

The Role of Frontal Executive Functions in Hypnosis and Hypnotic Suggestibility

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Frontal Executive Functions in Hypnosis and Hypnotic Suggestibility

Abstract

There is both theoretical and empirical evidence supporting a role for frontal executive functions (FEFs) in hypnosis and hypnotic suggestibility. However, the precise nature of this involvement is debated. Whilst there is clear evidence that FEFs are impaired under hypnosis, the cause of this decreased function is unclear. Theories make differing predictions as to the role of FEFs in hypnotic suggestibility, with some arguing that decreased baseline (normal function outside of the hypnotic context) FEFs lead to greater hypnotic suggestibility and others arguing that increased baseline FEFs lead to greater hypnotic suggestibility. Other theories posit that suggestibility is more a consequence of attitude rather than aptitude. The present work provides a critical review of the involvement of frontal executive functions in hypnosis and hypnotic suggestibility. The review considers behavioural evidence from studies employing putative frontal lobe tasks including tests of fluid intelligence, and both task- and non-task based neuroimaging evidence. It is concluded that the evidence to date is inconclusive and that more work is needed to establish a necessary and sufficient role for FEFs in hypnosis or hypnotic suggestibility. Recommendations are made for future research.

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Hypnosis is usually achieved following an interaction in which one person, the hypnotist, induces another individual into a different mental state or set. Tellegen (1981) described the hypnotic induction as leading to a more experiential (i.e., effortless/involuntary) mental set, as opposed to an instrumental (i.e., effortful/volitional) mental set. By concentrating on the hypnotist's voice following induction some individuals can produce a form of control over their thoughts and actions not usually possible via more self-directed, effortful approaches (with the exception of self-hypnosis, but this might be essentially the ability to re-experience hetero(or other)-hypnosis). Under the influence of hypnotic suggestion (or post-hypnotic suggestion which is a suggestion given under hypnosis but activated post-hypnosis) the experience of pain (Derbyshire, Whalley, Stenger, & Oakley, 2004; Tan et al., 2015), colour (Kosslyn, Thompson, Costantini-Ferrando, Alpert, & Spiegel, 2000), cognitive conflict (Raz, Shapiro, Fan, & Posner, 2002), and delusions (Rahmanovic, Barnier, Cox, Langdon, & Coltheart, 2011) can be produced or extinguished (see Oakley & Halligan, 2009, for a review).

Given that successful hypnotic induction appears to require focussing on the hypnotist's voice (Crawford & Gruzelier, 1992; Oakley & Halligan, 2013), and that suggestibility appears to be a result of giving control over to the person giving the suggestion, it is unsurprising that the executive functions of the frontal cortex have been theoretically linked to hypnotic suggestibility. The PFC is the portion of the frontal lobes most associated with executive control (Miller & Cohen, 2001) and for present purposes will be defined as the area anterior to the primary motor cortices. Whilst executive functions are also subserved by other cortical regions, historically much of the research linking hypnosis or hypnotic suggestibility to executive functions has referred to frontal executive functions, and with good reason. The connectivity and therefore potential influence of prefrontal cortex over other cortical regions and itself, make it the likely prime mover in behavioural and thought

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control (Miller & Cohen, 2001). The present paper will use the all-encompassing term Frontal Executive Functions (FEFs) to refer to the executive control functions of the prefrontal cortex (PFC), or will refer to the PFC directly and as a metonym for the same executive functions. Whilst this review will consider the contribution of FEFs to hypnosis and hypnotic suggestibility, it is important to note that there is work showing that suggestibility is related to more than the contributions of these functions (e.g. Evans, 1991; Santarcangelo, 2014).

The aim of the present work is to provide a critical review of the involvement of frontal executive functions in hypnosis and hypnotic suggestibility. Whilst the author has attempted to be comprehensive in the coverage of the relevant literature, inevitably relevant studies will have been overlooked, but it is hoped that enough of the key studies are described such that, at the very least, key evidence is presented for the key issues. This review is presented in three main sections. The first, shorter section, considers theories linking the PFC to suggestion more generally and also to hypnosis more specifically. The second section considers the involvement of FEFs in hypnosis and the processes of the hypnotic induction. The third section considers the contribution of FEFs to individual differences in hypnotic suggestibility.

The prefrontal cortex and suggestion

Given that hypnosis involves suggestion, it represents a potential case study of the wider concept of suggestion (Halligan & Oakley, 2014), and therefore for the involvement of the executive functions of the PFC in suggestion in general. For example, it has been argued that hypnosis is placebo without deception (Kirsch, 1994; Raz, 2007) and can therefore be used to understand and study placebo effects. Indeed, by taking other forms of suggestion into account, a strong case can be made for PFC involvement in hypnotic suggestibility. Benedetti

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(2009) has argued that without the PFC there would be no placebo effects. Damasio (1994) described how patients with damage to the prefrontal cortex are more vulnerable to “snake-oil” salesmen and disreputable characters. Asp et al. (2012) investigated belief and doubt in patients with damage to ventromedial prefrontal cortex. They presented PFC patients, patients with damage outside of the PFC and healthy controls, with misleading advertising. Their results showed that patients with vmPFC damage were more likely to believe in misleading advertisements even when their misleading nature was corrected with a disclaimer clearly visible on the ad.

Asp et al.’s research was based on the False Tagging Theory of Asp and Tranel (2013) the fundamental premise of which is that we initially, even if only for the briefest of moments, believe everything we hear. It takes the PFC to “false tag” a statement so that it is not believed; a theory with potential implications for hypnotic suggestibility. A damaged or underactive PFC would lead to greater belief in presented statements. Asp and Tranel (2013) point out that the prefrontal cortex is the last region of the brain to mature and as such is underdeveloped in comparison to other brain regions during childhood. An underdeveloped PFC leads to credulity and a tendency toward credulous belief. They note that this is likely to have a developmental and evolutionary advantage since it would mean children are likely to believe what their parents or other authority figures tell them, which is likely to keep them safe. There is good evidence to show that children are more responsive to hypnotic suggestions than adults (London & Cooper, 1969).

It is however likely that these different forms of suggestion are not strongly related. Research suggests that measures of placebo suggestibility do not correlate with hypnotic or imaginative suggestibility measures (Kihlstrom, 2008; see also Parris, 2016). The work by Asp and Tranel mainly concerns gullibility, a type of suggestion shown not to be related to hypnotic suggestibility (Eysenck & Furneaux, 1945). Hull (1933) distinguished between

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direct suggestions, which were experimenter-administered explicit suggestions, and indirect suggestions, where no direct suggestive statement is conveyed to the participant. Hypnotic suggestions are an example of direct suggestions, whereas as placebo suggestions and false statements inducing gullibility are examples of indirect suggestions. Thus, the PFC might only play an important role in indirect suggestions.

Frontal executive functions and theories of hypnosis

Many theories of hypnosis consider hypnosis to result in the impairment of some FEFs (Crawford & Gruzelier, 1992; Gruzelier, 2006; Jamieson & Woody, 2007; Jensen, Adachi & Hakimian, 2015; Woody & Bowers, 1994). For example, based on the Supervisory Attentional System (SAS) model (Norman & Shallice, 1986) the original Dissociated Control Theory (DCT) of hypnosis (Woody & Bowers, 1994) proposed that hypnosis disrupts the frontally-mediated SAS, leaving the participant under the guidance of contention scheduling, a process of lateral inhibition between activated neural assemblies (schemata), and therefore by schemata elicited by external cues (e.g. the hypnotist). The primary role of the SAS was to represent and maintain representations of goals to ensure behaviour coincided with those goals, a function attributed to the PFC. Under its original formulation hypnosis resulted in the disruption of all or most SAS functions. Jamieson and Woody (2007) proposed a modification of Dissociated Control Theory by suggesting that hypnotic suggestion resulted from the breakdown of particular supervisory operations. According to Jamieson and Woody, instead of the original proposal of control being ceded entirely to contention scheduling, some level of PFC guided control is still possible under hypnosis. This is consistent with the notion that participants under hypnosis still seem to evidence controlled processing and is also consistent with evidence showing increased activity in some frontal regions under hypnosis (see below). Under their view hypnosis is the result of the breakdown in functional connectivity between conflict monitoring in the Anterior Cingulate Cortex

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(ACC) and the subsequent adjustments that result from operations of the Dorso-Lateral PFC (DLPFC); a breakdown that results in reduced behavioural flexibility.

Gruzelier (2006) describes a three-stage model of hypnosis which culminates in a 'letting go' of executive functions and handing control to the hypnotist. Gruzelier and colleagues have provided evidence showing shifts in hemisphere dominance from hypnotic induction through to hypnosis. Highs but not lows start off exhibiting greater left hemisphere dominance but activity shifts to the right as the induction continues until a state of right hemisphere dominance is observed under hypnosis, thereby reducing the efficacy of left hemisphere control functions. Gruzelier & Warren (1993) proposed that frontal lobe functions become engaged through instructions of focussed attention during the hypnotic induction procedure in suggestible individuals. Following this period of focussed attention other frontal functions become inhibited under hypnosis according to their model. Gruzelier argued that the findings observed across his studies are not consistent with accounts of hypnosis and hypnotic suggestibility based on attitudinal or social factors such as expectation or task demands.

Theories that do not link hypnotic suggestibility strongly with FEFs include those proposed by Dienes & Perner (2007), Kirsch & Lynn (1997) and Spanos (1986). Spanos (1986) provided a social psychological explanation of hypnotic phenomena. Spanos regarded hypnosis as the employment of voluntary response strategies, and described a set of studies convincingly highlighting such strategies in the context of three hypnotic phenomena. Kirsch and Lynn (1997) have described responses to hypnotic suggestion as the result of a kind of generalised implementation intention where participants intend to respond to suggestions at a given time and in a given context. Since they do not know in advance what suggestions they will be asked to experience, participants cannot have specific implementation intentions; they can only intend in advance to respond according to the hypnotist's suggestions. Kirsch and

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Lynn (1997) also argued that people differ in the degree to which they expect to succeed in generating the required response to implementation intentions, and that this is a determinant of the strength of the response. Given the hypothesized importance of expectancies in the production of suggestions under this account, the authors argue there is no need to postulate differences in frontal lobe functions (Kirsch & Lynn, 1997).

Dienes and Perner (2007) proposed a theory of hypnotic responding based on Rosenthal (2002)'s higher-order thought theory. In essence, their theory states that highs are better at blocking awareness of their intentions to act according to the suggestions. Highs can block awareness of higher-order thoughts (HOTS) or higher-order intentions and thus unconsciously intend to do something (thoughts that are not accompanied by HOTS are 'cold', hence Dienes & Perner naming their theory Cold Control theory).

Whilst in each of these latter theories, the processes that lead to hypnotic responding do not strictly depend on FEFs, both Kirsch and Lynn (1997) and Dienes and Perner (2007) make reference to possible links to performance and FEFs (e.g. see Dienes & Hutton, 2013). Furthermore, maintaining a voluntary response strategy in mind as per Spanos (1986) would be expected to tax FEFs, if only minimally. Thus, these different accounts render theoretically important a consideration of the role of FEFs in hypnosis and hypnotic suggestibility.

Frontal executive functions and hypnosis

A relatively well-supported finding in the hypnosis literature is that of poorer performance on behavioural tasks that tap frontal lobe functions following hypnotic induction (Farvolden & Woody, 2004; Gruzelier & Warren, 1993; Jamieson & Sheehan, 2004; Jamieson & Woody, 2007; Sheehan, Donovan, & Macleod, 1988; Wagstaff, Cole, & Brunas-Wagstaff, 2007). Indeed, disruption of the left DLPFC using theta burst stimulation has been shown to increase hypnotic suggestibility (Dienes & Hutton, 2013) indicating a relationship between reduction

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in frontal functions and hypnotic suggestibility. A recent study provides further compelling evidence of frontal inhibition under hypnosis (Nemeth, Janacsek, Polner, & Kovacs, 2013). Nemeth et al. showed that implicit, procedural learning is improved under hypnosis. Nemeth et al. hypothesised that given the effect of hypnosis on frontal functions, and its consequent impeding effect on explicit learning mechanisms that inhibit implicit learning, hypnosis could be used to reduce frontal lobe involvement and thus increase procedural learning. And this it did. Strikingly, hypnosis improved procedural learning in the same way that theta burst stimulation of DLPFC does (Galea, Albert, Ditye, & Miall, 2010). Wagstaff et al. (2007) also present evidence of improved performance on non-frontal tasks under hypnosis. Thus, consistent with both the DCT and Gruzelier and colleagues approach, FEFs have been shown to be impaired under hypnosis, and the resultant loosening of control appears to lead to the enhancement of cognitive abilities that are subserved by more posterior regions.

Wagstaff (2004) levies a strong argument against any study attributing poorer performance under hypnosis to hypnosis itself: Anyone believing they are hypnotised will perform differently compared to when they do not think they are hypnotised; and highs are more likely to believe they are hypnotised. Maintaining the sense of being hypnotised uses resources that could otherwise be devoted to the task at hand, resulting in poorer performance. The implication is not that they are necessarily deceiving themselves or others; it is merely that it is possible that being confronted with an induction procedure results in highs creating the experience of hypnosis as they understand it. This experience creation would involve the use of resources and could lead to frontal inhibition. Wagstaff et al. (2007) point out that proponents of the frontal inhibition account of hypnosis need to establish that frontal inhibition is not simply an epiphenomenon. In contrast, Gruzelier and Warren (1993) have argued that it is precisely the deliberate engagement of frontal functions through the focussing of attention that leads to frontal inhibition. Gruzelier and colleagues' model is

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eminently testable however and also predicts better baseline or non-hypnotic frontal efficiency in highs; a topic to which I shall return. Nevertheless, there is an obvious difficulty in distinguishing these two accounts of frontally-impaired performance under hypnosis. The notion that frontal inhibition under hypnosis is a direct consequence of hypnotic induction procedures needs to be experimentally contrasted with the experience creation/epiphenomenon account.

Nemeth et al.'s finding would escape Wagstaff's criticism if it were shown that implicit procedural learning is differentially affected under dual-task conditions. Such a finding would show that the improvement in procedural learning following hypnotic induction could not be due to dual-task-like conditions created by highs when creating the experience of being hypnotised. However, Nemeth et al.'s account would also predict that dual-task conditions should lead to an improvement in procedural learning so a failure to observe an improvement under dual-task conditions would also count against their approach. Evidence shows that striatal-based procedural learning is either improved or no significant differences are observed when participants are given a demanding secondary task (Filoteo, Lauritzen, & Maddox, 2010; Foerde, Knowlton, & Poldrack, 2006; Fu & Anderson, 2008). Thus, whilst the notion that hypnosis results in executive function deficits for suggestible individuals is well-supported, it is possible that this is due to the way in which suggestible individuals actively create dual-task-like conditions.

Disconnection between Conflict Monitoring (ACC) and Conflict Control (DLPFC) processes during Stroop task performance under hypnosis

There is evidence to suggest that hypnosis modifies the relationship between sub regions of the anterior brain. One of the first findings indicating reduced functional activity in the frontal lobes following hypnotic induction came from a study by Egner, Jamieson, and

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Gruzelier (2005). Egner et al. tested the assumption that attentional control is compromised under hypnosis. They had participants undertake the Stroop task in which participants have to respond as quickly and accurately as possible to the colour of the font a word is present in whilst ignoring the meaning of the word itself. Typically colour related words that are incongruent with the colour to be named (e.g. RED in blue) interfere with colour classification. Using both EEG and fMRI Egner et al. observed greater Anterior Cingulate Cortex (ACC) activity, a midline frontal structure thought to be involved in conflict monitoring, in highly suggestible individuals under hypnosis. This conflict related neural activity was also greater under hypnosis compared to baseline. In contrast, no significant differences in DLPFC activity were observed between groups or conditions. As with all non-significant differences one must avoid interpreting the results since a non-significant result could either be evidence for no difference or merely an absence of evidence for a difference. However, in Egner et al.'s study this finding was interpreted as evidence for no difference between groups. In the context of the Stroop task DLPFC activity is thought to be related to control mechanisms that react to the signaling from the ACC about increased conflict. This reaction of the DLPFC to increased conflict was not observed in the highly suggestible individuals under hypnosis. Functional connectivity analysis in Egner et al.'s study revealed a decrease in connectivity between frontal midline (medial PFC/ACC) and lateral PFC sites under hypnosis, indicating that hypnosis leads to a functional disconnection between conflict monitoring (ACC) and cognitive control (DLPFC) processes such that, despite greater conflict being detected in the ACC, the DLPFC was not receiving the modifying signals.

Notably, Egner et al.'s results were observed in the context of a specific task (the Stroop task) and they point out that differences/no differences in activations between groups and conditions might be specifically related to the experimental conditions. For example, it is possible that no differences in dorso-lateral PFC activity between the two groups is the result

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of two opposing influences; a combination of increased activity due to increased interference, and decreased activity due to hypnosis, in highs. Wagstaff (2004) noted that such opposing findings are likely the result of an interaction between hypnosis and the task undertaken in each particular study, highlighting the difficulty of interpreting neural correlates of hypnosis during task performance. As a way around this, McGeown, Mazzoni, Venneri, & Kirsch (2009) also reported differences in lateral PFC regions in highs under hypnosis but under conditions that do not involve task performance of any kind. This study involved comparing activations in the Default Mode Network (DMN), which includes anterior medial frontal regions. They observed decreased activity in anterior regions of the DMN (including superior, middle and inferior frontal gyri and the ACC) in highs when under hypnosis compared to being at rest; no such differences were observed in lows.

Neuroimaging evidence reveals both increased and decreased frontal activity under hypnosis

Wagstaff et al. (2007) discuss a paradoxical effect in terms of the frontal inhibition hypothesis of the Dissociated Control Theory: Neuroimaging studies consistently indicate *increased* involvement of regions within the frontal cortex during hypnosis and suggestion, and particularly the left frontal cortex (Crawford, 1996; Jamieson, Dwivedi, & Gruzelier, 2005; Rainville, Carrier, Hofbauer, Bushnell, & Duncan, 1999). For example, Rainville et al. observed increased activity in the left DLPFC cortices (BA44 & BA45), and the right cingulate cortex (BA24) during hypnosis. Following hypnotic suggestion for analgesia, additional increases in activity were observed in left PFC and medial and lateral posterior parietal cortex. Imaging the Default Mode Network (DMN) under low task demand conditions (viewing visual images of a reversing checkerboard pattern) before, during and after hypnosis also revealed greater activity during hypnosis bilaterally in ventrolateral PFC (left BA47 & right BA46; Deeley et al., 2012). This activity correlated with subjective reports of absorption, depth of hypnosis and a reduction in cluttered thoughts, suggesting

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better attentional focus under suggestion. More recently, Jiang, White, Greicius, Waelde and Spiegel (2016) have reported greater resting state functional connectivity between the left and right DLPFC (seed regions, BA not reported) and ipsilateral insular cortex under hypnosis. Increased left or bilateral frontal activity and connectivity under hypnosis is inconsistent with the notion of frontal inhibition and is also inconsistent with findings showing greater right hemisphere dominance under hypnosis (cf. Gruzelier, 2006; see also Jasiukaitis, Nouriani, & Spiegel, 1996 for evidence of left hemisphere dominance under hypnosis).

In contrast to observed increases in neural activity following hypnotic induction, Rainville et al. also observed *decreases* in activity the left dorso-medial PFC under hypnosis (BA6), although this was observed at a lower statistical threshold. Deeley et al. (2012) also observed reduced (DMN) activation under hypnosis (right BA6, left BA9, & right BA32) as did McGeown et al. (2009; DLPFC (BA6-11 & 47) and (ACC (BA25 & 32))). Jiang et al. (2016) observed reduced activity in dorsal ACC and reduced connectivity between the left and right DLPFC (seed regions, BA not reported) and core DMN regions with the latter covarying inversely with intensity of hypnosis. These results indicate that the frontal lobes should not be considered an homogenous whole when determining its involvement in hypnosis and hypnotic suggestibility (see also Jamieson & Woody, 2007, for an elaboration of the notion of fractionation of function in the PFC).

A consideration of the specific loci (as per Brodmann areas) activated across these neuroimaging studies indicates an interesting pattern. Increases in neural activity under hypnosis appear to be more likely in more mid to inferior lateral PFC regions (BA44, 45, and 46) whilst decreases are more likely in mid to superior (dorsal) medial regions (BA6, 8, & 9), with most but not all of these differences being observed in the left hemisphere. There appears to be contradictory evidence as to the role of ACC (BA24, 25 & 32) and other more anterior regions (BA10 & BA47) which may represent task-related, as opposed to

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hypnosis/suggestion-related, changes. Interestingly, Dienes and Hutton (2013) targeted BA8/9 with rTMS to left DLPFC to disrupt activity in this region and reported an increase in hypnotic suggestibility, which is consistent with evidence showing that hypnotic suggestibility is related to reduced functional activity in this region. A stronger effect might be observed if one were to apply facilitatory tDCS to more superior regions of the PFC. However, one must be mindful of the fact that identifying the region responsible for this effect is not straightforward without the concomitant use of fMRI since TMS can have indirect effects through synaptic connections. Stimulation of the DLPFC results in activation of the VLPFC (Eisenegger, Treyer, Fehr, & Knoch, 2008) which has been shown to be activated by surprising and rewarding stimuli (Parris, Kuhn, Mizon, Benattayallah, & Hodgson, 2009; Parris, Thai, Benattayallah, Summers, & Hodgson, 2007; Rolls, Grabenhorst, & Parris, 2008). It has also been shown that rTMS of the DLPFC results in blood flow changes in the ACC and midbrain neurons (Speer et al., 2003) again implicating regions other than the PFC in suggestibility to hypnosis.

In summary, whilst there is good evidence that hypnosis is associated with frontal inhibition, it is unclear whether this is a special consequence of hypnosis or merely reflects suggestible participants creating the experience of being hypnotized as they understand it, leading to a dual-task like state. However, areas of the frontal lobes are heterogeneous in function and neuroimaging studies report both increases and decreases in frontal lobe function following hypnotic induction. Whilst some researchers have argued for a differential role for the cerebral hemispheres in producing the hypnotic experience (e.g. Gruzelier, 2006), an equally fruitful approach might be investigating functions associated with superior medial regions (BA6, 8, & 9) and contrasting those with functions associated with inferior lateral regions (BA44, 45, and 46) of the PFC (see also e.g. Kallio, Revonsuo, Hämäläinen, Markela, & Gruzelier, 2001; Jamieson & Woody, 2007).

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Neural correlates of post-hypnotic suggestions

Most neuroimaging studies of performance under suggestion have been studies of hypnotic, not post-hypnotic, suggestion. However, since post-hypnotic suggestions are not activated under hypnosis, studying their neural correlates could reveal brain mechanisms associated with FEFs required to produce effects of suggestions, and without the interpretative issues associated with suggestions carried out under hypnosis. Unfortunately, few studies have investigated the neural correlates of post-hypnotic suggestions, and those that have are, by their very nature, associated with task performance. For example, Raz, Fan, & Posner (2005) undertook a neuroimaging assay of a post-hypnotic suggestion using fMRI and Event Related Potentials and showed reduced activity in visual areas and in the ACC, interpreted as representing reduced visual processing and reduced conflict, respectively. The study appears to offer no insights in to the neural substrate of the control of the suggestion itself however. Similarly, Ludwig et al. (2014) have shown reduced activation in reward-related frontal regions (ventromedial PFC) following a post-hypnotic suggestion to diminish the attractiveness of unhealthy food. In both these cases the reduced neural activity in the frontal regions was directly related to the task (ACC for conflict, and vmPFC for reward) and no post-hypnotic activations/deactivations were established. In contrast, Mendelsohn, Chalamish, Solomonovich, & Dudai (2008) gave participants a post-hypnotic suggestion for amnesia for details about movies they had previously seen. Activity associated with post-hypnotic amnesia was observed in left middle frontal gyrus (BA10). As far as the author is aware this is the only evidence for activity specifically related to the control and application of a post-hypnotic suggestion but one must account for why this was not observed in the other studies mentioned and consider the possibility that the finding by Mendelsohn et al. represents task specific activity. A final consideration is that since post-hypnotic suggestions are constructed in advance of the conditions needed to activate them it is possible that the cognitive processing required to enact them is very efficient (e.g. see Parris, Dienes &

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Hodgson, 2012). This would reduce oxygenation requirements and therefore the resulting fMRI signal (Gruzelier, 2006) making it more difficult to identify the neural loci of such processes via neuroimaging. Further work is needed to identify the neural correlates of control following post-hypnotic suggestions given their potential to elucidate the contribution of FEFs to the production of suggestions.

Frontal executive functions and hypnotic suggestibility

A prediction of the Dissociated Control Theory (DCT) in both the original and more recent formulations is that individual differences in hypnotic suggestibility are driven by poorer baseline FEFs, facilitating the release of supervisory operations during hypnosis. In contrast to the DCT, Crawford & Gruzelier (1992) proposed that suggestible individuals have better cognitive flexibility/efficiency outside of hypnosis which, they argue, accounts for evidence showing weak but consistent correlations of hypnotic suggestibility with absorption, creativity, dissociation, attention and vividness of imagery.

Consistent with Gruzelier, better performance on executive function tasks have been reported in highs when tested outside of the hypnotic context (to be referred to as *baseline* performance; Braffman & Kirsch, 1999; 2001; Castellani, D' Alessandro, & Sebastiani, 2007; Crawford, Brown, & Moon, 1993; Rubichi, Ricci, Padovani, & Scaglietti, 2005; Wagstaff et al. 2007), especially with regards to cognitive flexibility (Aikins & Ray, 2001; Crawford, 1994) and sustained attention (Castellani et al., 2007; Crawford et al., 1993). Notably however, just as many studies have observed worse baseline performance by highs (Dixon & Laurence, 1992; Dixon, Brunet, & Laurence, 1990; Farvolden & Woody, 2004; Terhune, Cardeña, & Lindgren, 2011a; Varga, Németh, & Szekely, 2011) or no significant baseline performance differences between high and low suggestible individuals (Aikins & Ray, 2001; Braffman & Kirsch, 2001; Dienes et al., 2009; Jamieson & Sheehan, 2002; Jamieson &

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Sheehan, 2004; Iani, Ricci, Baroni, & Rubichi, 2009; Kallio et al., 2001; Raz et al., 2002; Varga et al., 2011). For example, in one study with a very large sample size, (n=180) Dienes et al. (2009) tested the relationship between hypnotic suggestibility and inhibition using three inhibition tasks. They report evidence for no relationship between the three inhibition tasks and suggestibility.

Wagstaff et al. (2007) reported evidence of better word fluency in highs in a study with a large sample size (n=80). However, Farvolden and Woody (2004) observed no significant baseline performance differences between groups in a word fluency task in a study with a large sample size (30 highs vs. 30 lows). Similarly, non-significant differences on word fluency tasks were reported by Kallio et al. (2001) and Aikins and Rey (2001), albeit in studies with small sample sizes.

Further support for better cognitive flexibility comes from Aikins and Ray (2001) who showed that highly suggestible individuals were better at the Wisconsin Card Sorting task than lows by performing the task with fewer trials, implying better set shifting performance and increased flexibility in highs. However, as noted above the sample size in Aikins and Rey's study was small, making it difficult to interpret their result in light of contrasting findings from studies with large sample sizes (n=116) such as that of Varga et al. (2011) who reported that those higher in suggestibility actually performed worse on a task switching task, implying reduced flexibility.

Sabourin, Cutcomb, Crawford, & Pribram (1990) reported substantially greater mean theta (4-7Hz range) power in highs compared to lows in both left and right regions of the frontal (F3, F4), central (C3, C4) and occipital (O1, O2) regions across waking, hypnosis and suggestion conditions; a difference that was particularly large in frontal regions. Greater theta power was also observed following hypnotic induction in both highs and lows. Sabourin et al.'s findings replicated those of other studies showing greater theta power in parietal and

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temporal locations (Galbraith, London, Leibovitz, Cooper & Hart, 1970; Tebecis, Provins, Farnbach & Pentony, 1975). However, they were able to show that increased theta power is also observed at frontal locations. This effect of increased theta power in frontal regions in highs at baseline was replicated by Graffin, Ray and Lundy (1995). Increased frontal-central theta is associated with greater attentional focus and improved performance supporting the notion of better attentional performance in highs at baseline, and greater attentional focus under hypnosis (Schacter, 1977). Contrastingly, Williams and Gruzelier (2001) did not observe group differences in theta power before or during hypnosis at posterior or frontal locations (see also De Pascalis & Perrone, 1996), although they did observe greater theta power after hypnosis. They interpreted theta activity as representing relaxation, not better attentional performance, which is consistent with more diffuse (all locations) increases in theta power (Schacter, 1977). Williams and Gruzelier observed group differences in alpha (8-13Hz) power before and during hypnosis suggesting that alpha, not theta power is related to hypnotic suggestibility. Contrasting with both Sabourin et al.'s and Williams and Gruzelier findings, Graffin et al.'s study reported greater theta power in lows following hypnotic induction, not highs (who showed a decrease), and observed no relationship between hypnotic suggestibility and alpha activity.

A recent paper has argued that an increase in theta power is the common change in brain oscillations associated with hypnosis and hypnotic suggestibility (Jensen, Adachi & Hakimian, 2015). Jensen et al. have proposed a theory of hypnosis and hypnotisability based on a mechanistic link between theta (and perhaps gamma) oscillations and hypnosis. They note that hippocampal-generated theta is strongly associated with declarative memory, which they argue could be central to responses to hypnotic suggestions. This then, is not a theory about FEFs and hypnosis. Whilst changes in theta power do seem to be the most consistent finding across studies, as already noted, the timing (i.e. baseline, pre-induction, post-

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induction, post-hypnosis) and location (i.e. occipital, frontal, temporal) of changes in theta power is not consistent across studies (Sabourin et al., 1990). They also hypothesize a concomitant reduction of activity in FEFs to reduce conscious control of responses. Thus Jensen et al.'s theory is dependent not only on the consistency of evidence for changes in theta power, which has been address above, but also on reliable evidence for changes in FEFs.

Another study supporting a more efficient frontolimbic system in highs, particularly in regard to sustained attention comes from Crawford, Brown and Moon (1993) who showed that highs perceived a greater number of reversals on the Necker cube task (see also Jamieson & Sheehan, 2002, for a replication of this effect). Since frontal lobe lesions result in the perception of fewer reversals perceived (L. Cohen, 1959; Teuber, 1964) their result was interpreted as highs outperforming lows. However, only in patients with unilateral frontal lesions are fewer reversals perceived. Bilateral frontal lesions actually increase the number of reversals perceived (L. Cohen, 1959; Teuber, 1964), meaning that, like enhanced theta, this measure cannot be used unambiguously as a sign of better frontal lobe function (although see below for evidence for a left hemisphere-only baseline functional connectivity difference in highs). Moreover, as Dienes and Perner (2007) noted, the finding of a greater number of perceived reversals by Crawford et al., as well as their result showing more cases of autokinetic movement observed in the same study, is difficult to interpret without knowing what subjects were trying to do. Good FEFs should confer the ability to maintain one perspective of the Necker cube for a long time if that is what the highs were trying to achieve, and conversely make the perspective change frequently if that was their aim. Finally, Jamieson and Sheehan (2002) observed no overall relationship between sustained attention and hypnotic suggestibility in a large study (n=182).

When taken together, it is difficult to draw strong conclusions in favour of any position positing a relationship between frontal attentional/executive function capacity and hypnotic

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suggestibility. However, as Jamieson & Woody (2007) have pointed out, a failure to titrate task difficulty might have resulted in the contradictory results observed thus far. Outside of the context of research on hypnosis, when investigating differences in Stroop interference in individuals with high and low working memory capacity, Kane & Engle (2003) only observed group differences under experimental conditions that made it difficult to maintain goal focus. When the experimental conditions were not challenging, no group differences were observed. This result highlights the fact that future research would benefit from comparing suggestibility groups on at least two levels of difficulty to establish the existence or not of differences on any particular task. Whilst previous studies have gone to the trouble of selecting tasks on the basis on their ability to discriminate between certain groups (e.g. Dienes et al., 2009), group differences in suggestibility might simply be more subtle than comparator clinical groups.

Much of the research alluded to above compared the performance of just highs and lows. To truly understand what factors contribute to suggestibility one needs to include a medium suggestible group. Without this group it would not be possible to ascertain whether the highs or the lows were special with regard to the efficacy of frontal lobe executive functions at baseline. There are examples of studies reporting differences between highs and lows on tasks of executive functions, but where the same tasks fail to discriminate between highs and mediums (e.g. Wagstaff et al., 2007).

A critical point to note from recent research is that individual differences have been shown to modulate the relationship between baseline frontal executive functions and suggestibility. Both the tendency for dissociative experiences (Terhune, Cardeña, & Lindgren, 2011b) and gender (e.g. Dienes et al., 2009) have been shown to modify this relationship (see also Terhune, 2015). Future research would do well to explore these and other individual differences that can be theoretically linked to hypnotic suggestibility.

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Nevertheless, the fact that the relationship between suggestibility and frontal executive functions is modulated by individual differences could be taken as evidence that poorer or better executive functions are neither necessary nor sufficient for suggestibility to arise. Such findings also indicate that titration of task difficulty is less likely to be a variable modulating this relationship.

Intelligence, the frontal lobes and hypnotic suggestibility

If the failure to titrate task difficulty were responsible for the lack of group differences on frontal executive tasks, it would be expected that a measure of frontal lobe integrity that has in-built difficulty levels might reveal such differences. Here I take intelligence as a proxy for frontal lobe integrity. Intelligence tests such as the WAIS comprise of multiple tests of increasing levels of difficulty. Traditionally it was assumed that the frontal lobes and intelligence were unrelated due to frontal lobe damage having little effect on measured intelligence (Hamlin, 1970; Teuber, 1972). However, Duncan and colleagues (Duncan, 2003; 2005; Duncan & Emslie, 1996) have shown that fluid, but not crystallised, intelligence is in fact related to frontal lobe integrity. This means that fluid intelligence measures could be used as a proxy for frontal lobe function.

The literature on the relationship between hypnotisability and intelligence appears to be generally mixed (Geiger, Peter, Prade, & Piesbergen, 2014). A number of investigators have reported positive correlations of intelligence with hypnotizability (Barry, MacKinnon, & Murray, 1931; Davis & Husband, 1931; Hull, 1933; Roach, 1947; White, 1930) but there are reports of negative (Friedlander & Sarbin, 1938; Reymert & Kohn, 1940; Roach, 1941; Shor, Orne, & O'Connell, 1966) or curvilinear (Curtis, 1943; Eysenck, 1943) correlations between these factors. For example, using Wechsler-Bellevue Intelligence Scale, Form II, Shor et al. (1966) observed a negative correlation between hypnotizability and intelligence.

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The Wechsler-Bellevue Intelligence Scale, Form II comprises both verbal (crystallised) and performance (fluid) measures of intelligence. However, Shor et al. did not report the scores on the 11 individual subtests of the WAIS, nor did they report the relationship between hypnotisability and verbal vs performance IQ.

One study that has considered the relationship between hypnotisability and varieties of intelligence is reported by Geiger et al. (2014). In common with the literature, Geiger et al. observed no overall relationship between hypnotisability and IQ. However, they divided their intelligence tests into three types: 1) Verbal (crystallised); 2) Numerical (fluid); and figural (fluid). They reported that verbal intelligence, but not measures of fluid intelligence (numerical or figural tests), correlated positively with hypnotic suggestibility; and in females only. In males there was no relationship between hypnotisability and any of these forms of intelligence despite their male and female participants being equally suggestible. This study indicates that whilst verbal intelligence might contribute to suggestibility in females, it is not a core component determining hypnotic suggestibility. Moreover, with no observed relationship between suggestibility and measures of fluid intelligence, one might conclude in support of the position that the frontal lobes do not differ in those of high and low suggestibility. In summary, in as far as one is comfortable using fluid intelligence as a proxy for frontal lobe integrity, the results from Geiger et al. support the same conclusion reached above: there is as yet no consistent evidence for a relationship between frontal executive functions and hypnotic suggestibility.

The relationship between Intelligence and performance on frontal lobes tasks

The finding of little or no relationship between hypnotisability and fluid intelligence carries more weight in light of recent findings from the frontal lobe function literature. Roca et al., (2011) have shown that many tests of executive functions that show deficits after frontal lobe

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lesions (e.g. the Wisconsin Card Sorting task), and whose performance has been attributed to specific regions of damage, are actually a result of the effect of the lesion on fluid intelligence. Once group differences in fluid intelligence were controlled, frontal patients no longer presented with deficits on these tasks. Thus, the use of such tasks in evaluating frontal contributions to hypnotic suggestibility might in fact be testing the contribution of fluid intelligence to suggestibility. Future studies should therefore be careful to select tasks whose performance is not accounted for by fluid intelligence, but is instead attributable to functions of separate and specific regions of the prefrontal cortex. Moreover, whilst hypnotic suggestibility might not be related to fluid intelligence, performance on certain frontal tasks could be, and so any differences observed between highs and lows on, for example, tests of verbal fluency, could be entirely due to differences in fluid intelligence, a fact that might explain many of the contradictory findings since most studies have not controlled for fluid intelligence across groups. At the very least, future research would do well to control for fluid intelligence when making group comparisons.

Executive function tasks that have been shown to be unrelated to fluid intelligence and putatively underpinned by relatively well-circumscribed regions of the frontal cortex such as the Go-No-go task, the Hayling task, and the Hotel task, might be the most revealing. Friedman & Miyake (2004) also provide evidence showing that not all executive tasks are related to intelligence. In their data, the executive functions of inhibition and shifting mental sets (cognitive flexibility) were not related to intelligence (neither fluid nor crystallised), whereas updating working memory was related to both fluid and crystallised intelligence. It is possible therefore that tasks that tap the former two executive functions are more likely to reveal a relationship with hypnotic suggestibility than those that tap the latter. However, as already noted, the literature is not easily interpreted as supporting the notion that inhibition tasks (e.g. Dienes et al., 2009) or cognitive flexibility (e.g. Varga et al., 2011) tasks will

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enable us to distinguish between those high and low in hypnotic suggestibility, although this might be resolved when more difficult tasks or difficult versions of tasks are employed (Farvolden & Woody, 2004), and/or individual differences are considered.

Differences in neuroanatomy and resting (baseline) functional connectivity in highs and lows

If the behavioural tests employed so far have not been sensitive enough to distinguish groups, perhaps baseline differences at the neural level could be observed. In a recent study, Cojan, Piguet, & Vuilleumier (2015) showed that, despite no behavioural differences in performance, highs showed greater activity than lows in the right inferior frontal gyrus and reduced activity in the ACC and intra parietal sulcus during Flanker task performance outside of hypnosis. Indeed, reduced ACC activity suggests a reduced experience of conflict perhaps due to greater IFG activity. This suggests that neural-level differences might provide a useful complimentary approach when investigating mechanisms responsible for hypnotic suggestibility. Cojan et al. (2015) interpreted their findings as evidence for better baseline attentional control in highs, despite the lack of differences in the behavioural data. However, given the lack of observed differences in the behavioural data, it is possible that greater IFG activity (which is related to conflict control in the Flanker task) is related to the need for a greater level of control to achieve the same level of performance as lows. Such an interpretation again highlights the potential confounds associated with establishing the neural correlates of hypnosis and/or hypnotic suggestibility under task conditions. Research reporting differences in baseline functional connectivity and/or neuroanatomical differences between highs and lows could be key.

Hoefl et al. (2012) compared the brains of high and low suggestible individuals at baseline using a number of methods. They employed resting state fMRI, voxel-based morphometry (VBM) of grey and white matter structures and diffusion tensor imaging (DTI)

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to examine white matter microstructure. They found no differences between highs and lows in terms of grey and white matter densities nor in white matter microstructure. However, they did observe greater resting state functional connectivity in highs between more lateral/inferior left DLPFC (reported as BA9, 10 & 46) and the dorsal ACC (reported as BA9 & BA32), anterior insula, amygdala, and ventral striatum, regions involved in filtering relevant somatic, autonomic, and emotional information. They interpreted this as evidence for a greater capacity for top-down control in highs.

Greater baseline functional connectivity between DLPFC and ACC might well facilitate the disconnection observed under hypnosis (Egner et al., 2005) and could be interpreted as evidence for better executive functions in suggestible individuals (Gruzelier, 2006). It is also consistent with the increased activity in these same regions observed during functional neuroimaging under hypnosis (e.g. Rainville et al., 1999).

To support the increased functional connectivity between DLPFC and ACC indicated by Hoefft et al.'s study, one might turn to a behavioural measure thought to rely on functional connectivity between the DLPFC and ACC. One such behavioural effect is the conflict adaptation or congruency sequence effect (Gratton, Coles, & Donchin, 1992). This effect refers to the finding that response times to incongruent trials that follow, in trial sequence, other incongruent trials, are shorter. This up-regulation of control following increased conflict from incongruent trials is thought to result from ACC detecting conflict resulting in increases in activity in DLPFC which temporarily increases control processes thereby affecting RTs to subsequent trials (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Greater functional connectivity at baseline, as shown by Hoefft et al.'s work should result in greater adaptation to conflict at baseline, and reduced conflict adaptation under hypnosis (as per McGeown et al., 2009). Terhune, Cardeña, & Lindgren (2011a) compared the conflict adaptation effect in highs and lows, but also compared highs that were either high or low

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dissociators (as determined by the Dissociative Experiences Scale of (Bernstein & Putnam, 1986). At baseline, the highs who were also high dissociators exhibited the expected conflict adaptation effect, but the lows and highs who were low dissociators did not, suggesting better baseline functional connectivity in the high dissociators (in line with Hoeft et al.'s findings). The adaptation effect was not observed in the high dissociators under hypnosis supporting the notion of reduced connectivity under hypnosis (supporting McGeown et al.'s, result). However, lows, and highs that were low dissociators, exhibited a greater raw conflict adaptation effect during hypnosis, which, when sticking to the neural interpretation of conflict adaptation effects above, suggests hypnosis resulted in better functional connectivity for these groups; an interpretation that is hard to accept given the above. However, there was in fact no interaction between the conflict adaptation effect and hypnosis condition for these two groups rendering difficult a confident interpretation of these results. Overall, these results indicate dissociative tendencies as an important potential mediator of increased connectivity and hypnosis-related decoupling between DLPFC and ACC. A further connotation of which is that such tendencies are not solely responsible for hypnotic ability since participants can be highs without being dissociators. However, given the potential increase in conflict adaptation under hypnosis in the lows and highs that were also low dissociators the interpretability of the findings is somewhat reduced.

A finding that challenges the generality of the Hoeft et al. work is a recent study also comparing grey matter volume and resting state activity across levels of hypnotic ability (Huber, Lui, Duzzi, Pagnoni, & Porro, 2014). In contrast to Hoeft et al., et al. (2014) observed positive and negative relationships between hypnotic suggestibility and grey matter densities. They report a positive relationship between grey matter volume in the left superior and medial frontal gyri (corresponding with the supplementary and pre-supplementary motor area; BA6 & BA8/9) and hypnotic suggestibility, corresponding to regions where decreases

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in activity were observed under hypnosis in functional imaging studies. A negative relationship with grey matter volume was also observed in left superior temporal cortex (BA41) and the insula (BA13).

Functional connectivity analysis also did not replicate Hoeft et al.'s finding. Huber et al. report a positive correlation between hypnotic suggestibility and functional connectivity between posterior neural regions (including the posterior cingulate / precuneus (BA31)) and lateral visual and left fronto-parietal networks, which includes the DLPFC. Positive correlations were also observed between the right postcentral/parietal areas (BA2 & 40) and the executive control network (ACC and paracingulate regions). Negative correlations between hypnotic suggestibility and functional connectivity were observed between the right fronto-parietal network and the right thalamus.

Huber et al. used a greater number of participants than did Hoeft et al. and included the full range of hypnotic experience, but the extreme group design employed by Hoeft et al. might permit a clearer distinction between groups (albeit without indicating which is the special group; for which a medium suggestible group is needed). Huber et al.'s study included only 4 highs and thus might not have captured the true neural substrates of high suggestibility. They also only included female participants and as previously noted, gender has been shown to modify the causal relationship between hypnotic suggestibility and executive functions (e.g. Dienes et al., 2009). Finally, Hoeft et al. used the Hypnotic Induction Profile (HIP; Spiegel & Spiegel, 1978) to assign high or low hypnotic suggestibility whereas Huber et al. used the Stanford Hypnotic Susceptibility Scale – Form A (SHSS:A; Weitzenhoffer & Hilgard, 1959). These are two very different approaches to measuring hypnotic suggestibility with the former including an eye roll test during induction, which is theorized to indicate a biologically-based capacity to enter a 'trance' state. The latter uses response counts to a variety of motor and challenge suggestions. Council (2002) has

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noted numerous studies have failed to show a relationship between the HIP and other measures of suggestibility. Orne et al. (1979) directly compared scores on the HIP and SHSS scales and observed only a moderate relationship. The differences between the two studies could therefore be entirely explained by the different measures of suggestibility. The fact that there are so many measures of hypnotic suggestibility could have contributed to the mixed findings reported in all the studies reported so far. Future research would benefit from using more than one measure when establishing groups. Indeed, a recent resting state fMRI study (Jiang et al., 2016) employed both the HIP and the Harvard Group Scale for Hypnotic Susceptibility (HGSHS:A; Shor & Orne, 1962) to establish groups. Their results show decreased functional connectivity between the left DLPFC and the left insula at rest (baseline), contrasting with the increased DLPFC connectivity (to different regions) in both Hoeft et al. and Huber et al., although Jiang et al. report that the highs who felt most hypnotized exhibited greater connectivity between left DLPFC and left insula which they interpreted as being consistent with Hoeft et al.

Clearly, with just a few studies so far, more work in this area is needed before firm conclusions can be drawn. Nevertheless, taken together the studies do point towards a role for increased DLPFC connectivity in determining hypnotic suggestibility independent of task- and belief-related factors. However, whilst greater functional connectivity between the DLPFC and ACC was observed in similar regions to those in which greater activity was observed under hypnosis in the functional imaging studies (inferior PFC in Hoeft et al.), greater grey matter density was observed in regions similar to those in which decreases in activity under hypnosis were observed in functional imaging work (superior PFC in Huber et al.). As with previous work producing contrasting findings in these groups, the lack of consistency could be due to heterogenous mechanisms behind hypnotic suggestibility (e.g.

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Terhune et al. 2011; Terhune, 2015) or to methodological differences (e.g. the use of only female participants and small number of highs in Huber et al.).

Overall, studies with implications for neural differences between highs and lows at baseline support a role for DLPFC and ACC in hypnotic suggestibility, but with some caveats. Since the studies show positive relationships between suggestibility and connectivity or density in highs (albeit inconsistently across studies), but highs do not convincingly perform better on putatively frontal tasks, they question the utility of the latter task-based approaches. Presumably, greater connectivity between the DLPFC and ACC and greater neural density in the DLPFC are best interpreted as predicting better performance on tasks involving those regions, but given the complexity and connectivity of the human brain this is by no means a necessary conclusion. However, one must not rush to trump one approach to the study of group differences with another, especially given the contradictory findings observed. The paucity and contradictory nature of the results from the baseline neural differences approaches means more work is needed before conclusions can and should be drawn.

Conclusions and Future Directions

The difficulty in distinguishing between accounts of reduced FEFs under hypnosis is something proponents of the notion that it is a special and direct result of the hypnotic induction need to address. Furthermore, the commonly observed increases in frontal activity following hypnotic induction needs to be heeded, although this latter finding does not escape the same interpretative issues associated with frontal inhibition. The contradictory nature of the findings concerning baseline behavioural performance differences on tasks presumed to index frontal lobe function is currently best interpreted as not having yet revealed a necessary or sufficient role for FEFs in hypnotic suggestibility. Neural baseline differences are

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generally supportive of better functional connectivity and denser grey matter in left frontal regions in highs, but differences in the location of increased connectivity and increased density, reports of reduced connectivity and density, and the paucity of studies of this type do not permit strong conclusions. Nevertheless, the findings are suggestive of a core involvement of the left fronto-parietal network which includes the insula and is activated in several cognition/language and in the perception-somesthesis-pain domains (Smith et al., 2009). More research is needed however before conclusions, including those favouring any theoretical perspective, can be drawn.

Future research investigating baseline or hypnosis-induced FEF differences between groups should test high, medium and low hypnotically suggestible individuals and establish groups using at least two measures of suggestibility (and consider interactions involving the measures). Consideration needs to be given to other potential between- and within-group individual differences such as in fluid intelligence, gender and tendency to dissociate. Task selection could be based on the putative region of the prefrontal cortex that underpins them. Tasks that index functions associated with left superior medial regions of the PFC (BA6, 8, & 9), where decreases in activity have been observed, might provide evidence for frontal inhibition. Tasks that index functions associated with left inferior lateral regions (BA44, 45, and 46) of the PFC where increases in activity have been observed, might provide evidence for better FEFs. Evidence for better cognitive performance might also be observed following hypnotic induction on tasks that do not involve FEFs (Nemeth et al., 2012; Wagstaff et al. 2007). However, consideration must be given to the involvement of fluid intelligence in those tasks, or alternatively groups should be matched for fluid and crystallised intelligence. Tasks employed could also be titrated to ensure levels of difficulty sufficient to identify group differences in non-clinical samples.

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Exploring baseline and hypnosis-induced differences between highs, mediums and lows using newer neuroimaging techniques such as resting-state fMRI, DTI and VBM could also prove fruitful given they permit assessments without the need for participants to engage in tasks. The application of brain stimulation techniques such as TMS and tDCS (transcranial Direct Current Stimulation) also provides a route to discovering potential causal relationships between brain regions and hypnotic suggestibility, although such approaches would be better served by combining them with fMRI to enable better localisation of causal networks.

Given the clearer role FEFs play in other types of suggestibility, it would be somewhat surprising if it were convincingly shown that FEFs were not involved in hypnosis and hypnotic suggestibility. Nevertheless, it is possible that the distinction between direct and indirect suggestions (Hull, 1933) might be underpinned by differential recruitment of FEFs.

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