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Hypnosis meets neuropsychology: Simulating visuospatial neglect in healthy participants

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ABSTRACT

Neglect patients are not aware of stimuli in the contralesional space. We aimed to simulate neglect-like behaviour in healthy participants, by asking them to orient their visuospatial attention in two conditions: non-hypnotic suggestion and post-hypnotic suggestion. Results showed that directing visuospatial attention to one side of space caused neglect of stimuli in the opposite side of space, but only when participants were under post-hypnotic suggestion. Furthermore, directing visuospatial attention to the right side of space caused more neglect of left-sided stimuli than directing visuospatial attention to the left side of space did for right-sided stimuli. We propose that post-hypnotic suggestion can be a useful tool for (de)activating neurocognitive mechanisms underlying visuospatial awareness, a function that is fundamental for our survival. The use of post-hypnotic suggestion could be applied to the study of many domains of cognitive neurosciences (e.g., neurocognitive rehabilitation).

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1. Introduction

Our survival in complex environments would be impossible without our specific brain mechanisms subserving visuospatial attention, that is, our ability to select and to process efficiently specific locations in the environment (for review, see Umiltà, 2000). Visuospatial attention orienting can be impaired selectively, because of damage to the parietal-frontal networks (for review, see Corbetta & Shulman, 2002). One of the most dramatic manifestations of impaired visuospatial attention orienting is neglect, a neurological deficit, which affects awareness of contralesional stimuli (Bisiach & Vallar, 2000; for the relation between awareness and attention, see Mack & Rock, 1998; but see Lamme, 2003, for an alternative account). Following right-hemisphere damage, left neglect patients fail to respond, report, or orient to stimuli in the left side of space (Heilman, Watson, & Valenstein, 1979).

Neglect has been studied extensively in order for researchers to unlock the secrets of visuospatial attention and awareness (e.g., Bisiach, Luzzatti, & Perani, 1979). But how does visuospatial attention operate? Visuospatial attention can be deployed in the environment as the result of two opposing subsystems (Kinsbourne, 1993). The first subsystem is localised in the left hemisphere. This subsystem orients visuospatial attention from the left to the right side of space (i.e., a left-to-right gradient). The second subsystem is localised in the right hemisphere. This subsystem directs visuospatial attention from the right to the left side of space (i.e., a right-to-left gradient). These gradients are asymmetric. The left-hemisphere subsystem is more powerful in directing visuospatial attention rightwards than the right-hemisphere subsystem is in directing visuospatial attention leftwards (Kinsbourne, 1993). In the chronic phase (i.e., after three months from the onset of the lesion), this hemispheric asymmetry could explain the higher rate and severity of left neglect following right-hemisphere lesion with respect to right neglect after left-hemisphere lesion (Stone, Halligan, & Greenwood, 1993). In sum, neglect would not be the result of contralesional hypoattention, but the consequence of ipsilesional hyperattention (Kinsbourne, 1993).

Visuospatial attention orienting is the result of three neurocognitive processes. More precisely, visuospatial attention "disengages" from its current spatial location because of inferior parietal lobule activation, "moves" to the new spatial location because of superior culliculi activation, and finally "engages" at the new spatial location because of pulvinar activation (Posner, Cohen, & Rafal, 1982). When targets are presented in the left side of space, left neglect patients with right parietal damage are very

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slow in disengaging their visuospatial attention from the right side of space (Posner, Walker, Friedrich, & Rafal, 1987). Thus, ipsilesional hyperattention might be the result of two brain mechanisms. First, hyperactivation of the left-hemisphere subcomponent directs visuospatial attention to stimuli in the right side of space. Second, the disengagement deficit maintains visuospatial attention in the right side of space overtime (Kinsbourne, 1993; Posner et al., 1982, 1987).

Good evidence in favour of the ipsilesional hyperattention hypothesis could be obtained through the experimental induction of neglect-like behaviour in healthy participants. We hypothesised that by asking healthy participants to direct their visuospatial attention either to the right or to the left side of space, they would show neglect-like behaviour. That is, they would be less efficient in processing stimuli presented in the opposite side of space (i.e., left or right, respectively). In addition, the aforementioned hemispheric asymmetry should be expected (Kinsbourne, 1993). That is, directing visuospatial attention to the right side of space should cause more severe neglect for stimuli in the left side of space than vice versa.

Using post-hypnotic suggestion, we tested this hypothesis. It has been proposed recently that post-hypnotic suggestion can be a valuable tool for simulating and exploring neuropsychological disorders in healthy participants (Oakley & Halligan, 2009). That is, specific cognitive components can be (de)activated selectively by means of post-hypnotic suggestion, in order to improve our understanding of normal neurocognitive functions (Oakley & Halligan, 2009).

Several clinical conditions, indeed, have been simulated by means of post-hypnotic suggestion, such as blindness, amnesia, auditory hallucinations, conversion disorder paralysis, and selected delusions (for review, see Oakley, 2006; Oakley & Halligan, 2009). In the domain of attention, Raz, Fan, and Posner (2005) and Raz, Kirsch, Pollard, and Nitkin-Kaner (2006) have showed that, in highly hypnotisable participants, post-hypnotic suggestion reduces the automatic tendency to read printed words in a Stroop task, where participants have to indicate the colour of the word by pressing a key (see also Casiglia et al., 2010). Iani, Ricci, Baroni, and Rubichi (2009) have reported that the Simon effect (i.e., facilitation of lateralised responses, when they are executed in the same side of space as that of the stimulus) can be reduced following post-hypnotic suggestion, but only in highly susceptible participants.

Oakley and Halligan (2009) have proposed that post-hypnotic suggestion might be comparable to neuroscientific techniques (e.g., transcranial magnetic stimulation, TMS; for review, see Sandrini, Umiltà, & Rusconi, 2011) that can interfere selectively with the function of specific brain regions, in order for the researcher to study behavioural changes. Oakley and Halligan reported analogues of well-known neuropsychological disorders, such as prosopagnosia and hemianopia, which were induced by post-hypnotic suggestion in BW, a neurologically healthy, highly susceptible participant (see Oakley & Halligan, 2009, supplementary material online). In addition, when BW was given the following instruction: 'When you open your eyes in a moment the left half of your world will have disappeared from your awareness and you will feel no need to make any allowance for it at all (that is you will not be aware of the deficit)", he ignored the left side of visual arrays of stimuli (i.e., left visuospatial neglect).

In the present study, we elaborated more on Oakley and Halligan, 2009 pioneering observations on BW. In order to investigate further whether post-hypnotic suggestion could be used to induce visuospatial neglect in healthy participants, we designed an experiment, following the theoretical framework proposed by Kinsbourne (1993) and by Posner et al. (1982, 1987). Therefore, we asked healthy participants to direct their visuospatial attention to either visual hemifield (right vs. left), in two experimental conditions: non-hypnotic suggestion and post-hypnotic suggestion. We hypothesised that we would achieve some control over their visuospatial attention orienting, but only when participants were under post-hypnotic suggestion (see MacLeod, 2011; Raz et al., 2005). We expected that if neglect was a consequence of ipsilateral hyperattention, then by asking participants to direct their visuospatial attention to one side of space, they would neglect stimuli in the opposite side of space. Finally, we assumed that after having directed their visuospatial attention to the right side of space participants would show more severe neglect of stimuli in the left side of space than vice versa (i.e., the hemispheric asymmetry; Kinsbourne, 1993).

2. Methods

2.1. Participants

Ten healthy participants (mean age: 28 ± 3 years; 6 women) were enrolled in the study. They had been defined previously as eligible for hypnosis, on the basis of an ad-hoc questionnaire and of a personal interview. In addition, participants were administered the Minnesota Multiphasic Personality Inventory II (Cancheri & Sirigatti, 1995), because we wanted to exclude participants with borderline personality disorder, who could show unwanted effects during hypnosis (see Kroger, 2007, p. 226). We measured the level of hypnotisability of each participant, by means of the Harvard Group Scale of Hypnotic Susceptibility (De Pascalis, Russo, & Marucci, 2000). All participants were highly susceptible to hypnosis (Harvard Group Scale range: 8–12). The present study adhered to the principles of the Declaration of Helsinki and was approved by the local Ethics Committee. All participants gave their consent in order to take part in the study.

2.2. Apparatus, stimuli, and procedure

2.2.1. Preliminary study

The preliminary study took place some days before the experimental study (see below). In the preliminary study, we aimed to test directly the hypnotisability of the participants and to train them for reaching hypnosis more rapidly in the experimental study. Participants underwent hypnotic induction individually (Casiglia et al., 2006, 2010). An expert hypnotist guided each participant to focus his/her attention on a single thought. Hypnotic induction consisted of a brief enumeration coupled with suggestions to feel good, to perceive eyelid heaviness, to breath regularly and deeply, and to stare at a point (Casiglia et al., 2006, 2010). After spontaneous eyelid closure was reached, participants were invited to concentrate their attention on their own body (from head to foot), while the hypnotist induced them to reach a feeling of heaviness and muscular relaxation. The hypnotist verified whether participants were hypnotised by observing in them the presence of signals, such as arm levitation, easing of facial tension, dropping of the lower jaw accompanied by a slight opening of the mouth, and slowing of the breathing rate (Casiglia et al., 2006, 2010). The analysis of these signals enabled the hypnotist to verify that the participants were really hypnotised and to maintain or modify their level of hypnosis, by means of continuous, appropriate suggestions. At the end of the preliminary session, participants were non hypnotised.

2.2.2. Experimental study

The experimental study took place in a sound-attenuated and dimly lit room. Participants sat at a distance of 87 cm in front of a 17 in. computer screen. Each participant positioned his/her head in an adjustable head-and-chin rest. Stimuli were white and were displayed against a black background. Each trial (Fig. 1) started with the presentation of a fixation cross (0.4° × 0.4°) in the centre of the screen. The fixation cross was displayed together with four horizontally aligned square boxes (side: 2°). Two of the boxes were placed to the right of the fixation cross (near right, far right) and the other two were placed to the left of the fixation point (near left, far left). The distance between the centre of the fixation cross and the inner side of each near box was 3°. The distance between the centre of the fixation cross and the inner side of each far box was 6° (Fig. 1). On each trial, the target (i.e., a circle measuring 0.8° in diameter) was displayed randomly for 90 ms in the centre of one of the four boxes, after a variable stimulus onset asynchrony interval (i.e., the time interval between the onset of the fixation cross/boxes and the onset of the target; range: 500–700 ms). Participants were asked to fix and to maintain their eyes on the fixation cross. They were asked to press as fast as possible the right button of the mouse each time the target appeared on the screen. The right button of the mouse was aligned with the centre of the screen. Visual feedback on reaction time (RT) was displayed for 1500 ms after response execution. The inter-trial interval was 2500 ms.

In the non-hypnotic suggestion condition, participants were asked "to pay attention to the left visual hemifield" (session 1) and then "to pay attention to the right visual hemifield" (session 2). Following session 2, participants were hypnotised and they received the suggestion "to pay attention to the left visual hemifield", once non hypnotised. Participants were, then, non hypnotised and performed session 3 under post-hypnotic suggestion. Afterwards, participants were hypnotised again, the previous suggestion was removed, and they were asked "to pay attention to the right

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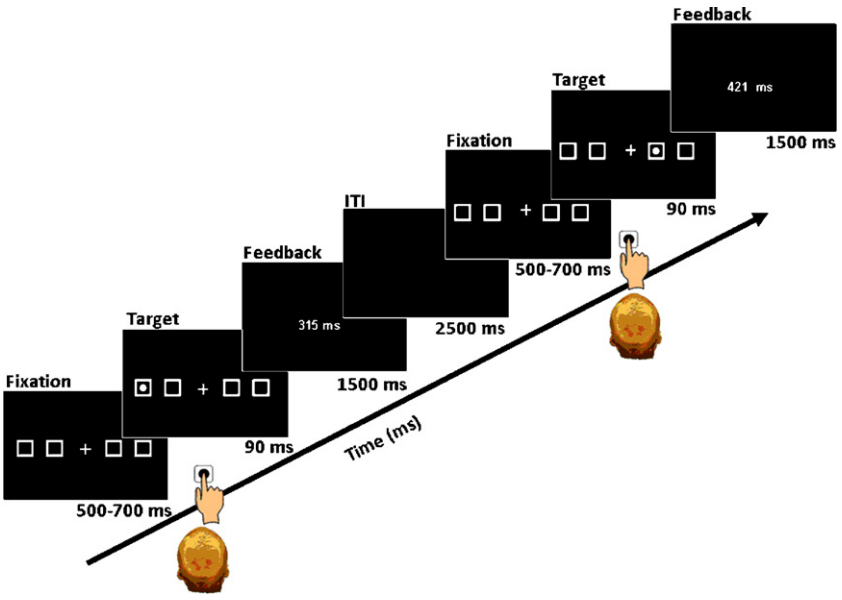


Fig. 1. Example of two trials. Participants had to keep their gaze in the centre of the screen and to respond as fast as possible, by pressing a key, when a target appeared in one of the four boxes. On half of the trials, participants were asked to direct their visuospatial attention to the right visual hemifield. On the other half of the trials, they were asked to direct their visuospatial attention to the left visual hemifield. ITI = inter-trial interval.

visual hemifield", once non hypnotised. Then, participants were non hypnotised and performed session 4 under post-hypnotic suggestion. Following session 4, each participant was induced once more to deep hypnosis. Posthypnotic-induced amnesia was delivered to remove from the participants' memory both the last suggestion and the recollection of the experiment (Casiglia et al., 2006, 2010). Finally, participants were non hypnotised through a brief enumeration from 3 to 1, and they were debriefed. Note that the same instructions were given to the participants both in the non-hypnotic suggestion condition and in the post-hypnotic suggestion condition.

The order of conditions (i.e., non-hypnotic suggestion condition vs. post-hypnotic suggestion condition) and the order of sessions within each condition (i.e., "pay attention to the right hemifield" vs. "pay attention to the left hemifield") were counterbalanced across participants. Each session started with a practice block of 24 trials, which was followed by an experimental block of 120 trials (i.e., 30 trials for each of the four target positions: far left, near left, near right, far right).

3. Results

To exclude outliers, median RTs were calculated for each participant and each condition. A three-way analysis of variance for repeated measures was performed on the means of the median RTs. The independent variables were suggestion (non-hypnotic vs. post-hypnotic), visuospatial attention orienting (left vs. right visual hemifield), and target position (far-left, near-left, near-right, far-right; Fig. 2).

The main effects were not significant. By contrast, the three-way interaction of mental status, visuospatial attention orienting, and target position was significant, $F(3, 27) = 6.4$, $p = 0.002$, $\eta_p^2 = 0.41$. This interaction revealed that directing visuospatial attention to the right visual hemifield caused left neglect, whereas directing visuospatial attention to the left hemifield caused right neglect (Fig. 2). For the post-hypnotic suggestion condition, planned contrasts revealed that the difference (mean: 145 ms) between RTs to targets in the far left position (i.e., directing visuospatial attention to the right visual hemifield minus directing visuospatial attention to the left visual hemifield) was larger than the difference (mean: 79 ms) between RTs to targets in the far right position (i.e., directing visuospatial attention to the left visual hemifield minus directing visuospatial attention to the right visual hemifield), $t(9) = 3.03$, $p = 0.014$, $r = 0.7$, two-tailed. We performed the same contrast, as that described above, on the difference in RTs to targets in the near-left position. This contrast was not significant, $t(9) = 1.7$, $p = 0.12$, two-tailed. Taken together, these two contrasts revealed that visuospatial attention orienting affected more the processing of targets in the far-left spatial position than the processing of targets in the near-left spatial position. This result suggested that participants allocated their visuospatial attention along a gradient (Kinsbourne, 1993).

For the non-hypnotic suggestion condition, we performed the same planned contrasts as those for the post-hypnotic suggestion condition. There were no significant differences (all $ps > 0.05$, two-tailed). This result suggested that post-hypnotic suggestion was a necessary condition, in order to obtain some control over visuospatial attention (MacLeod, 2011; Raz et al., 2005).

4. Discussion

We asked healthy participants to direct their visuospatial attention either to the left or to the right visual hemifield, and to react as fast as possible to lateralised targets. Visuospatial attention orienting was manipulated in two conditions: the non-hypnotic suggestion condition and the post-hypnotic suggestion condition. Results showed that when participants directed their visuospatial attention to one visual hemifield (right vs. left), they were slower in processing contralateral stimuli. This occurred, however, only when participants were under post-hypnotic suggestion. Furthermore, the predicted asymmetry (Kinsbourne, 1993) was also observed. Indeed, directing visuospatial attention to the right visual hemifield resulted in slower RTs for stimuli presented in the left hemifield than directing visuospatial attention to the left visual hemifield did for stimuli presented in the right hemifield. This phenomenon has been reported many times in studies on left neglect patients (e.g., Posner et al., 1987).

In sum, we used post-hypnotic suggestion to induce neglect-like behaviour in healthy participants (see also supplementary data in Oakley & Halligan, 2009) in an experiment that was designed following the theoretical framework of the pioneering studies of Kinsbourne (1993) and Posner et al. (1982, 1987). We suggest that left visuospatial neglect might be attributed to ipsilesional hyperattention, because of asymmetric allocation of visuospatial attention to the right side of space (Kinsbourne, 1993). Our findings are in agreement with those of studies that have suggested that neglect of the left side of space after right-hemisphere damage is

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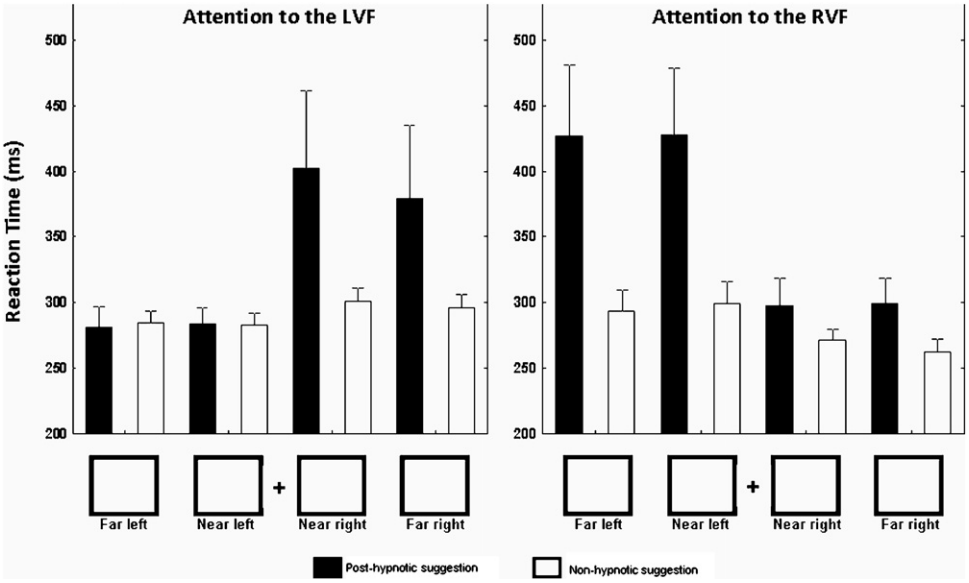


Fig. 2. LVF = left visual hemifield; RVF = right visual hemifield. Error bars represent 1 SEM.

more frequent, severe, and disabling than neglect of the right side of space after left-hemisphere damage (Stone et al., 1993).

It is important, however, that our pilot behavioural study be replicated using a brain imaging technique (e.g., functional magnetic resonance imaging, magnetoencephalography, etc.). Indeed, the specific brain mechanisms that are activated or deactivated during post-hypnotic suggestion for inducing visuospatial neglect might be investigated by means of modern functional neuroimaging techniques (Oakley & Halligan, 2009). The use of these techniques might shed light to the neural implementation of post-hypnotic suggestions and to their effects, compared to those of non-hypnotic suggestions, on the functions of the brain. Although it has been shown in "virtual" patients that post-hypnotic suggestion might induce patterns of neural activation similar to those observed in real patients, one must be careful not to conflate post-hypnotically induced symptoms with their underlying neurocognitive processes (Oakley & Halligan, 2009). Thus, to investigate the similarities and differences between non-hypnotic and post-hypnotic suggestions, functional neuroimaging data might be of crucial importance.

Post-hypnotic suggestion can be used as a promising tool for (de)activating specific neurocognitive mechanisms. A complex neurocognitive function (e.g., visuospatial attention orienting), instead of an isolated brain area (e.g., the inferior parietal lobule), can be modified, activated, or even suppressed by means of post-hypnotic suggestion. Thus, post-hypnotic suggestions might interfere with the overall performance of healthy participants, who might behave as if they were "virtual patients" (Oakley & Halligan, 2009). The use of post-hypnotic suggestion could open new horizons, not only to our understanding of the neurocognitive mechanisms underlying visuospatial attention, but also to the cognitive rehabilitation of neglect and of other neuropsychological disorders (Singh-Curry & Husain, 2010). Neglect, indeed, is the most "negative" single predictor of functional outcome in stroke patients (Buxbaum et al., 2004). Consequently, neglect can cause increased financial costs of the clinical management of the patients. Thus, neglect rehabilitation is an important financial and clinical issue, given that approximately 50% of patients affected by right-hemisphere stroke would show left neglect (Farnè et al., 2004). Under post-hypnotic suggestion, for example, left neglect patients might be required to direct their visuospatial attention to the left side of space, in order to counterbalance their rightward spatial bias.

We suggest that post-hypnotic suggestion can be a valuable, non-invasive technique for testing hypotheses regarding the brain mechanisms underlying various cognitive functions (Oakley & Halligan, 2009).

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