

Hypnotic Suggestibility is Unaffected by a Challenging Inhibitory Task or Mental Exhaustion

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Abstract

Executive functioning is paramount to the successful exertion of inhibitory control over automatic impulses and desires. Despite disagreements in determining the exact mechanisms responsible for hypnosis, many theories involve the use of, or alterations in, frontal processing and top-down executive functioning. The present study sought to explore this relationship by examining whether a transient state of reduced inhibitory control influences susceptibility to hypnosis. Specifically, participants completed a colour naming task designed to place differing demands on inhibitory control processes before experiencing a hypnotic induction and four suggestions. Bayesian analysis indicated substantial evidence that the prior exertion of inhibitory control processes does not influence subsequent susceptibility to hypnotic suggestion. The study provides evidence that inhibitory impairment, often experienced by those with a range of disorders (such as anxiety and depression), should not affect receptiveness to hypnotic procedures.

Keywords: Self-control; hypnosis; inhibitory control; suggestibility; depletion

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Hypnosis refers to two related concepts: A putative altered state of consciousness in which an individual is receptive and attentive to suggestions (Elkins, Barabasz, Council, & Spiegel, 2015); and a way of responding to suggestions involving distortions in the sense of voluntariness and of reality (Kihlstrom, 2008; APA, 2003). Hypnotic response may be facilitated by a hypnotic state, but it need not be: the two concepts are in principle empirically distinguishable (Kirsch, 2011). Hypnosis has been linked to changes in frontal executive functioning (e.g. Egner & Raz, 2007), processes which have previously been reported to be implicated following the application of inhibitory control (see Hagger, Wood, Stiff, & Chatzisarantis, 2010, for a meta-analysis). Furthermore, hypofrontality, defined as a state of reduced blood flow to the prefrontal cortex and decreased executive functioning often associated with neurological conditions such as schizophrenia and depression (see Franzen & Ingvar, 1975), has been linked to altered states in general (Dietrich, 2003). This paper will explore whether a transient state of reduced inhibitory functioning influences hypnotic responding.

Hypnotic suggestibility is measured via responses to standard scales of hypnotic susceptibility, such as the Harvard Group Scale of Hypnotic Susceptibility (HGSHS; Shor & Orne, 1962) and the Waterloo Stanford Group Scale of Hypnotic Susceptibility (WSGC; Bowers, 1993), usually involving a hypnotic induction procedure followed by a series of suggestions. Susceptibility varies greatly with around 70-80% of the population being moderately susceptible to suggestion (referred to as 'medium' responders), 10-15% responding to few or no suggestions ('lows') and the remaining 10-15% responding to most or all suggestions ('highs'), (Woody, Barnier, & McConkey, 2005). Whilst hypnotic suggestibility is thought to be influenced by modifiable factors such as expectancy (Kirsch & Lynn, 1997), test-retest reliability of an individual's hypnotic suggestibility has been reported to remain stable over twenty-five to thirty years (Piccione, Hilgard, & Zimbardo, 1989).

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The best theoretical account of hypnosis remains unresolved. Whilst some suggest that hypnosis stems from an altered state of consciousness (e.g. Bowers, 1992; Hilgard, 1977; Woody & Bowers, 1994), often referred to as ‘state-theories’, others maintain that hypnosis requires no special state (e.g. Spanos & Coe, 1992; Spanos, 1986).

Dissociation state models of hypnosis, such as the Neo-dissociation (Hilgard, 1977) and dissociated control (Bowers, 1992; Woody & Bowers, 1994) theories, regard hypnotic responding as based on a state of separation of normal cognitive control systems. The Neo-dissociation theory holds that hypnotic phenomenon come about through a dissociation of high level executive control systems, resulting in distorted motor control, perception, and memory (Hilgard, 1977). Specifically, it is proposed that hypnotic inductions split the central executive functioning into different streams. One stream continues to function normally but due to an amnesic barrier is not consciously accessible, meaning that the hypnotised individual is aware of the resulting action but not of the process eliciting it.

The dissociated control theory (Bowers, 1992; Woody & Bowers, 1994) explains hypnotic responding as a state of dissociation between the supervisory attentional system and the contention scheduling system. As these systems cease to work together efficiently it results in diminished frontal supervisory attentional control. This dissociation between high level control systems results in a reliance on automatic, low-level, control system processing and thus the feeling of involuntariness which accompanies hypnosis. If hypnosis is due to dissociation, then levels of hypnotic responding should plausibly, positively correlate with dissociative experiences. Research has provided evidence for a relationship between dissociative tendencies and hypnotic suggestibility, demonstrating that for highly suggestible individuals, dissociative tendencies alter the influence of hypnosis on cognitive control (Terhune, Cardeña, & Lindgren, 2011). However, research to date has been inconclusive with evidence both of (Kirsch & Council, 1992; Nadon, Hoyt, Register, & Kihlstrom, 1991;

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Terhune, Cardeña, Lindgren, Terhune, & Carden, 2011) and a lack of (Butler & Bryant, 1997; Dienes et al., 2009) a relationship between everyday dissociative experiences and hypnotic responding.

Alternative non-state models of hypnosis include Spanos' (1986) socio-cognitive theory which takes the social-psychological perspective that participants' views of hypnosis will affect the degree to which they respond. That is, rather than holding dissociative processes at the forefront of hypnosis, the socio-cognitive approach explains responding in terms of misattributions of experience, and as stemming from strategically responding to demand characteristics and schematic knowledge of what is expected to happen during the hypnotic experience (Spanos & Coe, 1992). For example, a positive hallucination (perceiving something that is not there) could be produced by imagining the stimulus and misattributing the act to hypnosis rather than oneself; a negative hallucination (not perceiving something that is there) could be produced by deliberately ignoring the stimulus without realising one is doing so. Support for the socio-cognitive approach comes from studies reporting that individuals' motivation, expectancy, and beliefs predict their hypnotic suggestibility (Kirsch & Lynn, 1997; Spanos, Brett, Menary, & Cross, 1987). According to Kirsch's (1985) response expectancy version of this theory, the single mediating variable is expectancy, which directly causes the hypnotic response (just as expectancy can directly cause pain relief in the placebo response).

The cold control theory (Dienes & Perner, 2007) draws on both the socio-cognitive and dissociation approaches to explain hypnotic responding. According to cold control theory, the distinctive nature of hypnotic responding is entirely metacognitive: A strategic failure to develop a higher order thought (HOT) that one is intending. That is, there is a lack of awareness of the intention to act and consequently, the act is experienced as involuntary. See Norman, Scott, Price, and Dienes (2016), for a demonstration of similar strategic control

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in the absence of conscious awareness. From this perspective, both Spanos' (1986) non-state and Hilgard's (1977) state theories can be regarded as variants of cold control, because in each case there is an intention to act the subject is not aware of. Conversely, the state dissociated control theory of Woody and Bowers (1994) is not a cold control theory, because hypnotic response is regarded as occurring without executive intentions; and similarly, for Kirsch's (1985) non-state response expectancy theory: Expectancies, not intentions, cause responses.

Despite disagreements surrounding the mechanisms underlying hypnotic responding, many theories involve the use of, or alterations in, frontal processing and top-down cognitive control. Hilgard's (1977) and Spanos' (1986) theories require hypnotic suggestions be carried out by executive functions; thus, disruptions to executive processes should impair hypnotic response. Conversely, the dissociated control theory of Woody and Bowers (1994) likens the hypnotic state to a "functional prefrontal lobotomy" whereby disruptions to executive function should enhance hypnotic response. As Kirsch's (1985) response expectancy theory holds expectancy as the sole factor underlying hypnotic responding, it should not obviously predict any change in hypnotic response resulting from disruption to frontal function (cf. Buhle, Stevens, Friedman, & Wager, 2012, for independence of placebo effects from distraction). However, expectancy itself has been related to executive function (see Schjoedt, Stødkilde-jørgensen, Geertz, Lund, & Roepstorff, 2011), thus any disruption to frontal function could impair expectancy and hypnotic response. According to the cold control theory of Dienes and Perner (2007), if disruptions to frontal function impair the ability for accurate metacognition, hypnotic response should be facilitated. That is, if it is harder to form accurate higher order thoughts of intending, it will be easier to have inaccurate higher order thoughts when required for hypnosis. However, if frontal function is disrupted without affecting metacognition, then hypnotic response will be unaffected unless there is a

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diminished capacity to carry out the behavioral or cognitive act required (e.g. impaired imagining, or ignoring a stimulus in the case of positive or negative hallucinations) in which case hypnotic response will be impaired.

There are clinical reasons for postulating a relation between executive function and hypnotic response. Executive functioning is paramount to successful self-regulation, and in exhibiting inhibitory control over automatic impulses and desires. Hypnosis is applied as a valuable tool used to control undesirable behaviours such as in the cessation of smoking (Elkins, Marcus, Bates, Rajab, & Cook, 2006; Green & Lynn, 2000, 2017). Neuroimaging research has provided support for postulating a relation of hypnotic response to frontal function by pinpointing structures involved in top-down regulation (Gazzaley & D'esposito, 2007; Miller & Cohen, 2001) which are consistently implicated in hypnotic responding, such as the frontal and parietal cortices and the anterior cingulate (Cojan et al., 2009; Dienes & Hutton, 2013; Huber, Lui, Duzzi, Pagnoni, & Porro, 2014; McGeown, Mazzoni, Venneri, & Kirsch, 2009). Dienes and Hutton (2013) applied repetitive TMS to the dorsolateral prefrontal cortex (DLPFC), many functions of which such as, logic, willed action, and memory are particularly affected by hypnosis (Dietrich, 2003), and reported that disrupting the DLPFC increased hypnotic responding (cf. Coltheart et al., 2018). Similarly, Semmens-wheeler, Dienes, and Duka (2013) found that alcohol intoxication facilitated hypnotic response.

On the other hand (consistent with Hilgard, 1977, and Spanos, 1986), there is evidence to suggest that cognitive demands created by a secondary task can hamper hypnotic responding (Kirsch, Burgess, & Braffman, 1999). Kirsch et al. (1999) report that cognitive load from an additional task compromised the subjective experience of suggestions such as feelings of rigidity during the rigid arm suggestion. Furthermore, non-hypnotic tasks appear to interfere with responses to posthypnotic suggestions even when the necessary responses do

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not conflict (e.g. Tobis & Kihlstrom, 2010). Secondary tasks may impair hypnotic responding because hypnotic response requires executive performance of the required actions, such as control of attention. Nonetheless, the results contrast with the interventions above that facilitate hypnotic response.

In terms of the effect of hypnotic induction on executive function tasks, studies have shown impaired performance (exhibited by longer reaction times) on a colour-naming Stroop task following hypnotic induction, in comparison to non-hypnotised controls (Jamieson & Sheehan, 2004; Sheehan, Donovan, & MacLeod, 1988). Jamieson and Sheehan (2004) suggest that this difference in reaction times on the Stroop task is not due to the response selection process itself being altered under hypnotic induction, but rather the efficiency (or speed) of such processes. Thus, there is some evidence that hypnotic inductions impair executive ability. One explanation for this might be the requirement of executive control processes in order to maintain the altered state itself. However, Jamieson and Sheehan explain such impairments by proposing a modification to dissociative control theory centered around the IDLPFC (left dorsolateral prefrontal cortex). Under normal conditions, the IDLPFC would implement control over the feedback monitoring processes of the ACC (anterior cingulate cortex). Jamieson and Sheehan suggest that impaired stroop performance during hypnosis is due to a dissociation between the executive control functioning of the IDLPFC and the feedback monitoring processes of the ACC (anterior cingulate cortex), leading to impaired responses on executive function tasks such as the Stroop.

In terms the relationship between hypnotic response and executive ability, Dienes et al. (2009) found little correlation between hypnotic suggestibility and performance on inhibitory attention tasks; and despite initial promising findings reviewed by Crawford, Brown, and Moon (1993), later Varga, Németh, and Szekely (2011), and Jamieson and Sheehan (2002), failed to find correlations between various attentional tasks and

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hypnotisability. Further, Martin, Sackur, and Dienes (2017) showed that one task (perspective switching), previously argued to show differences in attentional abilities between high and low hypnotizable subjects, is sensitive to demand characteristics and motivation differences between high and low hypnotizable subjects. In sum, despite the effects of interventions influencing hypnotic response, individual differences in executive ability seems unrelated to hypnotisability (see Parris, 2017).

One way to reconcile these findings is to postulate that executive resources are needed for the normal behavioural and cognitive acts involved in hypnotic response: Imagination, attentional control, or appropriate action control. These acts do not lose the resources needed for their completion just because they are hypnotic (Dienes & Perner, 2007). Thus, major attention demanding secondary tasks interfere with hypnotic response. Yet special attentional abilities are not needed to perform these everyday acts: hence the lack of correlation of attentional tasks with hypnotisability. On the other hand, if sufficient resources are available to perform the motor or cognitive act, impairing metacognition will enhance hypnotic response (Dienes, 2012). Thus, rTMS to areas shown to be relevant to metacognition, such as the DLPFC (Dienes & Hutton, 2013) and alcohol which prominently affects the DLPFC (Semmens-wheeler et al., 2013) may be especially likely to facilitate hypnotic response. Testing this theoretical resolution requires interventions that impair executive function without harming metacognition.

One potential intervention which meets both of these requirements involves inhibitory tasks commonly employed in the self-control literature. An extensive body of research has previously claimed that applying control on an initial task has a negative impact on an individuals' subsequent ability to control impulses, urges and behaviours (cf. Dang, 2017; Hagger et al., 2010, with Carter & McCullough, 2014). Such research has reported increased risk taking (Fischer et al., 2012), over-eating (Hofmann, Rauch, & Gawronski, 2007; Vohs &

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Heatherton, 2000), and heightened aggression (DeWall, Baumeister, Stillman, & Gailliot, 2007) following a prior task requiring high levels of self-control, such as the colour naming Stroop task. Similarly, Wheeler, Briñol, and Hermann (2007), found that the prior use of inhibitory control decreased subsequent resistance to persuasion. Popular models designed to explain such findings hold that the inability to control behaviours following previous attempts at control stem from either diminishing resources needed to exert self-control (the resource model; Baumeister, Bratslavsky, Muraven, & Tice, 1998), a change in motivation shifting attention away from the need for control and toward rewards (the process model; Muraven & Slessareva, 2003), or from the reallocation of computational mechanisms to a more beneficial task (the opportunity cost model; Kurzban, Duckworth, Kable, & Myers, 2013). The overarching principle of self-control research is that providing the task is mentally exhausting, then subsequent exertion of self-control will be implicated. When the cognitive capacity for control is unavailable, behaviour is instead driven by bottom up processing, impulses, and implicit response tendencies (Bertrams et al., 2015; Hofmann et al., 2007). An issue is ensuring a given task is demanding enough: While one task designed to tax self-control failed to impair subsequent self-control in a large-scale replication (Hagger et al., 2016), a pre-registered study using the Stroop task found subsequent self-control impairments (Dang et al., 2017). The latter study used rated fatigue as an outcome-neutral check on the effectiveness of the Stroop task.

The question arises as to what effect taxing inhibitory control would have in hypnotic response; and it is interesting to consider what the various theories of hypnosis would predict. The state dissociated control theory of Woody and Bowers (1994), which compares hypnotic responding to a prefrontal lobotomy, would predict an increase in hypnotic response following a taxing inhibitory task as this disruption to executive function will facilitate hypnosis. Conversely, Hilgard's (1977) and Spanos' (1986) theories require executive

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functioning to perform hypnotic suggestions. Thus, if inhibitory control tasks temporarily impair executive ability, then Hilgard's and Spanos' theories would predict a decrease in subsequent susceptibility following a taxing inhibitory task. Kirsch's (1985) theory views expectancy as the sole predictor of hypnotic response and thus would predict either no effect of inhibitory control tasks on subsequent susceptibility or an impaired hypnotic response if expectancies rely on successful executive function (see Schjoedt et al., 2011). The predictions of cold control theory (Dienes, 2012; Dienes & Perner, 2007) depend on the effect of inhibitory challenge on metacognition. Previous research has linked metacognition and the IDLPFC (see Dienes & Hutton, 2013) suggesting that implicating the IDLPFC disrupts metacognition and increases hypnotic suggestibility. The Stroop task employed here as the inhibitory manipulation has also been linked to the IDLPFC (see Macleod & Macdonald, 2000; Vanderhasselt, De Raedt, & Baeken, 2009). However, the left DLPFC is a large area and previous research (Gurney, Lagos, Manning, & Scott 2017) has showed that the inhibitory challenge used here (the Stroop) did not affect subjective thresholds in a subliminal perception task¹; thus, the formation of accurate higher-order thoughts was not affected. As such, cold control theory predicts that inhibitory challenge would have no effect on hypnotic response unless there is an impairment in the capacity to carry out the cognitive or behavioural act required for the suggestions, in which case responding would be impaired.

Here we tested whether a prior inhibitory challenge would change suggestibility to a set of standard hypnotic suggestions. Specifically, we manipulated inhibitory control processes via the completion of either an easy or difficult version of the colour classification Stroop task (cf. Dang et al., 2017). Our outcome neutral test was rated mental exhaustion (cf. Dang et al., 2017). We then examined participants' responsiveness to a hypnotic induction

¹ Whilst this is not reported in Gurney et al. (2017), the results show substantial evidence of no difference in subjective thresholds between the difficult and easy inhibitory task conditions, ($M_{diff} = 6.96$, $SE_{diff} = 5.56$), $t(116) = -1.25$, $p = .213$, $d_z = 0.23$, $B_{N(0, 50.10)} = 0.24$ RR[39.37,100]. Note. here the Bayes was modelled as a normal distribution from 0 to halfway between the control mean and the bottom of the scale.

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procedure and four standard suggestions including 'magnetic hands', 'rigid arm', and a taste and negative colour illusion. Adopting the stance of the cold control theory, we predicted that prior inhibitory control would not affect hypnotic response or would impair it only if the processes required for responses were similarly impaired (i.e. impaired motor response required for magnetic hands suggestion).

Experiment 1

Method

Participants

60 participants (45 female, 15 male) aged 18 to 44 years ($M = 20.70$, $SD = 3.57$) were recruited from the University of Sussex Hypnosis Database and paid £5 for participation. Participants had previously been screened using the Waterloo Stanford Group Scale of Hypnotic suggestibility (Form C, Bowers, 1993) and had been rated as 'medium responders' (between 5 to 8 out of 12) for hypnotic suggestibility. Participants were randomly assigned in equal proportions to one of two experimental task type conditions: difficult versus easy inhibitory challenge. All participants were naive to the experimental hypothesis. The experiment was considered low risk and received ethical approval from the University of Sussex School of Psychology ethics committee. All participants read an information sheet and signed a consent form before the experiment began. At the end of the experiment participants were fully debriefed as to the nature of the experimental aims.

Materials

The experiment was implemented in Matlab and run Pavilion DM4 computer with a 15" 60Hz monitor.

A standardised hypnotic induction and four hypnotic suggestions were presented to participants via headphones. The four suggestions included "magnetic hands", "rigid arm", a

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taste hallucination and a negative colour hallucination. The complete set of materials for both experiments, including the scripts for the hypnotic induction and four suggestions, and the corresponding data has been made publicly available on the Open Science Framework (OSF) and can be retrieved from <http://osf.io/xa9p8>.

Mood ratings were captured using a Visual Analogue Scale (VAS) for the emotions: happy, sad, anxious, mentally exhausted, aroused and angry, e.g. “At this precise moment how HAPPY do you *feel*?” with ratings provided on a scale from ‘not at all’ (1) to ‘extremely’ (10). The mood ratings for the emotions happy, sad, anxious, aroused and angry were included in order to ensure that the experimental manipulation itself (inhibitory control task; easy vs. difficult) did not unduly alter mood and thus mood did not confound the results. For this reason, mood ratings were taken at the outset of the experiment and immediately after the inhibitory control task in order to check there was no evidence of a between groups difference. In line with previous research (e.g. Dang, 2017; Vohs et al., 2011) the mood rating for exhaustion was included as the manipulation check in order to measure whether the inhibitory control task was experienced as more mentally exhausting. Here, if the inhibitory control manipulation was successful, we would expect to find substantial evidence that those in the difficult inhibitory control task were more mentally exhausted than those in the easy condition.

In order to measure how susceptible participants expected they would be, a rating of expectation was captured for each participant using a VAS, e.g. “how strongly do you think you will respond to the hypnotic suggestions?” with ratings provided on a scale from ‘not at all’ (1) to ‘very much’ (10). This score is referred to as ‘expectancy ratings’ in the results section.

Additional VAS were also employed as a measure of self-reported hypnotic experience following each suggestion. Questions for these VAS included "To what extent

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did your hands move together?", "To what extent did you find it difficult to bend your arm?", and "To what extent did you experience a taste in your mouth?" rated from "Not at all" to "Very much" and lastly, "What proportion of the block pattern did you perceive as being grey?" rated from "None at all" to "The entire pattern".

Two versions of the colour-naming Stroop task, previously shown to be among the stronger manipulations in ego-depletion studies (Hagger et al., 2010), were used as the inhibitory-control manipulation, see Procedure section.

The Self-Control Scale (SCS; Tangney, Baumeister, & Boone, 2004), was included as a measure of self-reported trait self-control. The Dissociative Experiences Scale (DES; Bernstein & Putnam, 1986), was included as a self-report measure of dissociative experiences. This was included in order to examine the relationship between dissociation and hypnotic responding in the context of a hypnosis study. Lastly, the Five Facet Mindfulness Questionnaire (FFMQ; Baer, Smith, Hopkins, & Toney, 2006), was used as a self-report measure of five facets of mindfulness including, observing, describing, acting with awareness, non-judging, and non-reactivity. This was included to examine any relationship between mindfulness and hypnotic suggestibility as previous research has reported a negative correlation between mindfulness and hypnotic response (Lush, Naish, & Dienes 2016).

Three further questions were included as a debrief in order to ensure that participants were naïve to the experimental hypothesis. These included "What do you think the experiment was trying to test?", "What do you think was the purpose of the colour classification task?", and "How do you think being mentally exhausted would affect your hypnotic suggestibility?".

Design

The experiment adopted a between subjects design with one independent variable: Inhibitory control manipulation (easy vs. difficult). The primary dependent variable was the

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hypnotic experience ratings taken after each hypnotic suggestion. VAS ratings of mood and mental exhaustion were used as outcome neutral manipulation checks (with changes in mental exhaustion but not mood desired); expectation, and personality measures (SCS, FFMQ, DES) were also captured for correlational analyses.

Procedure

The experiment was conducted in a quiet room with the experimenter available throughout. Instructions were presented on screen and clarification was provided by the experimenter if required. The experiment began with a sound check allowing participants to set a comfortable volume for the audio instructions. Participants then provided demographic information (e.g. age and gender) before instructions for the inhibitory control manipulation were provided.

Inhibitory control manipulation. Participants completed one of two versions of the colour naming Stroop task (easy vs. difficult). Those in the difficult inhibitory challenge condition completed a four-colour version requiring high levels of inhibition of responses to suppress the automatic tendency to read the word in order to report the colour of the text that it is written in (either Red, Green, Blue or Yellow). For example, 'red' written in blue must be classified as blue and not red. Participants were asked to be as accurate as possible. Trials began with a 300ms fixation cross before the colour word was presented for 1000ms in 'Arial' font size 50. Participants classified the text colour using keys 1-4. Failure to respond within 1 second or to correctly classify the colour resulted in a middle C pitch error tone. There were 240 trials in total with every 8 trials containing 2 trials of each colour word in a randomised order. Each set of 8 trials also contained 6 congruent trials (colour name and text colour match) and 2 incongruent trials (colour name and text colour did not match).

Those in the easy condition completed a two-colour version of the colour classification task, requiring lower levels of inhibitory responses, in which the colour of the

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text and the word presented were always congruent (i.e. 'red' written in red) and were only either red or green. Participants were again asked to keep errors to a minimum. Responses were made using keys 1-2. Each trial began the same way as the four-colour Stroop task but they were asked to classify the text colour as either Red or Green using keys '1' or '2' respectively. The duration of the task was fixed to match the duration of the inhibitory condition, irrespective of the number of trials completed.

Mood ratings. Following the inhibitory manipulation, a set of mood ratings were captured using the on-screen VAS for the emotions: happy, sad, anxious, aroused, angry, and exhausted e.g. "At this precise moment how happy do you feel?" with ratings provided on a scale from 'not at all' (0) to 'extremely' (10).

Expectation rating. An additional VAS was then employed to capture a measure of how participants expected they would respond to hypnotic suggestion.

Hypnotic responding. All participants were instructed to put on their headphones and were asked to listen to the standardised hypnotic induction procedure. This induction was followed by the four separate suggestions in the following order: hands together, rigid arm, taste hallucination, and negative colour hallucination. After each suggestion participants were prompted to give a measure of self-reported hypnotic responding. Responses for the hands together, rigid arm, and taste hallucination suggestions were made using on-screen VAS for the questions; "To what extent did your hands move together?", "To what extent did you find it difficult to bend your arm?" and "To what extent did you experience a taste in your mouth?" respectively, with the scale ranging from "not at all" (0) to "very much" (10). Responses to the negative colour hallucination was measured using a VAS for the question "What proportion of the block pattern did you perceive as being grey?" from "none at all" (0) to "the entire pattern" (10).

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Questionnaires. Participants then completed three on-screen questionnaires; the SCS, DES and FFMQ.

Lastly, participants were asked to answer the three on-screen debrief questions before being fully debriefed as to the true nature of the study and thanked for their participation.

Results

All raw data are available at <http://osf.io/xa9p8>.

Bayes factors (B) were used to assess the strength of evidence for the alternative hypothesis, H_1 , over the null, H_0 (Wagenmakers, Verhagen, Ly, Matzke, et al., 2017). A B of above 3 indicates substantial evidence for H_1 over H_0 and below $1/3$ substantial evidence for the H_0 over H_1 . All Bayes factors, B , reported here represent the evidence for H_1 relative to H_0 ; to find the evidence for H_0 relative to H_1 , take $1/B$. B s between 3 and $1/3$ indicate data insensitivity (see Dienes, 2014; cf. Jeffreys, 1939). Here, $B_{H(0, x)}$ refers to a Bayes factor in which the predictions of H_1 were modeled as a half-normal distribution with an SD of x (see Dienes & McLatchie, 2017); the half-normal can be used when a theory makes a directional prediction where x scales the size of effect that could be expected. As correlations with hypnotic response, if they exist, tend to be in the region of $r = 0.2$ (e.g. Laurence, Beaulieu-Prévost, & Du Chéné, 2008), for correlations the SD was set to be $x = 0.2$. For the mood ratings, in the absence of similar previous studies we followed a strategy recommended by Dienes (2017) for this situation. As we predicted that the control group would be happier and more aroused, as they had not undergone a fatiguing inhibitory control task, we estimated a difference between the mean of the experimental condition and the maximum shift possible, thus the SD for mood valence and arousal were set as half the difference between the mean of the difficult condition and the top of the scale (10) (i.e. $3.45/2 = 1.73$). For the manipulation check, using the same strategy would result in modeling H_1 with a half-normal with SD = 2.65. A previous study (Gurney et al., 2018) using the same difficult and easy tasks and the

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same measure of mental exhaustion estimated a change of 2.85, virtually the same as the estimate just calculated using the Dienes (2017) strategy. As conclusions do not depend on which SD is used; we chose the more informed value (2.85). Finally, for the change in hypnotic response, theoretically the effect could go in either direction, thus we used a normal distribution to model H1. $B_{N(0, x)}$ refers to a Bayes factor in which the predictions of H1 were modelled as a normal distribution with a mean of 0 and an SD of x (this can be used for non-directional predictions in general). The maximum difference between the groups is the largest difference between the control mean and the end of the scale. We then set the SD to be half this maximum. The effect observed in the control condition of Experiment 1 was 4.51 on a 10-point scale, thus, the SD was set to 2.75. With these assumptions for modeling H1, as it happened, where an effect yielded a p value of about .05, the Bayes factor was about 3, though there is no guarantee of such a correspondence between B and p values (Lindley, 1957). We will interpret all effects with respect to the Bayes factors.

To indicate the robustness of Bayesian conclusions, for each B , a robustness region is reported, giving the range of scales that qualitatively support the same conclusion (i.e. evidence as insensitive, or as supporting H0, or as supporting H1), notated as: RR [x1, x2] where x1 is the smallest SD that gives the same conclusion and x2 is the largest².

Participant Awareness

Responses to the question “What do you think the experiment was trying to test?” which included references to the influence of exhaustion, depletion, will-power (or similar) affecting hypnotic suggestibility were coded as ‘aware’. Responses to the question “What do you think the purpose of the colour classification task was?”, which mentioned depletion or exhaustion were coded as ‘aware’. Finally, any responses to the question “How do you think being mentally exhausted would affect your hypnotic suggestibility?”, which stated that it

² Thanks to Balazs Aczel for suggesting the use of robustness regions

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would increase suggestibility were coded as ‘increase’, those which stated suggestibility would decrease were coded as ‘decrease’ and ‘other’ for ambiguous answers. All responses were coded by two independent coders, and codes were found to correspond 100%.

No participants correctly identified the purpose of the experiment. Out of the five participants who correctly identified the purpose of the stroop task, all thought that mental exhaustion would increase suggestibility.

Correlational Analysis

Expectancy. Pearson’s correlation revealed a positive relationship between participants’ expectancy ratings (how participants believed they would respond) and their mean hypnotic response, $r = .28$, $p = .028$, $B_{H(0, 0.20)} = 6.08$, $RR[0.09, 0.97]$.

Personality. Correlational analyses were conducted for the relationship between each of the personality measures and mean hypnotic responding, see Table 1. Results show that responses to the DES showed a positive relationship with hypnotic responding.

Table 1. Relationship between mean hypnotic response and all personality measures.

	SCS	FFMQ: Observe	FFMQ: Describe	FFMQ: Act	FFMQ: Non- Judge	FFMQ: Non- React	DES
<i>r</i>	-.13	-.03	-.00	-.12	.00	-.20	.35
<i>p</i>	.310	.838	.995	.348	.981	.132	.006
<i>B</i>	0.31*	0.47	0.55	0.32*	0.55	0.25*	18.63*

Note. * Sensitive *B* at >3 or $<1/3$.

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Outcome Neutral Tests

Exhaustion. There was no evidence one way or the other for there being a difference in mental exhaustion between those in the difficult ($M = 5.49$, $SE = 0.42$) and easy ($M = 4.69$, $SE = 0.45$) conditions, $t(58) = 1.31$, $p = .197$, $d = 0.34$, $B_{H(0, 2.85)} = 0.85$ RR[0.00, 8.11].

Thus, we have not established, independent of the crucial test, that the tasks challenged the inhibitory system to a different extent. As well as establishing a difference in test difficulty we would also establish that mood was not changed. Changes in mood may accompany different degrees of fatigue as a matter of course, thus establishing no change in mood is not crucial to the logic of the experiment in the same way that establishing differences in inhibitory challenge is.

Mood (valence). There was no evidence one way or the other for there being a difference in valence between those in the difficult ($M = 3.09$, $SE = 0.61$) and easy ($M = 3.69$, $SE = 0.61$) conditions, $t(58) = 1.31$, $p = .489$, $d = 0.18$, $B_{H(0, 3.45)} = 0.46$ RR[0.00, 4.99].

Mood (arousal). There was no evidence one way or the other for there being a difference in arousal between those in the difficult ($M = 4.30$, $SE = 0.37$) and easy ($M = 4.67$, $SE = 0.38$) conditions, $t(58) = 0.71$, $p = .478$, $d = 0.18$, $B_{H(0, 2.85)} = 0.46$ RR[0.00, 3.15].

Main Analysis

The effect of a prior inhibitory challenge on hypnotic suggestibility. Here we sought to examine how hypnotic suggestibility differed with inhibitory control condition. A one-way ANOVA was conducted on mean hypnotic response and the inhibitory control manipulation condition (easy vs. difficult). The results revealed evidence for a main effect of inhibitory control condition on subsequent hypnotic response, ($M_{diff} = 1.07$, $SE_{diff} = 0.43$), $F(1, 58) = 6.13$, $p = .016$, $\eta_p^2 = .10$, $B_{N(0, 2.75)} = 3.17$ RR[0.39, 2.94], with those in the easy rather than difficult condition showing a greater hypnotic response, see Figure 1.

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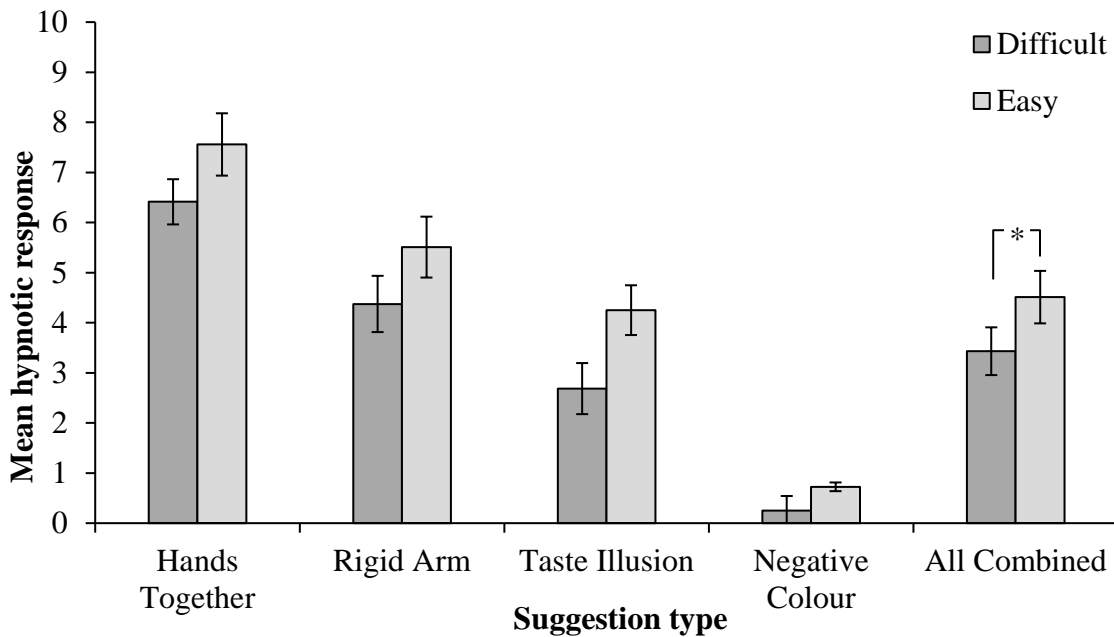


Figure 1. Change in mean hypnotic responding for each hypnotic suggestion as a product of inhibitory condition (\pm 1 SEM). Note. * $p < .05$

Discussion

Experiment 1 aimed to investigate the effect of a prior inhibitory task on subsequent susceptibility to hypnotic suggestions. Consistent with Hilgard (1977) and Spanos (1986) our results suggest that a prior inhibitory task decreases subsequent susceptibility. As such the findings contrast predictions from dissociated control theories of hypnosis which suggest that due to compromised functioning of the frontal cortices there would be an increase in suggestibility to hypnosis. The positive, correlation between participant's dissociative experiences as reported on the DES and their hypnotic responding provides some support for a relationship between dissociative processes and hypnosis. However, one limitation of the inhibitory control literature is ensuring that the task used is mentally exhausting (see Dang, 2017). Whilst the Stroop, as used here, has previously been shown to create necessary inhibitory demand (Dang, 2017; Gurney et al., 2017) we were unable to provide evidence for or against a difference in levels of mental exhaustion for the easy and difficult task

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conditions. As we did not have clear evidence for this outcome neutral test, and Experiment 1 was run without a pre-defined analytic protocol, we sought to directly replicate the procedure with a larger sample, using the same analyses.

Experiment 2

Method

Participants

96 participants (72 female, 24 male) aged 18 to 45 years ($M = 20.95$, $SE = 0.41$) were ‘medium responders’ recruited from the University of Sussex Hypnosis Database and paid £5 for participation. Participants were randomly assigned in equal proportions to one of two experimental task type conditions created by the inhibitory control manipulation: easy versus difficult. All participants were naive to the experimental hypothesis. Participants were run until the Bayes factor for the manipulation check indicated substantial evidence for either H_1 or H_0 . The experiment was considered low risk and received ethical approval from the University of Sussex School of Psychology ethics committee. All participants read an information sheet and signed a consent form before the experiment began. At the end of the experiment participants were fully debriefed as to the nature of the experimental aims. The experimental materials, design and procedure all remained the same as Experiment 1.

Results

Participant Awareness

Responses to the three debrief questions were coded as in Experiment 1. No participants simultaneously identified the purpose of the study, the purpose of the stroop and identified that exhaustion would decrease susceptibility. Therefore, all were included in the analysis.

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Correlational Analysis

Expectancy. Pearson's correlation revealed a positive relationship between participants' expectancy ratings and their mean hypnotic response, $r = .38$, $p < .001$, $B_{H(0, 0.2)} = 538.22$, $RR[0.03, 1]$.

Personality. Correlational analyses were conducted for the relationship between each of the personality measures and mean hypnotic responding, see Table 2. Results show evidence that responses to the SCS showed a negative relationship with hypnotic responding and the DES showed a positive relationship with hypnotic responding.

Table 2. Relationship between mean suggestibility and all personality measures.

	SCS	FFMQ: Observe	FFMQ: Describe	FFMQ: Act	FFMQ: Non- Judge	FFMQ: Non- React	DES
<i>r</i>	-.21	.01	-.11	-.09	-.14	.02	.33
<i>p</i>	.039	.903	.293	.395	.168	.851	.001
<i>B</i>	5.06*	0.48	0.24*	0.26*	0.21*	0.52	91.04*

Note. * Sensitive *B* at >3 or $<1/3$.

Outcome Neutral Tests

Exhaustion. There was substantial evidence for a difference in mental exhaustion between those in the difficult ($M = 6.26$, $SE = 0.31$) and easy ($M = 5.07$, $SE = 0.38$) conditions, $t(91.74) = -2.45$, $p = .016$, $d = 0.50$, $B_{H(0, 2.85)} = 5.90$, $RR[0.27, 6.06]$.

This is a key manipulation check to establish the integrity of the experiment. Establishing equivalence of mood would help narrow theoretical interpretation, but as mood may naturally vary with exhaustion (in that, for example, exhaustion is often unpleasant),

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presence or absence of mood differences do not threaten the integrity of the experiment as such.

Mood (valence). There was no evidence one way or the other for there being a difference in valence between those in the difficult ($M = 1.26$, $SE = 0.57$) and easy ($M = 2.42$, $SE = 0.47$) conditions, $t(94) = 1.56$, $p = .119$, $d = 0.32$, $B_{H(0, 4.37)} = 1.04$ RR[0.00, 14.53].

Mood (arousal). There was evidence for the null hypothesis, namely that there was no difference in arousal between those in the difficult ($M = 4.44$, $SE = 0.38$) and easy ($M = 4.65$, $SE = 0.31$) conditions, $t(94) = 0.43$, $p = .672$, $d = 0.09$, $B_{H(0, 2.78)} = 0.24$ RR[2.04, 10]. Thus, the differences in mental exhaustion were not accompanied by overall differences in arousal.

Main Analysis

The effect of a prior inhibitory challenge on hypnotic suggestibility. Here we sought to examine how hypnotic suggestibility differed with inhibitory control condition. A one-way ANOVA was conducted on mean hypnotic response and the inhibitory control manipulation (easy vs. difficult). The results revealed substantial evidence for the null hypothesis, namely that there was no main effect of inhibitory control condition on mean hypnotic response, ($M_{diff} = -0.17$, $SE_{diff} = 0.38$), $F(1, 94) = 0.20$, $p = .675$, $\eta_p^2 = .00$, $B_{N(0, 2.75)} = 0.15$, RR[1.23, 10], see Figure 2.

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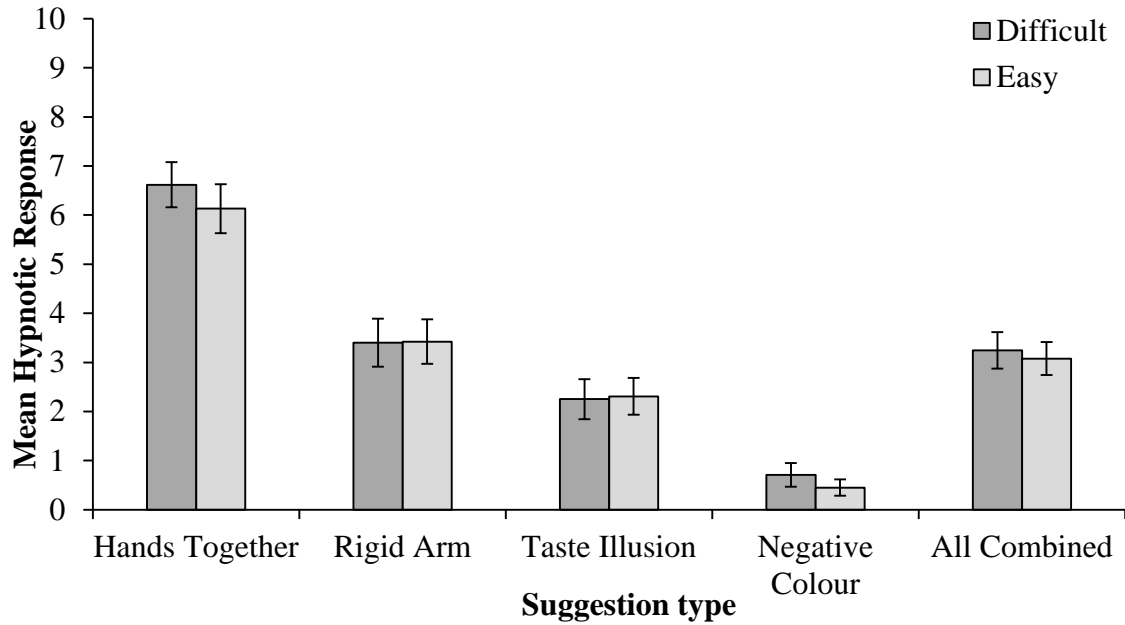


Figure 2. Change in mean hypnotic responding for each hypnotic suggestion as a product of inhibitory condition (+/- 1 SEM).

Next, we tested whether the crucial effect in Experiment 1 was different from that in Experiment 2. The results showed substantial evidence for an interaction between condition and experiment, ($M_{diff} = 0.81$, $SE_{diff} = 0.29$), $F(1, 152) = 4.52$, $p = .035$, $\eta_p^2 = .03$, $B_{N(0, 2.75)} = 4.63$, $RR[0.01, 4.38]$, suggesting that the crucial effect was different in the two experiments. We also tested whether Experiment 2 replicated the effect in Experiment 1, in the specific sense of using the posterior distribution of the effect found from Experiment 1 as the model of H1 for testing the effect in Experiment 2 (the strategy recommended by Verhagen & Wagenmakers, 2014). The resulting Bayes provided evidence that Experiment 2 did not replicate the effect observed in Experiment 1, $B_{N(0.80, 0.39)} = 0.16$, $RR[1.01, 10]$. Finally, we meta-analytically combined the raw effect sizes of Experiment 1 and 2 weighting by the square of the SE of each estimate

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and computed a Bayes Factor for the combined effect³. The resulting Bayes factor provided substantial evidence for the null hypothesis, namely that exerting inhibitory control does not decrease susceptibility to hypnotic suggestion, $B_{N(0, 2.75)} = 0.23$ RR[1.89,10].

Discussion

Experiment 2 sought to establish whether the effect reported in Experiment 1, namely that a prior inhibitory task decreases subsequent susceptibility, would be replicated over a larger sample size. Those in the difficult inhibitory task condition gave higher ratings of mental exhaustion suggesting that the challenging task had the desired effect of increasing inhibitory demand. We found evidence for no effect relative to a relatively uninformed model of H1, and evidence for no effect relative to the effect size found in Experiment 1. Combining both studies in a Bayesian meta-analysis provided support for the null hypothesis that exerting inhibitory processes on a challenging task has no effect on subsequent susceptibility to hypnotic suggestion. As the outcome neutral test was not satisfied in Experiment 1, and the analyses were not pre-defined, we treat Experiment 1 as exploratory (even though the analytic protocol was in fact simple); and Experiment 2 as more clearly testing the theoretical claim that an inhibitory challenge impairs hypnotic response, given the analytic protocol had been pre-defined by that used in Experiment 1.

Consistent with Experiment 1 and previous research there was a positive correlation between scores on the DES in the hypnotic context (Kirsch & Council, 1992; Nadon et al., 1991). This correlation may especially arise when hypnotic response and DES are tested in the same context (e.g. contrast Dienes et al., 2009, where they were tested in a different context). In addition to this we found a negative relationship between individuals' scores on

³ This is the same as a fixed effects meta-analysis. While the difference between experiments is evidence (but not strong evidence, $B < 10$) that the effect is not fixed, on the null hypothesis we are testing the effect is fixed at zero. That is, if we assume H0, we assume a fixed effect. Note that the same program exactly was run in the same university drawing from the same subject pool (largely psychology undergraduates at the University of Sussex) with no obvious contextual differences that would be relevant according to the theories tested. Thus, it is relevant to test the model there is one fixed effect of zero.

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the SCS and their mean hypnotic responding suggesting that those scoring highest in self-control, reported lower levels of hypnotic responding. Given this result, it is interesting that we did not observe lower levels of hypnotic responding for those who had completed the easy task. This suggests a difference between trait levels of self-control and the level of regulatory capacity altered by inhibitory control tasks. Interestingly, whilst some report a positive relationship between trait self-control and the ability to overcome the effects of ‘depletion’ (Gillebaart & de Ridder, 2015; Muraven, Collins, Shiffman, & Paty, 2005) others have reported the opposite effect (see Imhoff, Schmidt, & Gerstenberg, 2014).

General Discussion

Despite disagreements surrounding the exact mechanisms underlying hypnosis, many theories involve the use of, or alterations in, frontal processing and executive functioning (e.g. Dietrich, 2003; Egner & Raz, 2007). As executive functions are vital to inhibitory control, the present study sought to examine whether a temporary reduction in inhibitory control might influence hypnotic suggestibility. We sought to address this by manipulating the degree of demand required to complete a prior task, which consisted of either an easy or difficult colour naming task (see Dang, 2017), and comparing subsequent susceptibility to a set of four standard hypnotic suggestions.

Experiment 1 aimed to investigate the effect of the degree of inhibitory challenge on subsequent hypnotic responding. This constituted an initial exploration. There was not clear evidence for the difference in mental exhaustion produced by the inhibitory tasks in the intervention and control conditions; thus, the required outcome neutral task was not passed. Nonetheless, the results for Experiment 1 provided evidence for the hypothesis that a prior inhibitory task decreases subsequent hypnotic suggestibility. Crucially, Experiment 2, did provide evidence for the outcome neutral task, that is a difference in mental exhaustion between the intervention and control groups, and had researchers’ degrees of freedom

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removed by following the exact protocol as Experiment 1. Experiment 2 found evidence for no effect of prior inhibitory control on hypnotic response. A Bayesian meta-analysis combining the two experiments provided evidence for the null hypothesis that exerting inhibitory processes on a challenging task has no effect on subsequent susceptibility to hypnotic suggestion. The results presented here therefore suggest that the level of demand we placed on inhibitory processes does not influence the degree to which an individual is responsive to subsequent hypnotic influences.

It may be argued that although we had succeeded in placing different levels of inhibitory demand on participants, that difference was not large enough to interfere with hypnotic response. However, the Stroop task used in the experiments in this paper has been pinpointed as one of the strongest and most reliable inhibitory control manipulations in a recent meta-analysis of the depletion literature (Dang, 2017) and has also been used to show subsequently increased stereotype consistent errors (Govorun & Payne, 2006), decreased persistence on puzzle-solving tasks (Webb & Sheeran, 2003, Experiment 1), and reduced performance on tests of handgrip endurance (Bray, Martin Ginis, Hicks, & Woodgate, 2008). Furthermore, it is coupled with a manipulation check in which participants were asked to rate how mentally exhausted they are, a method which is common place within the literature (e.g. Bray et al., 2008; Fischer et al., 2012; Friese, Binder, Luechinger, Boesiger, & Rasch, 2013; Friese, Hofmann, & Wänke, 2008; Friese, Messner, & Schaffner, 2012; Govorun & Payne, 2006; Grillon, Quispe-Escudero, Mathur, & Ernst, 2015; Webb & Sheeran, 2003).

The results presented here are consistent with the cold control theory (Dienes, 2012; Dienes & Perner, 2007) in that previous work disrupting frontal function that improves hypnotic response has been interpreted by cold control as arising from a disruption in metacognition. That is, as cold control predicts an improvement in hypnotic response only where metacognition is affected. Previous research suggests that the inhibitory challenge

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utilised in the current study (the colour naming Stroop) does not affect the formation of accurate higher-order thoughts (Gurney et al., 2018), thus the cold control theory would predict no alteration - or an impairment in hypnotic responding if the disruption is sufficient to impair the strategies that must be performed to produce the hypnotic action. What cold control theories, including those of Spanos (1986) and Hilgard (1977) rule out is an improvement in hypnotic response by disrupting frontal function.

The positive relationship between expectancy and hypnotic response is consistent with Kirsch's (1985) response expectancy theory, which regards belief about ones susceptibility as the single direct cause of hypnotic response. However, expectancy itself has been linked to executive function (e.g. Schjoedt et al., 2011), thus if executive function (and thus expectancy) is disrupted, then hypnotic response could be impaired. Here we find no evidence that prior use of executive processes alters hypnotic response suggesting that perhaps expectancy has similarly been unaffected by prior inhibitory control.

The results do not provide evidence for the original dissociated control theory of hypnosis (e.g. Bowers, 1992; Woody & Bowers, 1994) as such approaches would have predicted an increase in hypnotic suggestibility following a challenging inhibitory task due to an implication of the frontal processes resulting in less control over the further splitting of executive control systems. However, second-order dissociated control models, which locate the dissociation in meta-cognitive monitoring, survive the challenge (Woody & Sadler, 2008). Further, the positive relationship observed between DES scores and mean hypnotic response mirrors findings previously documented (Kirsch & Council, 1992; Nadon et al., 1991) and provides some evidence of a link between dissociative experiences and hypnotic suggestibility, though the absence of this correlation when the measures are taken in different contexts suggests caution in using it to support dissociation theories (Dienes et al., 2009; Kirsch & Council, 1992). It should also be noted that this sample employs medium

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responders only. If related, dissociation should be observed mostly for highs, thus it is interesting that we observe a relationship between DES and responding here. This might suggest that dissociation is linked with hypnotic responding in general rather being limited to high responders only.

Previous research has shown that exerting control on one task reduces the degree of control which is readily applied to subsequent tasks (e.g. Baumeister et al., 1998; DeWall et al., 2007; Fischer et al., 2012; Hofmann et al., 2007; Vohs & Heatherton, 2000). Thus, if inhibitory control was necessary for hypnosis, the inhibitory control literature would predict impaired hypnotic responding following a task which placed high levels of demand on inhibitory processes. This was not observed in the present study and instead the results show substantial evidence of no effect of prior inhibitory control on hypnotic response. However, interestingly, we do report a negative correlation between individuals' trait levels of self-control and their mean hypnotic responding. This suggests a difference between trait self-control and temporary alterations in regulatory capacity induced by the inhibitory control manipulation. Further, the result suggests that those with low trait self-control should be more receptive to hypnosis. This is important given the clinical applications of hypnosis as a supplementary therapy in populations associated with chronically impaired self-control.

Hypnosis is thought to augment the effectiveness of cognitive behavioural therapies (Kirsch, Montgomery, & Sapirstein, 1995), decrease the symptoms of anxiety and depression (Heap, 2012), and facilitate treatment gains for a variety of psychological and medical conditions (see Green, Laurence, & Lynn, 2014, for a review). Previous work has highlighted the role of chronically impaired inhibitory control in disorders such as anxiety (Cisler & Koster, 2010; Cisler & Olatunji, 2012) and depression (Joormann & Stanton, 2016). Thus, it is interesting and arguably reassuring to report that placing a high level of demand on inhibitory control processes had no effect on hypnotic suggestibility. This

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encouragingly suggests that, at least within the constraints of study, those with low levels of inhibitory control should be no less receptive to the potentially beneficial effects of hypnosis as a treatment. Further, the correlation between low levels of self-control and high hypnotic response suggests those individuals with disorders characterised by impaired self-control might in fact, be more responsive to the benefits of hypnosis.

Cold control theory (Dienes & Perner, 2007) would predict a change in hypnotic response only where metacognition is impaired. As previous research has shown substantial evidence of no effect of the inhibitory task on subjective thresholds and metacognition (Gurney et al., 2017), cold control theory would predict no change in hypnotic response between inhibitory task conditions as metacognition should remain unaffected. As such, the results presented here provide support for the cold control theory and provide evidence that exerting inhibitory control processes does not influence subsequent susceptibility to hypnotic suggestion. Considering the use of hypnosis in facilitating treatments, it is reassuring that prior inhibitory control demand does not unduly effect receptiveness to hypnotic procedures.

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