one-sample test. Continuous variables were expressed as mean and standard error and compared with analysis of covariance and the Bonferroni's post-hoc test. Statistics were adjusted for the covariates age, body-weight and baseline values. Experiment-wise error rate was taken into account when considering significance levels. The trend within each curve, as well as the differences between the curves, were evaluated with the analysis of covariance for repeated measures. The null hypothesis was rejected for a *p* of 0.05 or less.

Results

General results in the whole study group in basal non-hypnotic conditions

No significant difference in basal characteristics was detectable between the 6 subjects showing high and the 6 showing low hypnotizability (Table 1). A Stroop effect was observed in all participants, with mean RT significantly shorter in congruent than incongruent conditions (593 ± 72 vs. 700 ± 111 ms, $p<0.001$). The visual analysis of grand-average (Figure 2) showed a slow modulation in fronto-polar electrodes Fp1 and Fp2. The mean amplitudes of segment 500-600, 600-700, 700-800 and 800-900 were therefore detected in these leads. LORETA (Figure 3) detected bilateral differences of activation between congruent and incongruent conditions in medial prefrontal gyrus (area 8 of Brodmann, NMI X=-21, Y=21, Z=47), in the anterior cingulate gyrus (area 32, X=-10, Y=19, Z=43), in the cingulate gyrus (area 24, X=7, Y=15, Z=31) and in the posterior parietal cortex (area 7, X=-21, Y=62, Z=62).

Highly hypnotizable participants

In highly hypnotizable participants, post-hypnotic alexia reduced the Stroop effect in comparison to basal non-hypnotic conditions from 121.0 ± 62.0 to 80 ± 32 ms (-34%, $p<0.03$). A significant interaction between suggestion, congruence and hypnotizability was detected ($F=5.33$, $p<0.04$). LPC amplitude was greater for the congruent than for the incongruent conditions ($p < 0.03$). The side of exploration also significantly influenced the model ($p < 0.03$). The multiple interaction between session, congruence, hypnotizability and side reached values near statistical significance ($F=2.95$; $p = 0.085$).

The late fronto-parietal potential detected during incongruence increased significantly from -0.6 μV (LF -2.7-25.7) to 8.3 μV (1.2-15.3) ($p<0.02$) when post-hypnotic conditioning was active. In conditions of post-hypnotic alexia, differences of activation between congruent and incongruent conditions were detected in the left hemisphere and more in detail in medial prefrontal gyrus (area 9, X=-31, Y=33, Z=40) and in the inferior parietal cortex (area 40, X=-40, Y=-48, Z=48) (Figure 3).

Figure 2: Analysis of event-related potentials in highly hypnotizable participants. The late fronto-parietal potential (Fp1, Fp2) detected during incongruence increased significantly from -0.6 to 8.3 μV ($p < 0.01$) when post-hypnotic conditioning was active.

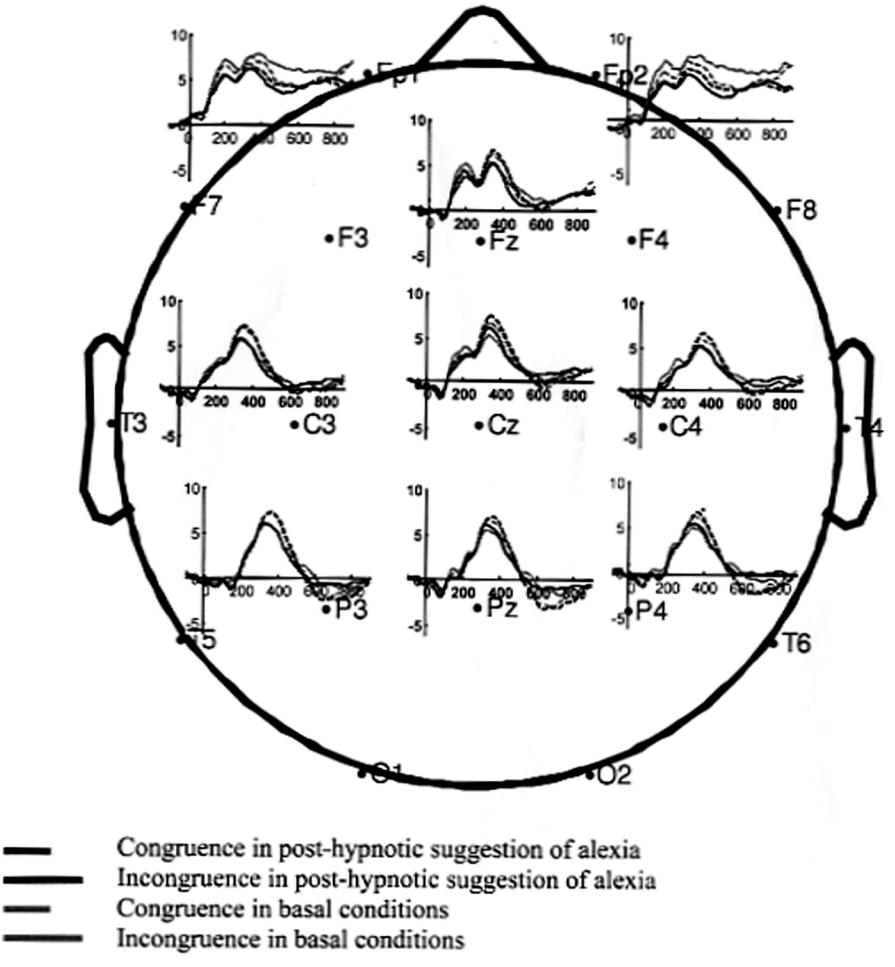
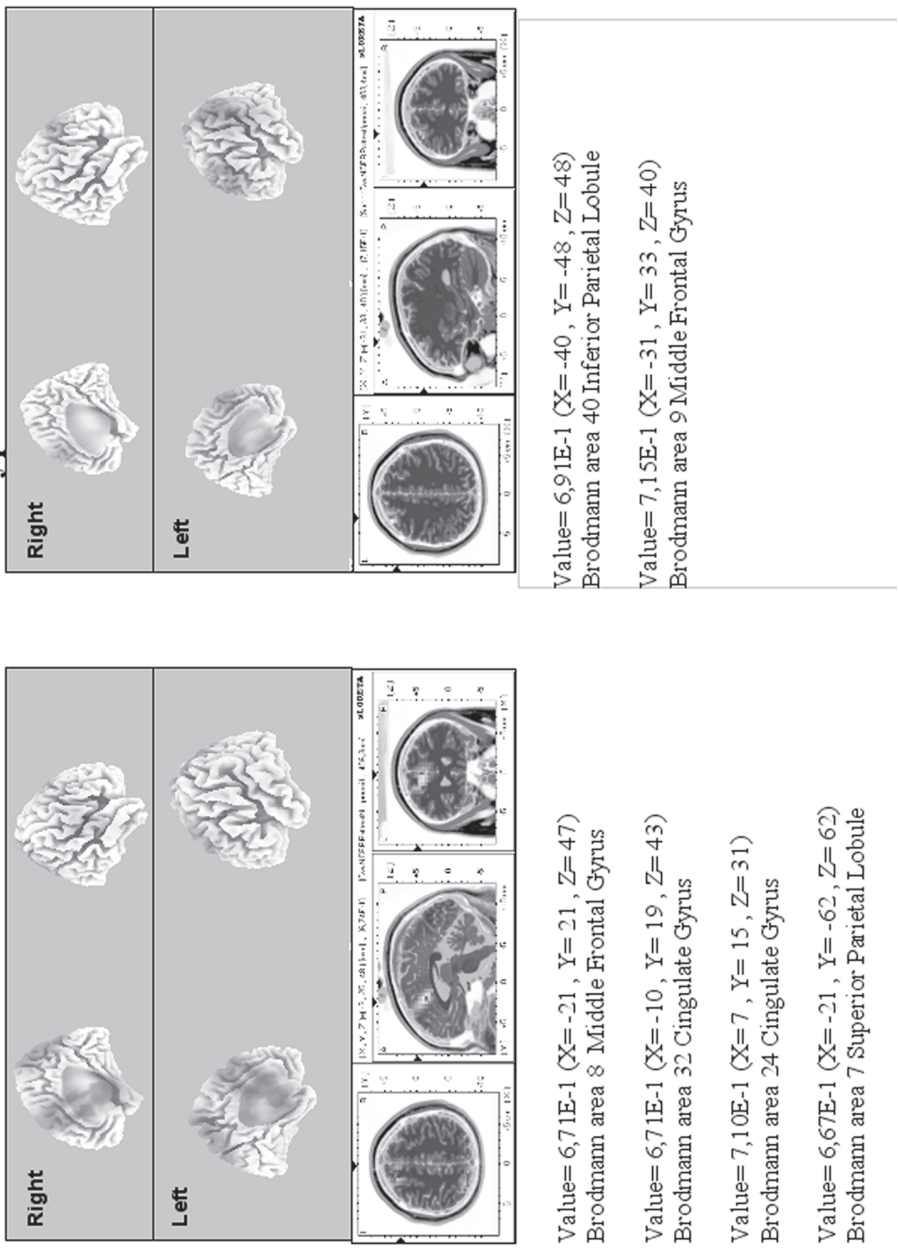


Figure 3: 3D-reconstruction of dipoles by LORETA (300-500 ms) in highly hypnotizable participants. Bilateral differences of activation between congruent and incongruent conditions are detected bilaterally in medial prefrontal gyrus, in the anterior cingulate gyrus, in the cingulate gyrus and in the posterior parietal cortex. During post-hypnotic alexia, differences of activation between congruent and incongruent conditions are particularly detected in the left hemisphere and more in detail in medial prefrontal gyrus and in the inferior parietal cortex.



In non-hypnotic conditions, the Stroop test induced a sharp increase of TPR (+21%, $p < 0.01$), a variation that was maintained along the entire test (Figure 4). In post-hypnotic phase with alexia, on the contrary, no variation of TPR was observed. Spectral analysis of RR interval did not show any variation in relation to post-hypnotic conditioning, to hypnotizability or to session (Table 2).

Figure 4: Variations of total peripheral resistance (TRP) during the Stroop test. In basal conditions TPR increases (systemic vasoconstriction) as a consequence of the stressor effect of the Stroop test, an effect that is absent during post-hypnotic alexia. Between-curves difference is significant ($p<0.05$) from minute 2 to 12.

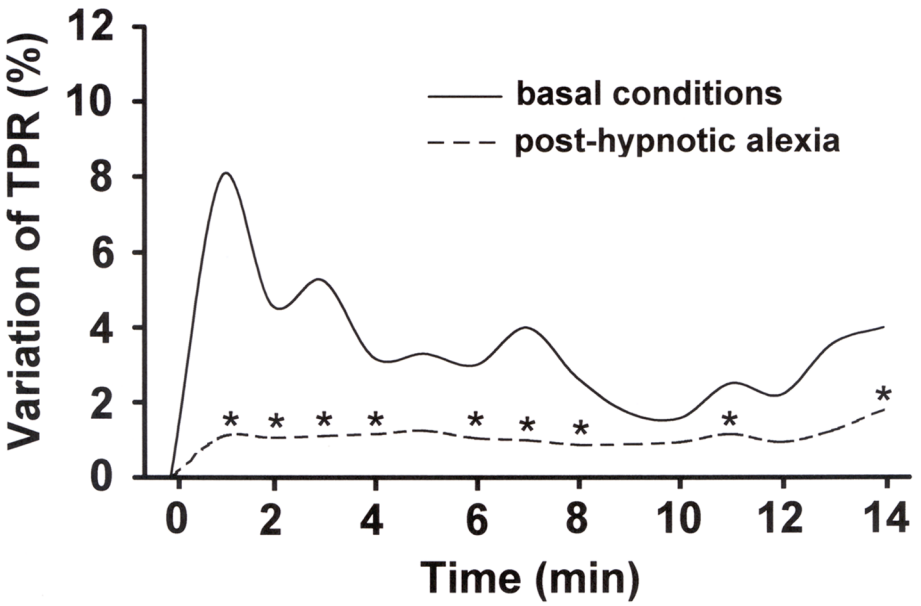


Table 2: Spectral analysis of RR interval. LF: low frequency, HF: high frequency. No significant difference detectable.

	Low hypnotizability		High hypnotizability	
	Basal	Post-hypnotic Alexia	Basal	Post-hypnotic Alexia
LF(ms2)	8.2 ± 8.6	9.8 ± 13.8	13.6 ± 20.7	11.6 ± 20.5
HF(ms2)	14.7 ± 20.7	19.7 ± 33.8	25.6 ± 37.4	23.9 ± 40.2
LF/HF ratio	1.2 ± 0.7	0.8 ± 0.2	0.7 ± 0.3	0.8 ± 0.1

Participants showing low hypnotizability

In participants with low hypnotizability, no reduction of Stroop effect due to color-word incongruence was detected during post-hypnotic alexia, the late fronto-parietal potential detected during incongruence was unchanged in comparison to basal non-hypnotic conditions, and post-hypnotic suggestion of alexia did not modify the haemodynamic response to test.

Discussion

The Stroop test as an experimental model

The cognitive processes can be automatic or controlled. Some are automatic from birth, others become automatic with practice and exercise (Spelke, Hirst, & Neisser, 1976). When automated, these processes are activated in a non-voluntary way and cannot be easily interrupted. Words are processed automatically (MacLeod, 1991; Neely, 1991). The Stroop interference (Stroop, 1935) (i.e. the difference between RT to congruent and incongruent stimuli) is considered the gold standard for evaluating the automatic performance associated with reading words (MacLeod, 1992). The basic principle postulated by Stroop in 1935 is that reading words interferes with word color. This interference is characterized by reduced reactivity and consequently by delayed identification of a word written in interfering color (incongruence) in comparison with congruence.

At a neurophysiologic level, the Stroop interference is characterized by a negative ERP component with a peak at about 410 ms generated in anterior cingulate cortex, followed by a late positive wave between 500 and 800 ms generated in left temporo-parietal cortex and in frontal areas (the sites of word interpretation) (Liotti, Woldorff, Perez, & Mayberg, 2000). A word is read more rapidly than a color is labeled: such a difference becomes critical when two potential answers compete for the access to the effector systems, generating an interference (Morton & Chambers, 1973). As a consequence, a color is recognized more slowly - and RT are longer - if a word indicating another color is presented (MacLeod, 1991; Berti, Frassinetti, & Umiltà, 1994). Nominating a color also requires a greater effort than reading, as humans are more trained to read words than to label colors: reading is therefore automatically activated, while color labeling requires a cognitive effort. The two above-mentioned mechanisms could also act sequentially: the processes of a level should be completed before those of the second level can start (Morton & Chambers, 1973).

Kirsch and Lynn (1998) have recently proposed an experimental method based on the Stroop test for confirming the Woody and Bowers theory based on dissociated control applied to hypnosis (Woody & Bowers, 1994). This topic has been summarized in an experimental setting by Jamieson, who highlighted the role of the supervisory attentional system in producing some of the experiences occurring in hypnosis (Jamieson & Shehan, 2004; Jamieson & Woody, 2007). Connessionistic models have also been proposed to account for the Stroop effect (Cohen, Dumbar, & McClelland, 1990; Cohen, Braver, & O'Reilly, 1998).

Post-hypnotic alexia as an experimental model

The basic idea of the present study was to administer a post-hypnotic command aimed at blocking or slowing down the automatic interpretation of written language, so producing alexia (Raz, Moreno-Iniguez, Martin, & Zhu, 2006). This idea was confirmed by the observation that, in post-hypnotic conditions experienced by participants as alexia, the Stroop effect due to the word-color interference was reduced, indicating that they were really incapable of reading. The current view suggested by neuroimaging is that hypnotic

suggestions mainly act on the anterior cingulate cortex (Raz, 2004; Raz, Fan, & Posner, 2005; Kerns et al., 2004). This was confirmed in the present research by the topographic analysis performed by LORETA. In fact, in basal non-hypnotic conditions the anterior cingulate cortex was more activated when the Stroop interference was greater (i.e. in the case of incongruence), while during post-hypnotic alexia this area was comparably activated by congruent and incongruent stimuli. A greater activity was also detectable in incongruent rather than congruent conditions for medium prefrontal cortex. This area has a role in the control of conflicts between the sources of the stimuli (specifically, the color and the meaning of the color-word) (MacLeod, 1991; Egner & Hirsh, 2005). Post-hypnotic suggestion could therefore act by modulating the areas involved in the monitoring and control of interference. The different activities at the level of fronto-parietal network could be in relation to activation of attentional voluntary circuit (Corbetta & Shulman, 2002; Raz, Shapiro, Fan, & Posner, 2002).

The question of whether alexia induced by post-hypnotic suggestion is neurogically based or psychologically based remains without answer. This question exceeds the present research, and concerns all the cases in which a neurological defect is produced through hypnotic commands. The protocol of the present study does not allow us to distinguish between the two hypotheses. Nevertheless, other studies performed by our group with different experimental models (unpublished data) indicate that the psychological hypothesis is the correct one. For instance, following hypnotic suggestion, subjects experience heminegligence which can be experimentally measured and has the same clinical picture of unilateral spatial neglect (a neurological condition leaving to heminattention to a side of word, usually deriving from a lesion in the right hemisphere). Although pathological and hypnotic neglects have comparable phenomenology, the former appears at the left side only, while the latter can be induced at right or left side indiscriminately, supporting its psychological rather than neurological origin. Furthermore, paralysis can be hypnotically induced at a side of the body; although this experimental condition has a phenomenology comparable to that accompanying stroke, deep reflexes are normal, indicating once more its psychological rather than neurological origin. Further studies involving neuroimaging are mandatory to clarify this point.

Haemodynamic measurements

In the present study, the Stroop test also acted as a stressor and induced reflex systemic vasoconstriction, as demonstrated by TPR increase. This response was similar to that observed by our research group with other stressors (Casiglia et al., 1997, 1998,1998a, 1999, 2000, 2006, 2007).

In the protocol described here, when post-hypnotic alexia was suggested, Stroop-induced vasoconstriction was lower in highly hypnotizable participants, while no effect was found in those showing low hypnotizability. We can therefore argue that post-hypnotic alexia was just at the basis of the reduced cardiovascular reaction to the stressor. It is our belief that the reduced sympathetic response to the Stroop test observed in post-hypnotic conditions was due the fact that subjects were incapable of reading. This constitutes a further demonstration that alexia was really induced by hypnotic suggestions. In previous studies it has been demonstrated that hypnotic suggestions can act on the cardiovascular system, preventing the cardiovascular response to stress (Raz, 2004), inducing segmental and systemic vasodilation (Casiglia et al., 1997), and inhibiting the cardiovascular response to cold through distraction from attention and focused analgesia (Casiglia et al., 2007). The heretofor described reduction of the sympathetic reflex response to a mental relative is a new piece in this puzzle.

Conclusion

In conclusion, post-hypnotic alexia appears to be a real and measurable phenomenon, that can be demonstrated by measuring adequate instrumental parameters such as the RT and the reflex cardiovascular response during the Stroop test. The decrease in RT during incongruence in the frame of the Stroop test measures the degree of alexia in highly hypnotizable subjects. Finally, changes of activation of cerebral areas can be observed during post-hypnotic alexia. These findings in turn demonstrate that hypnosis is a real and measurable phenomenon.

Nevertheless, the study suffers from some problems. Due to the complexity of the protocol, the number of participants is limited. Furthermore, hypnotizability per se could have altered the results independent of any Stroop effect, as people who are highly hypnotizable can modulate their neural responses underlying color perception.

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