Psychiatry Research: Neuroimaging 231 (2015) 151–159

Contents lists available at ScienceDirect

Psychiatry Research: Neuroimaging

journal homepage: www.elsevier.com/locate/psychresns

Structural and functional correlates of hypnotic depth and suggestibility

William Jonathan McGeown [a,*], Giuliana Mazzoni [b,1], Manila Vannucci [c], Annalena Venneri [d,e,1]

[a] School of Psychological Sciences and Health, University of Strathclyde, Glasgow, UK
[b] Department of Psychology, University of Hull, Hull, UK
[c] Department of Neuroscience, Psychology, Drug Research and Child Health – Section of Psychology, University of Florence, Florence, Italy
[d] Department of Neuroscience, University of Sheffield, Sheffield, UK
[e] IRCCS Fondazione Ospedale S. Camillo, Venice, Italy

ARTICLE INFO

Article history:
Received 19 June 2013
Received in revised form
11 September 2014
Accepted 25 November 2014
Available online 6 December 2014

Keywords:
Hypnosis
Susceptibility
Voxel-based morphometry
Grey matter
White matter
Functional connectivity

ABSTRACT

This study explores whether self-reported depth of hypnosis and hypnotic suggestibility are associated with individual differences in neuroanatomy and/or levels of functional connectivity. Twenty-nine people varying in suggestibility were recruited and underwent structural, and after a hypnotic induction, functional magnetic resonance imaging at rest. We used voxel-based morphometry to assess the correlation of grey matter (GM) and white matter (WM) against the independent variables: depth of hypnosis, level of relaxation and hypnotic suggestibility. Functional networks identified with independent components analysis were regressed with the independent variables. Hypnotic depth ratings were positively correlated with GM volume in the frontal cortex and the anterior cingulate cortex (ACC). Hypnotic suggestibility was positively correlated with GM volume in the left temporal-occipital cortex. Relaxation ratings did not correlate significantly with GM volume and none of the independent variables correlated with regional WM volume measures. Self-reported deeper levels of hypnosis were associated with less connectivity within the anterior default mode network. Taken together, the results suggest that the greater GM volume in the medial frontal cortex and ACC, and lower connectivity in the DMN during hypnosis facilitate experiences of greater hypnotic depth. The patterns of results suggest that hypnotic depth and hypnotic suggestibility should not be considered synonyms.

1. Introduction

Hypnosis can be used as an adjunct treatment for pain (Montgomery et al., 2002), depression (Alladin and Alibhai, 2007), weight loss (Kirsch et al., 1995, 1996), irritable bowel syndrome (Whitehead, 2006; Wilson et al., 2006), and it can also be used to study psychological phenomena (Szechtman et al., 1998; Barnier, 2002; Egner et al., 2005; O'Connor et al., 2008). It is not effective for everyone, however, and certain individuals appear to respond favourably to hypnosis and hypnotic suggestions while others are unaffected (Kirsch and Braffman, 2001).

Some studies suggest that hypnosis enables participants to respond successfully to certain task suggestions such as those aimed at altering cognition or perception (Faymonville et al., 2000; Kosslyn et al., 2000; Raz et al., 2002; Raz, 2005). Others suggest that successful performance predominantly relies on abilities/skills already possessed by the participants, which can be accessed with or without hypnosis (Raz et al., 2006; Raz, 2007; Raz et al., 2007; McGeown et al., 2012). Indeed, the difference between the number of suggestions that high suggestible participants respond to with or without hypnosis is small (Braffman and Kirsch, 1999; Kirsch and Braffman, 2001) and abilities thought possible only following a hypnotic suggestion can be achieved without hypnosis (e.g. colour hallucination (Mazzoni et al., 2009), Stroop effect reduction (Raz et al., 2006; Raz, 2007)). Low suggestible people on the other hand do not seem to be capable of demonstrating these abilities whether a hypnotic induction is attempted or not. Such findings suggest that, regardless of whether hypnosis is induced, highly suggestible people differ from low suggestible people on certain behavioural capabilities. In this study we investigate whether individual variations in brain structure or function exist that might explain differences in response to hypnotic suggestions and/or self-reported depth of hypnosis.

1.1. Structural neuroimaging

To our knowledge only two published studies have reported neuroanatomical differences between high and low suggestible

* Correspondence to: School of Psychological Sciences and Health, University of Strathclyde, 40 George Street G1 1QE Glasgow, UK. Tel.: +44 141 548 4477.
E-mail address: william.mcgeown@strath.ac.uk (W.J. McGeown).
[1] Joint Senior Authorship.

http://dx.doi.org/10.1016/j.pscychresns.2014.11.015
0925-4927/

people [2]. Horton et al. (2004), using a region of interest approach which focused on volumetric corpus callosum measurements only, provided evidence that high suggestible (who could eliminate pain) compared to low suggestible people, had a larger rostrum. They suggested that this characteristic might facilitate transfer of information providing benefit for attention, monitoring and inhibitory abilities. An alternative and potentially more informative approach is to use voxel-based morphometry (VBM), which does not restrict analyses to a priori regions of interest only or use manual measurements (it is an automated whole-brain technique). VBM was used by Hoeft et al. (2012) and in the current study. Hoeft et al. found no volumetric differences between high and low suggestible participants applying their principal statistical threshold (combined height threshold $p < 0.01$, extent threshold $p < 0.01$ FWE corrected), but when adopting a less conservative threshold (uncorrected height threshold of $p < 0.001$), between group differences were detected in parietal, temporal and cerebellar regions. The direction of the differences was not specified, nor was whether the regional differences occurred in grey or white matter specifically.

We sought to extend this literature, and using VBM, examined whether self-reported levels of depth of hypnosis and differences in hypnotic suggestibility were associated with regional volumetric variations in grey and white matter.

Given evidence of superior executive function on certain tasks in high suggestible people with (Raz et al., 2002, 2005) and without hypnosis (Raz et al., 2006; Raz, 2007), the role of the ACC and prefrontal cortex in attentional and executive function (e.g. Pardo et al., 1990; Botvinick et al., 1999; MacDonald et al., 2000; Milham et al., 2001; Lutcke and Frahm, 2008), and the accounts of activity modulation within these brain regions in previous functional neuroimaging studies of hypnosis (Maquet et al., 1999; Rainville et al., 1999, 2002), we expected that the volume of the ACC and the PFC might be larger in participants with greater self-reported depth of hypnosis or that are more responsive to hypnotic suggestions. This was based on the assumption that larger regional brain volume indicates greater capacity for function, as suggested by training (Draganski et al., 2004, 2006;) and cross-sectional studies (Maguire et al., 2000) outside of the hypnosis literature. Since hypnosis and certain forms of meditation appear to share features, such as absorption and the disengagement of attention from distracting stimuli (Holroyd, 2003; Cardeña, 2005; Lutz et al., 2008; Demertzi et al., 2011) and given that structural neuroimaging studies of meditation have shown volumetric adaptations within the cingulate (Grant et al., 2010; Holzel et al., 2011) and insular cortex (Lazar et al., 2005; Holzel et al., 2008; Luders et al., 2012), these brain structures might also be linked to hypnotic response. Visual cortical areas may be additional candidates for close investigation, given evidence of higher levels of activity in these regions during hypnosis (Maquet et al., 1999; Rainville et al., 1999) and reports of spontaneous imagery during hypnosis (e.g. Maquet et al., 1999; Cardeña, 2005).

1.2. Functional neuroimaging

Intrinsically connected networks (ICNs), identified through fMRI analysis include, but are not restricted to, the default mode network (DMN; Raichle et al., 2001; Greicius et al., 2003), the Salience Network (Critchley et al., 2004; Critchley, 2005; Seeley et al., 2007) and the Executive Control Network (Seeley et al., 2007). Hypnosis has been found to alter brain activity and connectivity within these networks (McGeown et al., 2009; Demertzi et al., 2011; Deeley et al., 2012).

Using independent components analysis (ICA), Hoeft et al. (2012) found that high suggestible compared to low suggestible people, in the absence of a hypnotic induction, had greater connectivity between the dorsal ACC and the dorsolateral prefrontal cortex (DLPFC). The authors suggested that the increased connectivity may reflect an extension of the salience network, and that this may underlie hypnotizability. Demertzi et al. (2011) alternatively, compared a number of ICNs following a hypnotic induction with a mental imagery condition, in participants who in a preceding hypnosis session reported high levels of absorption and dissociation. Modulation was detected within the DMN (increases in the medial prefrontal cortex and angular gyrus bilaterally, and decreases in the left parahippocampal gyrus and posterior cingulate). Decreased connectivity was also reported in the 'extrinsic system' (which processes sensory information and overlaps with the bilateral executive control network) and interpreted as a reflection of dissociation from the environment.

Using a block design rather than a data-driven approach, McGeown et al. (2009) reported decreased activity within the DMN in high suggestible participants during rest after a hypnotic induction. These changes fitted with the proposed hypothesis (Oakley, 2008; Oakley and Halligan, 2009) that DMN activity may be altered in hypnosis. Deeley et al. (2012) also showed decreased activity during hypnosis within the DMN (along with increases within bilateral regions of the frontal cortex) in medium to high suggestible people, during passive visual stimulation. In the hypnosis condition and presumably in correspondence with the neural changes, participants reported more absorption and relaxation, and less distractibility, analytical thought and cluttering of the mind.

In the current study we used ICA to examine whether reports of varying depths of hypnosis are associated with variation in connectivity within ICNs. In line with previous neuroimaging research (McGeown et al., 2009; Deeley et al., 2012), we expected that deeper levels of hypnosis would be associated with lower levels of functional connectivity within the DMN.

We also predicted alterations in the salience and executive networks, given descriptions of attentional focus and absorption in hypnosis (e.g. Demertzi et al., 2011; Deeley et al., 2012), evidence from PET studies showing activity modulation within the ACC during hypnosis (Rainville et al., 2002), findings of decreased connectivity in the 'extrinsic system' during hypnosis (Demertzi et al., 2011), and the findings of Hoeft et al. (2012) who observed differences in connectivity within these networks in high and low suggestible people (in the absence of hypnosis). Specifically, we anticipated that lateral cortical connectivity would decrease with greater depths of hypnosis, in correspondence with a reduction in processing of the external environment as suggested by Demertzi et al. (2011), and that connectivity in the dorsal ACC would increase, due to increased levels of absorption and inhibition of information processing of the external environment, as suggested by Deeley et al. (2012). Finally, given reports of spontaneous mental imagery in hypnosis, and accompanying activation in the visual cortex (Maquet et al., 1999; Rainville et al., 1999) we also expected connectivity to increase within visual (medial/ventral) networks.

2. Method

2.1. Participants

One hundred and fifty-six non-psychology university students were screened for hypnotic suggestibility with Comey and Kirsch's (1999) modification of the Carleton University Responsiveness to Suggestion Scale (CURSS; Spanos et al., 1983). The scale ranges from 0–7, and consists of ideomotor suggestions, motor

[2] Note the recent publication of an additional article:
Huber, A., Lui, F., Duzzi, D., Pagnoni, G., Porro, C. A., 2014. Structural and functional cerebral correlates of hypnotic suggestibility. PLoS One 9 (3), e93187. http://dx.doi.org/10.1371/journal.pone.0093187.