

Final Report

Bial Foundation Bursary 198/12

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Project aims:

The goal of this project was to examine whether hypnotic suggestibility can be enhanced using transcranial direct current stimulation (tDCS), a safe non-invasive form of brain stimulation and to explore how changes in metacognition may be the primary factor involved in this enhancement. The results of the first studies have further motivated research on the heterogeneous response patterns among highly suggestible individuals and theoretical work on the measurement of hypnotic suggestibility.

Study I: Enhancing suggestion for improved selective attention using tDCS

The first study investigated whether cathodal (inhibitory) tDCS applied to left dorsolateral prefrontal cortex would enhance hypnotic suggestibility. This prediction follows from a wide range of studies implicating this region in hypnotic responding. For instance, my colleagues and I previously showed that highly suggestible individuals reliably exhibit reduced frontal-parietal functional connectivity following a hypnotic induction than low suggestible individuals (Terhune, Cardeña, & Lindgren, 2011a). Research by McGeown and colleagues has further suggested that reductions in prefrontal activity following an induction in highly suggestible individuals may predict increased suggestibility following the induction in this subgroup (McGeown et al., 2012).

This study adopted the approach of Amir Raz and colleagues, who have used hypnotic suggestions for the inability to read to reduce the Stroop interference effect, thereby indirectly enhancing selective attention (Raz, Fan, & Posner, 2005). Medium and highly suggestible participants were administered the suggestion that they would be unable to process numerical information during completion of a numerical Stroop task in which numerical information interferes with judgments regarding the physical size of numbers (Cohen Kadosh, Gevers, & Notebaert, 2011). Participants completed the numerical Stroop task in a control condition and following a suggestion for the inability to process numerical information in a sham (placebo) stimulation condition and a real (cathodal tDCS) condition.

Across conditions, participants perceived the suggestion to have worked, experiencing a greater perception of being unable to process numerical information in the suggestion than in the control condition (**Fig 1**).

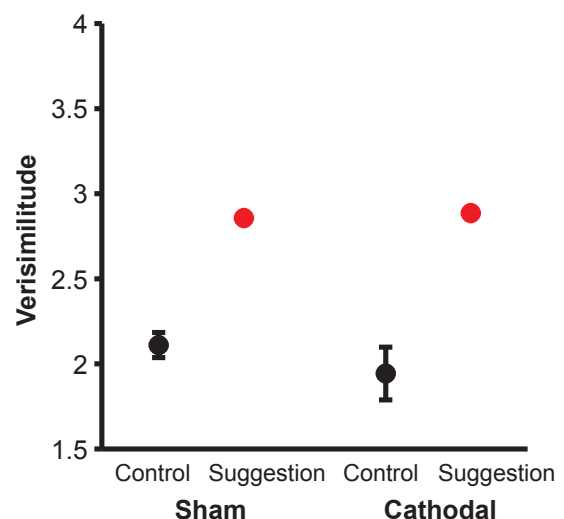


Fig 1. Participants exhibited greater verisimilitude (perceived reality of being unable to process numerical information) in the suggestion than in the control condition.

The behavioural results were not as clear-cut but are still indicative of superior performance during the conjunction of cathodal tDCS and suggestion. Data were analyzed using a drift diffusion model, which allows one to separate distinct cognitive processes including *drift rate* (speed of information accumulation), *boundary separation* (response conservativeness), *non-decision time* (non-cognitive [e.g., motor] contributions to response time). An interaction effect in drift rates revealed that participants displayed selectively greater drift rates (reflecting faster information accumulation) in the suggestion condition when receiving cathodal tDCS (**Fig 2**). Although this is consistent with superior performance selectively in this condition, there was no change in the congruency effect (i.e., poorer performance for incongruent than congruent trials).

I next examined how drift rates changed across conditions and whether this was related to individual differences in hypnotic suggestibility. This analysis revealed a dissociation between congruent and incongruent trials (**Fig 3**): the increase in drift rates for congruent trials in the suggestion (relative to control) and cathodal (relative to sham) stimulation was significantly positively associated with baseline hypnotic suggestibility (Weitzenhoffer & Hilgard, 1962). In contrast, this effect was not statistically significant (and in the opposite direction) for incongruent trials. Insofar as the change in drift rates is related to hypnotic suggestibility, it can be identified as a hypnotic effect (Woody & Barnier, 2008).

A further notable effect was that irrespective of suggestion condition, the interaction between hypnotic suggestibility and dissociative tendencies was associated with a larger congruency effect during cathodal than sham stimulation (**Fig 3**). This indicates that high dissociative highly suggestible individuals exhibit greater Stroop interference when prefrontal cortex is disrupted than in a control condition. This is consistent with my previous research showing that this subtype displays impaired cognitive control and sustained attention following a hypnotic induction (Marcusson-Clavertz, Terhune, & Cardena, 2012; Terhune, Cardena, & Lindgren, 2011b).

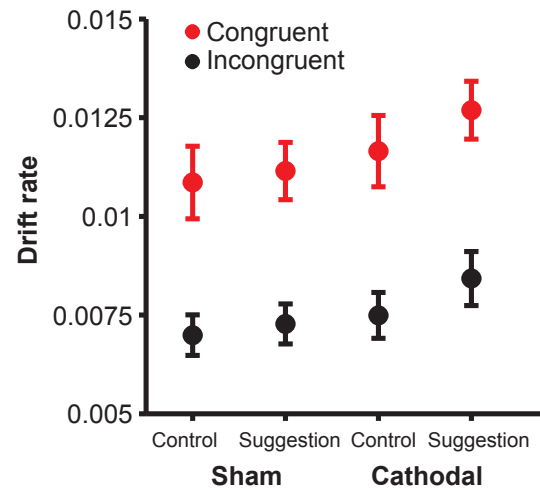


Fig 2. Participants exhibited superior drift rate (speed of information accumulation) for both congruent and incongruent stimuli in the suggestion condition coupled with cathodal tDCS than in the other conditions.

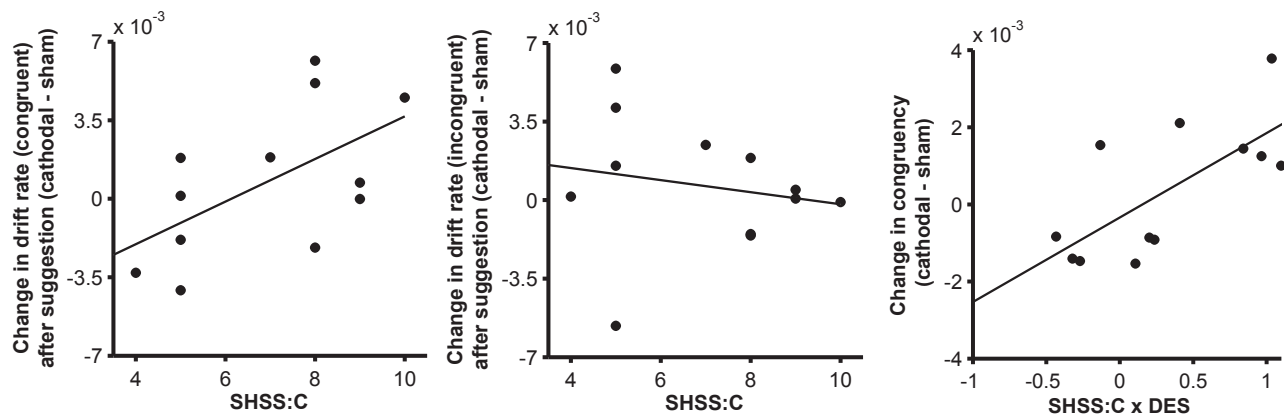


Fig 3. Changes in drift rates in the suggestion coupled with cathodal tDCS condition were positively related to hypnotic suggestibility (SHSS:C scores) for congruent (left), but not incongruent (middle), trials. Change in the congruency effect from sham to cathodal tDCS was greater in those individuals who were highly suggestible and highly dissociative (right).

There were no effects on non-decision times but there were two effects pertaining to boundary separation. Specifically, boundary separation was reduced in the suggestion condition relative to the control condition, irrespective of stimulation type (**Fig 4**). This indicates that participants became more liberal in their responding even as information accumulation

became faster (**Fig 1**). Taken together, these results indicate that there was no evidence for a speed-accuracy tradeoff in performance enhancement

driven by the suggestion. As was observed with drift rates, this change in boundary separation in the suggestion condition was related to hypnotic suggestibility with highly suggestible individuals exhibiting a greater decrease in boundary separation (**Fig 4**).

Collectively, the results of this study demonstrate that tDCS coupled with suggestion can enhance selective attention, thereby providing the first evidence that non-invasive brain stimulation can enhance suggestibility, as assessed by a rigorous cognitive task. The results further corroborate other results in the domain of hypnosis and demonstrate that a number of the observed effects can be understood as hypnotic insofar as they are associated with hypnotic suggestibility. A manuscript describing this experiment is currently in preparation and I anticipate that I will submit it to a peer-reviewed journal in 2015.

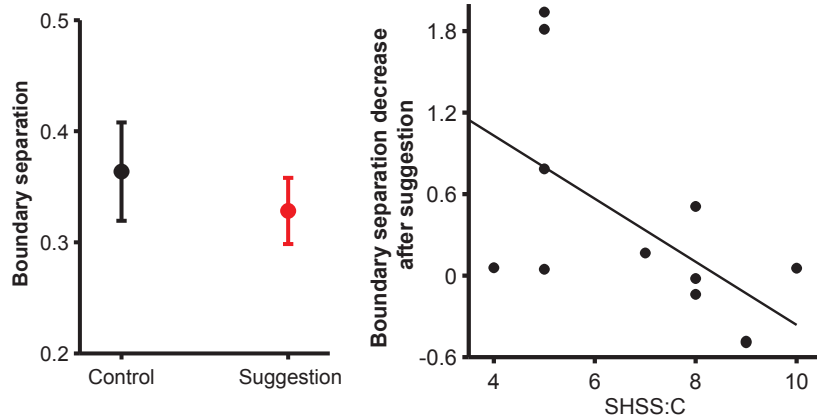


Fig 4. Boundary separation decreased in the suggestion, relative to the control, condition (left). This decrease was negatively correlated with hypnotic suggestibility (greater suggestibility was associated with a greater decrease).

Study II: Enhancing suggestion for improved sustained attention using tDCS

The second study sought to further investigate the utility of tDCS for enhancing hypnotic suggestibility. The study expanded upon Study 1 in multiple ways. First, sham, anodal (excitatory) tDCS, and cathodal (inhibitory) tDCS were contrasted on three separate days. Second, rather than stimulating only left dorsolateral prefrontal cortex, I stimulated this region and central parietal cortex concurrently to follow up on the finding that hypnotic suggestibility is characterized by reduced frontal-parietal connectivity (Terhune, et al., 2011a). Third, rather than a selective attention task like the Stroop, I used a sustained attention task that we've previously used (Marcusson-Clavertz, et al., 2012). In this task, participants have to respond as quickly as possible to numerical digits and inhibit responses to a particular digit. This task is widely used to study mind wandering, an attentional state in which attention is directed away from the task toward irrelevant mental representations. I suspected that cathodal tDCS would reduce frontal-parietal connectivity and thereby enhance responsiveness to a suggestion for reducing mind wandering. I analyzed three separate dependent variables: 1) subjective reports of task-focus (higher values reflect reduced mind wandering); 2) RTCV (response time coefficient of variation), a behavioural measure of response time variability (lower values reflect reduced mind wandering); and 3) commission errors (lower values reflect reduced mind wandering).

The results of this study were much clearer than in the first study. In particular, no evidence was found for a modulatory influence of tDCS on mind wandering or on responsiveness to the suggestion to disrupt mind wandering (**Fig 5**). In fact, there was a tendency for response to the suggestion to be strongest in the sham condition. However, there was converging evidence that the suggestion was effective in enhancing sustained attention. First, I observed that self-reports of task-focus were greater in the suggestion condition than in other conditions irrespective of the tDCS condition. This indicates that hypnotic suggestion enhances the subjective feeling that one is more focused. Second, there was a weak tendency for RTCV to be lower in the hypnotic suggestion condition, with the most pronounced effect

present in the sham condition. This indicates that hypnotic suggestion reduces mind wandering, as indexed by an established behavioural measure, but that this effect is only present in the absence of tDCS, suggesting that modulation of prefrontal and parietal regions may actually interfere with hypnotic responding. The third and final result was that commission errors were significantly lower in the hypnotic suggestion condition, again indicating that suggestion reduces mind wandering. There was a tendency for this effect to be most pronounced in the sham condition but this interaction did not achieve statistical significance.

This study did not find any evidence that tDCS can enhance hypnotic suggestibility. However, the results clearly show that hypnotic suggestion reliably reduces subjective and behavioural measures of mind wandering. This finding is notable because all previous studies purporting to enhance attention, such as by cancelling the Stroop effect, did so by altering perception (e.g., rendering someone unable to read, thereby reducing the Stroop effect), whereas this study demonstrated this effect with a suggestion that directly targeted attention. A manuscript describing this experiment is currently in preparation and I anticipate that I will submit it to a peer-reviewed journal in 2015.

Study III: Heterogeneous response patterns in the upper range of hypnotic suggestibility

The third study was motivated by my PhD research, which concerned heterogeneity in high hypnotic suggestibility, as well as the evidence provided for heterogeneity among medium and highly suggestible individuals in Study 1. I was further motivated by the idea that subsets of highly suggestible individuals may be more responsive than others to particular suggestions, an issue that will be especially crucial when attempting to modify hypnotic suggestibility as in the first two studies.

Against this backdrop, I sought to determine whether there were distinct

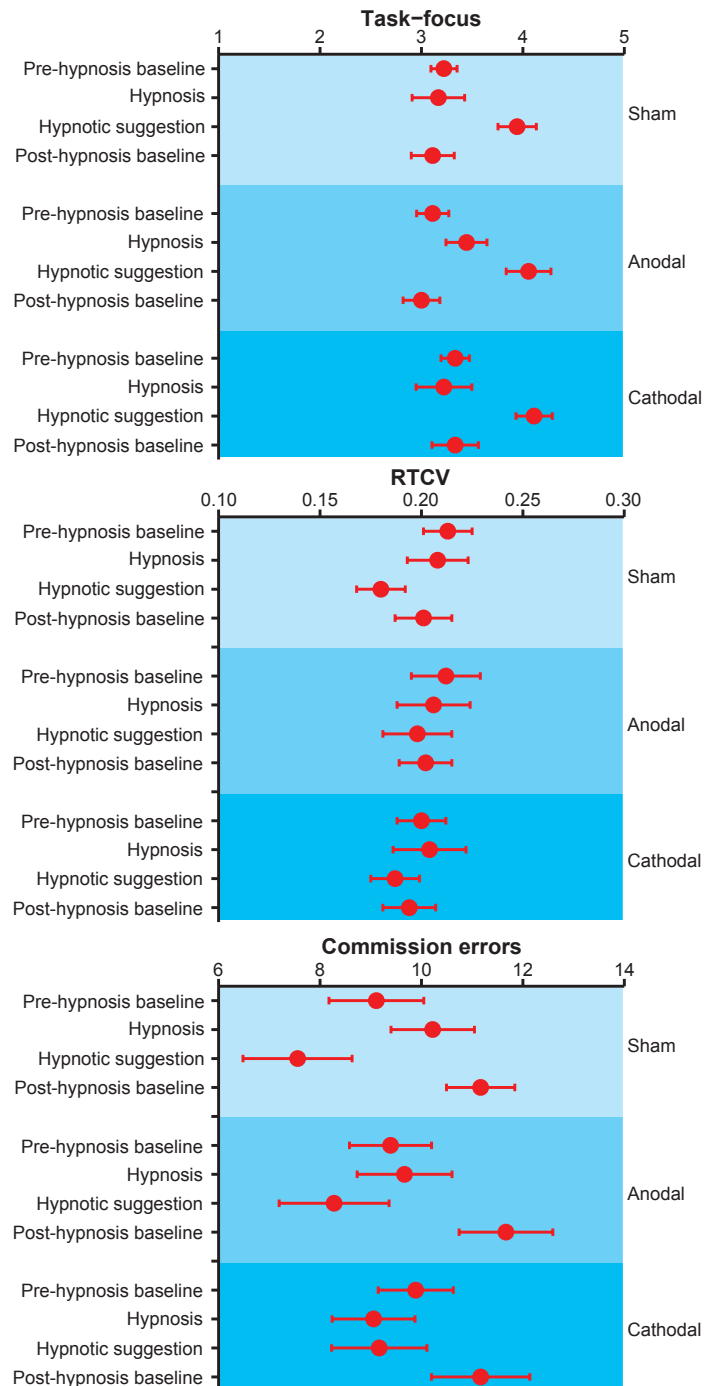


Fig 5. Self-reported task-focus was greater in the hypnotic suggestion condition with no differences across tDCS conditions (top). RTCV (response time coefficient of variation) was lower (reflecting reduced mind wandering) in the hypnotic suggestion condition, but only in the sham tDCS condition (middle). Commission errors were lower (reflecting reduced mind wandering) in the hypnotic suggestion condition with no differences across tDCS conditions (bottom).

patterns of responding in the upper range of hypnotic suggestibility. I applied latent profile analysis to a large data set of medium and highly suggestible participants' responses to a comprehensive battery of hypnotic suggestions. This analysis identified four classes overall, three of which represented distinct subtypes of highly suggestible individuals (**Fig 6**). One class was comprised of virtuosos who reliably displayed high hypnotic suggestibility (class 4 [blue data]), a second class was especially responsive to amnesia suggestions (class 1 [black data]), whereas a third was more responsive to agnosia suggestions (class 2 [red data]). This result suggests that there are three distinct response patterns by which an individual can achieve high hypnotic suggestibility.

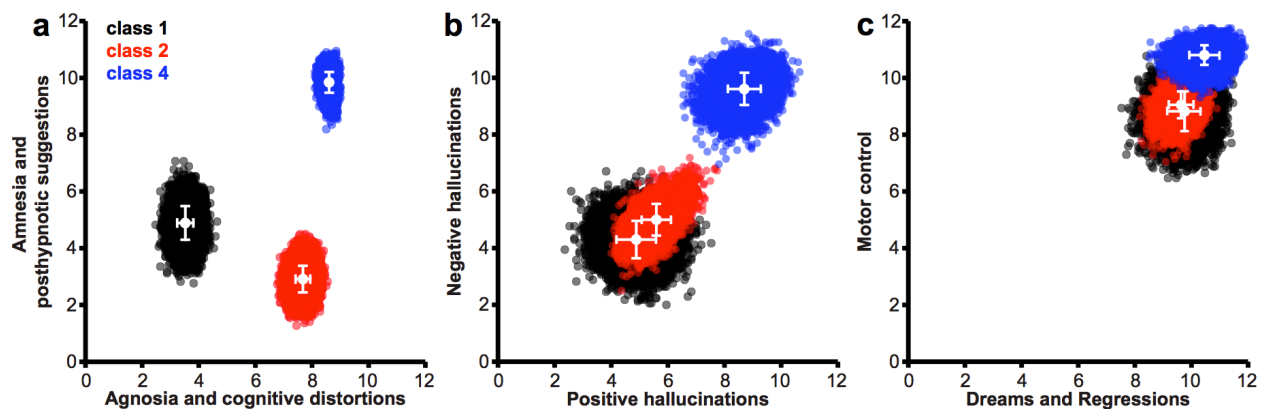


Fig 6. Scatterplots depicting mean SPS profile scores among HS participants as a function of class. a, Agnosia and cognitive distortions (AG) and amnesia and posthypnotic suggestions (AM) profiles. b, Positive (PH) and negative hallucinations (NH) profiles. c, Dreams and regressions (DR) and motor control (MC) profiles. Scatterplot data represent 10,000 Bootstrap resamples of the means for each of two SPS profiles in each of the three classes that included HS participants. White markers represent $M \pm 1$ SE.

This study also provides a number of novel insights regarding hypnotic suggestibility. First, it demonstrates that highly suggestible individuals do not display uniform patterns of responding to difficult hypnotic suggestions. Second, it identifies an important dissociation between inhibitory cognitive suggestions (amnesia and agnosia), highlighting that some individuals are more responsive than others to one or the other (compare classes 1 and 2). This is important because these types of suggestions are typically viewed as representing a homogeneous cluster (Woody, Barnier, & McConkey, 2005). Finally, it demonstrates that inhibitory cognitive suggestions, such as agnosia, are the best suggestions to use for studying individual differences in the upper range of hypnotic suggestibility and thus are most likely the best suggestions to use in studies investigating the modification of hypnotic suggestibility. A manuscript describing this study was recently accepted (pending minor revisions) in the journal *Consciousness and Cognition*. I have attached a .pdf copy of the revised manuscript; I anticipate that this paper will appear in print in 2015.

Study IV: Is hypnotic suggestibility related to metacognition of agency?

The fourth study aimed to better understand metacognition in high hypnotic suggestibility in order to more effectively target changes in metacognition in future studies examining the enhancement of hypnotic suggestibility. This study is motivated by the cognitive changes that relate to the relation between prefrontal cortex activity and hypnosis. Specifically, if hypnosis is characterized by reduced prefrontal functioning, or connectivity (Terhune, et al., 2011a) and this reduction is associated with enhanced hypnotic suggestibility (McGeown, et al., 2012), what cognitive-perceptual change mediates this enhancement? One theory maintains that hypnotic responses are driven by intentions that are inaccessible to consciousness, i.e., unconscious intentions (Dienes & Perner, 2007). A corollary of this

theory is that highly suggestible individuals should display reduced metacognition of agency, which is supported by dorsolateral prefrontal cortex (Metcalf, Eich, & Castel, 2010).

This study investigated the relation between hypnotic suggestibility and metacognition of agency. Seventy-four participants, were first screened on the *Harvard Group Scale of Hypnotic Susceptibility, Form A* (Shor & Orne, 1962), a widely use measure of hypnotic suggestibility. In addition to the standard behavioural measure of hypnotic suggestibility, I administered a self-reported measure of involuntariness during hypnotic responding, which taps the hallmark extra-volitional character of hypnotic responding. In an independent session, the participants completed two tasks measuring different facets of metacognition of agency: 1) *Metacognitive tracing task*, in this task participants had to trace an abstract line drawing on a computer monitor without feedback or visual information regarding the location of the cursor. They were subsequently presented with their own tracing and bogus tracing and had to judge which image was the one they created and their confidence. 2) *Metacognition of agency task*, in this task participants were presented with a screen of descending symbols (Xs and Os). They were instructed to “catch” the Xs with a moving cursor that was within a horizontal bar near the bottom of the screen and avoid the Os. They then judged their performance and their sense of control in the task. There were three separate conditions in the experiment: in the control condition, the cursor moved normally, whereas in the lag1 condition there was a small, barely noticeable lag in the cursor, and in the lag2 condition there was a large lag in the cursor. In each condition there were two speeds for the cursor, thus making up six conditions. Finally, as a control measure, participants completed the *Metacognitions Questionnaire* (Wells & Cartwright-Hatton, 2004), a self-report measure of individual differences in metacognition. I expected that hypnotic suggestibility would be associated with reduced awareness of experimental manipulations and the source of one’s performance changes across conditions. I further expected that hypnotic suggestibility would be unrelated to metacognition more generally, as indexed by the Metacognitions Questionnaire.

A number of results in this study are consistent with the predicted association between reduced metacognition of agency and hypnotic responding. First, in the metacognitive tracing task, behavioural hypnotic suggestibility and involuntariness were both unrelated to performance accuracy, behavioural: $r=.08, p>.5$ [CIs: $-.27, .40$], involuntariness: $r=-.08, p>.5$ [CIs: $-.40, .23$]. However, as predicted, the discrepancy between one’s self-perceived accuracy and their objective accuracy was positively correlated with involuntariness during hypnotic responding, $r=.27, p<.05$ [CIs: $.01, .51$], but was unrelated to behavioural hypnotic responding, $r=.04, p>.5$ [CIs: $-.27, .32$]. This indicates that reduced metacognition of one’s performance was associated with a tendency to experience hypnotic suggestions as happening on their own.

In the metacognition of agency task, those who failed to notice the lag and those who did notice the lag did not differ in behavioural hypnotic suggestibility, $t<0.25, p>.75$, or involuntariness, $t<0.1, p>.75$. Of interest, hypnotic suggestibility was associated with a tendency to report having greater control in all four lag conditions, $r_s>.34, p_s<.05$, but not the two control conditions, $r_s<.23, p_s>.2$. A similar (but weaker) trend was observed for judgments of performance: hypnotic suggestibility was associated with higher judgments of performance in the lag1 and lag2 conditions with slower speeds, $r_s>.32, p_s<.05$, but not those with faster speeds nor the control conditions, $r_s<.27, p_s>.1$. Crucially, this higher degree of confidence in performance was not reflected in actual superior performance: hypnotic suggestibility was not associated with hit rates or d' (a measure of sensitivity) in any of the conditions, $r_s<.20, p_s>.10$, and in some cases hypnotic suggestibility was negatively correlated with performance (although this did not reach statistical significance). When the difference between judgment of performance and actual performance is computed (larger values reflect poor metacognition), hypnotic suggestibility was positively correlated with this difference score in all conditions and significantly so in the lag1 fast condition, $r=.37, p<.05$. Interestingly, these values were unrelated to involuntariness during hypnotic responding, $r_s<.23, p_s>.10$. Cumulatively, these results indicate that hypnotic suggestibility is associated with reduced metacognition of one’s agency.

Finally, metacognition, as measured by the metacognitions questionnaire, was unrelated to hypnotic suggestibility, $r=-.11, p>.25$ [CIs: $-.42, .28$] or involuntariness, $r=.12, p>.25$ [CIs: $-.20, .44$].

This suggests that although individual differences are related to variability in metacognition pertaining to agency, they are not related to metacognition more generally.

Cumulatively, these results indicate that hypnotic suggestibility is associated with poor metacognition of agency, but not impaired metacognition more broadly. They further suggest an important dissociation between behavioural and experiential hypnotic suggestibility, which I hope to explore further in future research. These results provide the first line of robust support for Dienes and Perner's (2007) theory that hypnotic responding involves responses in which one's intentions are blocked from awareness.

Study V: Evaluating measures of hypnotic responding

An issue that has arisen in the course of this project is how hypnotic suggestibility is best measured. Nearly all previous research studies aiming to modify hypnotic suggestibility have used traditional measures of hypnotic suggestibility rather than more rigorous computer-based approaches measuring response times (e.g., Bryant, Hung, Guastella, & Mitchell, 2012; Whalley & Brooks, 2009). In contrast, the studies in this project have used computer-based, chronometric methods. The former methods may not be sufficiently sensitive to detect changes in hypnotic suggestibility. For instance, the self-report assessment of verisimilitude (perceived reality of the suggestion response) in Study 1 identified a difference between suggestion and control conditions, but not between sham and cathodal tDCS conditions, whereas behavioural analyses were able to identify such effects. Alternatively, the enhancement of hypnotic suggestibility may be observable on traditional scales, but not more rigorous methods because the respective changes are due to inherent flaws in these scales. This may explain the absence of effects of tDCS on hypnotic suggestibility in Study 2. In order to more fully consider these questions, I have begun writing a theoretical paper that critically evaluates different measures of hypnotic responding, including their assumptions and limitations, and the impact these have on contemporary theorizing about hypnosis. A manuscript describing these different arguments as well as recommendations for optimizing hypnotic suggestibility measures is currently in preparation and I anticipate that I will submit it to a peer-reviewed journal in 2015.

Summary and conclusions

This bursary was originally intended to investigate the enhancement of hypnotic suggestibility using tDCS. The first study provided preliminary, albeit somewhat ambiguous evidence, that this is possible, whereas the second study, although demonstrating a clear effect of suggestion, did not observe any effect of tDCS on hypnotic suggestibility. Given these ambiguous results, the remainder of the bursary was devoted to exploring the characteristics, measurement, and correlates of hypnotic suggestibility. Study 3 investigated heterogeneity in high hypnotic suggestibility and found evidence for three distinct clusters of individuals. Further research on the modification of hypnotic suggestibility may aim to specifically target one or another of these groups. Study 4 turned to the measurement of hypnotic suggestibility. This is a theoretical paper that is nearing completion and which criticizes contemporary measures of hypnotic suggestibility and offers suggestions for moving measurement methods forward. Finally, study 5 tested and found support for the prediction that hypnotic suggestibility is associated with poor metacognition of agency. This result provides robust support for a recent theory of hypnosis that argues that hypnotic responses are implemented through unconscious intentions. Cumulatively, this series of studies provides novel and highly valuable information about the modification of hypnotic suggestibility, its characteristics, measurement, and correlates. This research promises to drive further research exploring the cognitive and neural basis of hypnotic suggestibility.

Other activities

In addition to the progress achieved on these different projects, the support of the Bial Foundation was acknowledged in the following presentations:

- 1) I gave an invited talk describing a range of different experiments, including Studies 1-3, entitled “The emerging cognitive neuroscience of hypnosis” to the *University of Oxford Psychology Society*, Wadham College, University of Oxford (May 2014).
- 2) I presented the results of Studies 1 and 2 and briefly described the ideas expounded upon in Study 5 in a talk entitled “The neural basis of high hypnotic suggestibility: What we know and what we need to know” at the Annual Conference of the *Society for Clinical and Experimental Hypnosis* in San Antonio, TX, USA (October 2014).
- 3) I will be presenting the results of Study 4 at the Annual Conference of the *Association for the Scientific Study of Consciousness* in Paris (July 2015).
- 4) I will be presenting the results of Studies 1-2 and Study 4 in separate talks at the *International Congress of Hypnosis* in Paris (August 2015).
- 5) I was just awarded the Early Career Award from Division 30 (Society for Psychological Hypnosis) of the *American Psychological Association*. I will be giving a keynote address at the annual conference of the American Psychological Association in August 2015 in which I will describe my PhD dissertation research as well as recent experiments including Studies 1-5.

Papers published acknowledging previous Bial bursaries

Here I list all papers I have published that were supported by previous Bial bursary (54-06) and in which the Bial Foundation is acknowledged. I have attached a folder with .pdf copies of all of these papers.

10. **Terhune, D. B.**, & Cardeña, E. (in press). Heterogeneity in high hypnotic suggestibility and the neurophysiology of hypnosis. *Neurophysiologie Clinique/Clinical Neurophysiology*.
9. Cardeña, E., & **Terhune, D. B.** (2014). Hypnotizability, personality traits and the propensity to experience alterations of consciousness. *Psychology of Consciousness: Theory, Research, and Practice*, 1, 292-307.
8. Marcusson-Clavertz, D., **Terhune, D. B.**, & Cardeña, E. (2012). Individual differences and state effects on mind-wandering: Hypnotizability, dissociation, and sensory homogenization. *Consciousness and Cognition*, 21, 1097-1108.
7. **Terhune, D. B.**, & Brugger, P. (2011). Doing better by getting worse: Posthypnotic amnesia improves random number generation. *PLoS ONE*, 6, e29206.
6. **Terhune, D. B.**, Cardeña, E., & Lindgren, M. (2011). Differential frontal-parietal phase synchrony during hypnosis as a function of hypnotic suggestibility. *Psychophysiology*, 48, 1444-1447.
5. **Terhune, D. B.**, Cardeña, E., & Lindgren, M. (2011). Dissociated control as a signature of typological variability in high hypnotic suggestibility. *Consciousness and Cognition*, 20, 727-736.
4. **Terhune, D. B.**, Cardeña, E., & Lindgren, M. (2011). Dissociation and individual differences in high hypnotic suggestibility. *Cognitive Neuropsychiatry*, 16, 113-135.
3. **Terhune, D. B.**, & Cardeña, E. (2010). Differential patterns of spontaneous phenomenological response to a hypnotic induction: A latent profile analysis. *Consciousness and Cognition*, 19, 1140-1150.
2. **Terhune, D. B.**, Cardeña, E., & Lindgren, M. (2010). Disruption of synaesthesia by posthypnotic suggestion: An ERP study. *Neuropsychologia*, 48, 3360-3364.
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