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Bial Foundation final report

Grant Title

Heterogeneity in high hypnotic suggestibility and its implications for the study of anomalous experiences

Grant #

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Applicants

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Introduction

Our grant proposal outlined a series of studies that intended to test predictions derived from Barber's (1999) typological model of hypnotic suggestibility. In essence, this theory proposes that there are different subtypes of highly suggestible (HS) individuals who experience hypnosis and hypnotic suggestions through dissimilar mechanisms. Cardeña (2006) applied the model to the reporting of anomalous perceptual experiences and specifically argued that different HS subtypes may report different incidences and patterns of anomalous perceptual experiences. In addition to testing predictions from Barber's (1999) model, our proposed studies aimed to test some of the predictions proffered by Cardeña (2006). We argued that that these studies would provide valuable information regarding heterogeneity in high hypnotic suggestibility and could help to clarify the relationship between hypnotic suggestibility and the incidence of anomalous perceptual experiences (Kumar & Pekala, 2001). In what follows, we provide a brief description of the different studies that were conducted and their primary results. Completed versions of the different studies are included in the appendices.

Preliminary description of studies and current status

This project consisted of five studies. The first four studies tested different predictions derived from Barber's (1999) typological model, whereas the fifth study examined whether different HS subtypes report different incidences of anomalous experiences. The sixth study is a

case study that was not originally intended to be part of the study but occurred because of the discovery that one of our HS participants had synaesthesia.

Results

Study 1

Previous research indicates that HS participants exhibit marked variability in their spontaneous phenomenological response to a hypnotic induction. This study examined whether variability among HS participants exhibited a typological distribution and whether the resultant types corresponded to those predicted by the dissociative typological models (e.g. Barber, 1999). Specifically, Barber's (1999) model predicts that there are amnesia-prone, fantasy-prone, and positively-set subtypes. Amnesia-prone respondents experienced profound alterations in awareness, attention, volition, and poor memory following a hypnotic induction. In contrast, fantasy-prone respondents experience very vivid imagery, positive affect, and milder alterations in awareness. Finally, positively-set respondents experience relatively mild alterations in consciousness during hypnosis.

In this study 640 participants were administered the *Waterloo-Stanford Group Scale of Hypnotic Susceptibility, Form C* (WSGC; Bowers, 1993). A two-minute resting epoch was embedded within the WSGC. Following a de-induction, participants completed the *Phenomenology of Consciousness Inventory* (PCI; Pekala, 1991) in reference to the resting epoch. The PCI indexes a variety of dimensions of consciousness ranging from body image to volitional control. Participants also completed the *Inventory Scale of Hypnotic Depth* (ISHD; Field, 1965), which measures different aspects of hypnotic responding including involuntariness, in reference to their responses to the different hypnotic suggestions.

Five PCI factor scores (dissociated control, negative affect, positive affect, visual imagery, and attention to internal processes) were submitted to a latent profile analysis (LPA; Vermunt & Magidson, 2002) in order to derive different experiential profiles (clusters). LPA is a latent variable form of cluster analysis and allows for the computation of fit statistics that render class enumeration (the decision as to the optimal number of classes) less arbitrary than traditional cluster analysis methods.

The LPA discerned four experiential profiles, only two of which included HS participants. The first, labelled the inward-attention profile, was characterized primarily by greater attention to internal processes, whereas the second, the dissociative profile, was characterized by greater negative affect. Subsidiary analyses focusing on the HS participants in the two profiles found that the two subtypes closely correspond to those proposed by the

dissociative typological models. In particular, the inward attention profile exhibited greater attention and more vivid imagery than the dissociative profile, which experienced greater alterations in awareness and volition and greater negative affect. In addition, the dissociative profile also exhibited increased involuntariness during hypnotic responding.

This study provides preliminary support for dissociative typological models (e.g., Barber, 1999) and specifically suggests that there is an imagery subtype and a dissociative subtype among HS respondents.

Study 2

In addition to variability in spontaneous experiences following a hypnotic induction, HS participants vary considerably in various dimensions of hypnotic responding, such as the types of suggestions to which they respond, and different forms of cognitive functioning, such as imagery (McConkey & Barnier, 2004). This study examined whether heterogeneity in hypnotic responding and cognitive functioning among HS participants is consistent with the dissociative typological models.

In this study, three groups, 19 low dissociative HS (LDHS), 11 high dissociative HS (HDHS), and 21 low suggestible (LS) participants, completed measures of hypnotic suggestibility and cognitive functioning. Low and high suggestible participants were recruited from those who participated in study 1. Hypnotic suggestibility was corroborated with the *Revised Stanford Profile Scales of Hypnotic Susceptibility* (RSPS; Weitzenhoffer & Hilgard, 1967). Participants completed the two complementary RSPS scales in separate sessions administered by two different, masked experimenters. Each session was followed by a measure of involuntariness during the RSPS scales. In a separate session, participants completed two measures of working memory capacity (Crawford, Stewart, & Moore, 1989; Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004) and a behavioural measure of object visual imagery. In addition, they were given a questionnaire packet that included measures of fantasy-proneness, dissociation, and general psychopathology (Derogatis, 1993; Klinger, Henning, & Janssen, 2009; Körlin, Edman, & Nyback, 2007).

HDHS participants were found to be more responsive to positive and negative hallucination suggestion profiles on the RSPS than LDHS participants, but the two groups didn't differ on the remaining profiles. As in study 1, the HDHS participants were found to exhibit greater involuntariness during the RSPS profiles than the LDHS and LS participants. HDHS participants were also found to exhibit impaired performance relative to the LDHS and LS participants on both measures of working memory capacity, whereas LDHS participants

displayed superior performance on the measure of object visual imagery. Finally, the three groups didn't differ in general psychopathology nor a measure of imaginative involvement; however, the HDHS participants reported greater dissociative and fantasy pathological phenomena, suggesting a predisposition to psychopathology in this group.

This study provides further evidence for the dissociative typological models. In particular, we provide strong evidence for a dissociative subtype and an imagery subtype, thus conceptually replicating the principal findings of study 1.

Study 3

An important issue in contemporary hypnosis research is how a hypnotic induction impacts cognitive control functions subsumed under executive attention (Egner & Raz, 2007). Cognitive control can be understood as the ability to bias attention toward particular stimulus dimensions in a task in order to improve one's performance in the task. This question is important because the two current dominant theories of hypnosis, dissociated control theory (Woody & Sadler, 2008) and response set theory (Lynn, Kirsch, & Hallquist, 2008), make different predictions regarding how hypnosis modulates cognitive control. Dissociated control theory predicts that a hypnotic induction impairs cognitive control, whereas response set theory maintains that a hypnotic induction will not have a deleterious effect on cognitive control or that it may actually marginally improve cognitive control. A previous study on HDHS and LDHS participants provides an interesting solution to this question. King and Council (1998) found that whereas HDHS participants required minimal attention to respond to a hypnotic suggestion, as predicted by dissociated control theory (Woody & Sadler, 2008), LDHS participants' responsiveness to a suggestion required greater attention, as predicted by response set theory (Lynn et al., 2008). On the basis of this finding, we predicted that a hypnotic induction would impair cognitive control in HDHS participants (as predicted by dissociated control theory), but would have no effect, or would improve cognitive control, in LDHS participants (as predicted by response set theory).

In this study, 19 LS, 18 LDHS, and 11 HDHS participants completed a Stroop color-naming task in a control condition and following a hypnotic induction. The Stroop task requires participants to identify the color of colored words, while ignoring the word itself (e.g., respond 'RED' to the word 'BLUE' printed in the color red), and is a recognized measure of selective attention (Egner, 2007). Rather than computing the traditional Stroop interference effect (i.e., the response time difference between incongruent and congruent trials) as a performance measure, we opted to examine sequential congruency effects as a measure of cognitive control. The

sequential congruency effect refers to a reduction in Stroop interference following incongruent trials relative to congruent trials (Gratton, Coles, & Donchin, 1992). Trials are parsed as to whether the preceding trial was congruent or incongruent and whether the current trial is congruent or incongruent. A sequential congruency effect is observed when Stroop interference between congruent trials preceded by an incongruent trial (IC) and incongruent trials preceded by an incongruent trial (II) is significantly lower than the Stroop interference between congruent trials preceded by a congruent trial (CC) and incongruent trials preceded by a congruent trial (CI). The conflict monitoring model (Botvinick, 2007) maintains that incongruent trials engender increased response conflict and subsequently trigger an increase in cognitive control on the subsequent trial, which leads to the observed reduction in Stroop interference following incongruent trials.

We specifically predicted that sequential congruency effects would weaken (reflecting poorer cognitive control) in the HDHS participants from the control to the hypnosis condition, whereas they would remain stable or improve (reflecting superior cognitive control) in the LS and LDHS participants. HDHS participants were found to exhibit significantly more pronounced sequential congruency effects in the control condition than the two other groups, who didn't differ from one another. This indicates that the HDHS participants exhibit greater cognitive control at baseline. Following a hypnotic induction, the sequential congruency effects in LS and LDHS participants improved, as reflected in a greater reduction in Stroop interference following incongruent trials. However, the improvement in the hypnosis condition was non-significant in LS participants and only marginally significant in the LDHS participants. This suggests that a hypnotic induction marginally improves cognitive control in LDHS participants. In contrast, the sequential congruency effect in the HDHS participants was significantly weakened in the hypnosis condition. This indicates that, as predicted, a hypnotic induction effects a weakening of cognitive control in HDHS participants.

This study demonstrates that dissociative tendencies modulate the impact of a hypnotic induction on cognitive control in HS participants. Specifically, we found that HDHS participants exhibited poorer cognitive control during hypnosis relative to a control condition, whereas LDHS participants exhibited marginally superior cognitive control. This study provides further support for the dissociative typological models and indicates that a hypnotic induction differentially impacts the ability to flexibly utilize cognitive control processes. These results also conceptually replicate those of study 1 in which the inward-attention (low dissociative) subtype exhibited superior attention, awareness, and volition than the dissociative subtype.

Study 4

A further area of inquiry in which the dissociative typological model may yield insights is the neurophysiology of hypnosis. Hypnosis researchers have found it very difficult to identify the electrophysiological correlates of the hypnotic state using spectral analysis of the electroencephalogram (EEG). In contrast, a number of studies have suggested that hypnosis reduces resting state functional connectivity (or neural synchrony), that is, the synchronization among neural assemblies (Cardeña et al., 2008; Fingelkurts et al., 2007). Insofar as state dissociation is characterized by disruptions between different dimensions of consciousness, we reasoned that increased state dissociation following a hypnotic induction would be reflected in a reduction in neural synchrony, particularly over anterior regions of the cortex. In addition, we predicted that this effect would be more pronounced among HDHS individuals.

The same samples of LS, LDHS, and HDHS individuals that took part in studies 2-4 participated in this study. Scalp EEG was recorded during control and hypnosis conditions. Specifically, three-minute periods of EEG were recorded once in a control condition, once during hypnosis, and once more following a de-induction. In addition, participants completed a measure of state dissociation (Marshall, Orlando, Jaycox, Foy, & Belzberg, 2002) in reference to each resting epoch.

Raw EEG data were segmented into two-second epochs. Epochs with artifacts ($\pm 80 \mu\text{V}$) were excluded as were epochs that had other artifacts identified by visual inspection. Two measures of synchronization, omega complexity and synchronization likelihood, were computed on band-pass filtered data for each epoch over left anterior, right anterior, left posterior and right posterior electrodes in the following frequency bands: delta (0.5 – 4), theta1 (4.5 – 6), theta2 (6.5 – 8), alpha1 (8.5 – 10), alpha2 (10.5 – 12), beta (15 – 25) and gamma (35 – 45). Values were subsequently averaged for each epoch prior to statistical analysis.

In contrast with our central prediction, and the dissociative typological model more broadly, the two subtypes did not differ in state dissociation or neural synchrony across conditions. As a result, they were pooled into one group. Across the two experimental sessions, HS and LS individuals exhibited increases in state dissociation during hypnosis, but these effects were more pronounced among HS individuals. In a similar fashion, both groups displayed reductions in neural synchrony, as measured by synchronization likelihood, in all regions and nearly all frequency bands during hypnosis. However, these effects were more pronounced among HS individuals. Importantly, the analyses on omega complexity only revealed significantly greater decreases in neural synchrony during hypnosis among HS individuals over anterior regions and in fast (beta and gamma) frequency bands. Increases in state dissociation

during hypnosis correlated with reductions in neural synchrony as measured by synchronization likelihood but not as measured by omega complexity. This suggests that the two measures are indexing overlapping but distinct elements of synchronization.

The results of this study clearly indicate that HS individuals display a uniform phenomenological and neurophysiological response to hypnosis. The results also corroborate and extend previous studies demonstrating that hypnosis reduces functional connectivity (Cardeña et al., 2008; Fingelkurts et al., 2007). We extend these studies by showing that such reductions are associated with increases in state dissociation and are present in a wide range of regions and frequency bands. Insofar as these findings point to uniformity in the two HS subtypes, they point to the need for a revision of the dissociative typological model.

Study 5

This study aimed to apply the dissociative typological model to the reporting of anomalous perceptual experiences. Previous studies have demonstrated a consistent relationship between hypnotic suggestibility and the reporting of anomalous perceptual experiences (Kumar & Pekala, 2001). In addition, there is reason to believe that HS participants may exhibit superior performance on psi tasks (Cardeña, 2006). Previous research has suggested that hypnotic suggestibility and dissociative tendencies interact in the experience of anomalous perceptions, leading HDHS participants to report more anomalous experiences (Kumar & Pekala, 2001). Barber's (1999) model offers a refined version of this relationship. Barber (1999) specifically argued that fantasy-prone HS participants are more likely to experience imagery-based anomalous experiences such as hallucinations, precognitive dreams, synaesthesia, and out-of-body experiences (OBEs). In contrast, amnesia-prone (or dissociative) HS participants are more likely to experience amnesic or dissociative anomalous experiences such as mediumship or spirit possession. Cardeña (2006) further extended Barber's (1999) model by predicting that fantasy-prone HS participants will perform better on free-response psi tasks that more critically invoke imagery abilities, such as the Ganzfeld (Wackermann, Putz, & Allefeld, 2008), whereas amnesia-prone (or dissociative) HS participants will perform better on implicit psi tasks that rely more on non-conscious processing of the purported psi stimulus. The present study attempted to test a number of these predictions.

The same samples of LS, LDHS, and HDHS participants as in studies 2 through 4 were included in this study. Participants completed two self-report measures of anomalous experiences (Kumar, Pekala, & Gallagher, 1994; Bell, Halligan, & Ellis, 2006) and a third that concerned the experience of OBEs and their phenomenology. In addition, the three groups completed a

behavioural task of weak color-pitch synaesthesia that consisted of black and white squares and high and low pitch tones. Previous research has indicated that participants exhibit a tendency to respond faster to auditory stimuli when they are paired with a conceptually congruent color (black/low pitch and white/high pitch) than when they are not (black/high pitch and white/low pitch) (Martino & Marks, 1999). We predicted that LDHS participants would exhibit a greater color-pitch correspondence than the other two groups, as Barrett (1996) argued that fantasy-prone HS participants report more synaesthetic experiences. Finally, participants completed a pre-stimulus response (PSR) task modelled after that of Hinterberger and colleagues (Hinterberger, Studer, Jäger, Haverly-Stacke, Walach, 2007). In this study, EEG was recorded from participants' scalps while they viewed low arousal (e.g., a chair) and high arousal (e.g., war footage) visual stimuli in random order. Previous studies have found that high arousal stimuli are associated with a negative-going slow wave event-related brain potential component prior to stimulus onset that is of greater magnitude than that for low arousal stimuli. The PSR has been argued to reflect an anomalous form of precognitive anticipation of the subsequent stimulus. We predicted that HDHS participants would exhibit a greater PSR effect (i.e. greater magnitude pre-stimulus component for high arousal than low arousal stimuli) than LDHS and LS participants.

HDHS participants were found to exhibit greater scores on both measures of anomalous experiences than LDHS and LS participants, who didn't differ from one another. LS participants reported fewer OBEs than both HDHS and LDHS participants, who did not differ. Among those reporting OBEs (8/19 LDHS, 7/10 HDHS, and 4/21 LS), hypnotic suggestibility was found to moderate the experience of visual content during the OBE. None of the LS participants reported that their OBE(s) possessed any visual features, whereas a majority of the OBEs reported by HS participants had visual features (LDHS: 75%, HDHS: 86%). Importantly, no differences were found on the color-pitch task across the three groups.

Turning next to the PSR task, we found no overall PSR effect, that is, the total sample didn't exhibit a greater negative component for high affect stimuli prior to stimulus onset relative to low affect stimuli. However, the three groups were found to exhibit significant differences. Importantly, and counter to the central hypothesis of the dissociative typological model, HDHS and LDHS participants did not exhibit differences in the pre-stimulus or post-stimulus periods; the two subtypes were henceforth amalgamated to increase statistical power. HS participants did not exhibit a significant PSR effect whereas the LS participants exhibited a significant PSR effect with a moderate effect size. Although this finding runs counter to our hypothesis and the common intuition that HS participants – who report more anomalous perceptual experiences – should perform better on a psi task, an intriguing result of this study may account for this unexpected

finding. Importantly, the HS participants did not exhibit significant differences between high and low affect stimuli in the *post*-stimulus period; this finding seems to indicate that these participants exhibit blunted affect, that is, minimal affective response to the stimuli. In contrast, the LS participants exhibited robust differences between the two types of stimuli in the post-stimulus period. These findings are paramount because previous studies have found a relationship between the magnitude of the PSR and participants' post-stimulus response (e.g., Radin & Borges, 2009). Accordingly, this study conceptually replicates this finding.

The results of this study replicate previous studies and provide novel information about how hypnotic suggestibility may influence the experience of anomalous perceptions. In particular, it was found that the elevated general reporting of anomalous experiences in HS participants was isolated to those who exhibit high dissociative tendencies, whereas LDHS and HDHS participants both reported greater amounts of OBEs relative to LS participants. Furthermore, hypnotic suggestibility was found to influence the phenomenology of OBEs. Although HDHS participants report more spontaneous anomalous perceptual experiences, HS participants were cumulatively found to exhibit no PSR effect, whereas LS participants did exhibit the PSR effect. These results strongly suggest that dissociative and hypnotic processes play a critical role in the incidence and phenomenology of spontaneous anomalous perceptual experiences and psi in the laboratory.

Study 6

This study departed from the general aims of the five previous studies by examining whether synaesthesia can be disrupted by posthypnotic suggestion. Synaesthesia is an unusual neurological condition characterized by anomalous correspondences between or within sensory modalities (e.g. seeing colors when listening to music). This study was not part of our original grant proposal nor our research on different HS subtypes, but was done when we discovered that one of our HDHS participants had face-color synaesthesia. Following on from previous research that used posthypnotic suggestions for aphasia to eliminate the Stroop interference effect, we sought to examine whether synaesthesia could be disrupted using posthypnotic suggestion. This is an important question because there is broad consensus among synaesthesia researchers that synaesthesia is automatic and resistant to control (Hochel & Milán, 2008).

A single female HS synaesthete (A.R.) and six age and sex-matched HS controls without synaesthesia, drawn from the same sample as in the other studies, participated in this study. The reliability of A.R.'s synaesthesia was determined with a face-color correspondence task. The main task involved identifying the color of different faces on a computer monitor. The face-color

combinations differed such that most of the faces were presented in a different color than the one experienced by A.R. for the particular face (incongruent faces), whereas some of the faces were presented in the same color as the one that A.R. experienced with that face (congruent faces). In the experiment, A.R. completed the task three times: at baseline, following a posthypnotic suggestion for the termination of her synaesthesia, and following the cancellation of the suggestion. She completed the experiment twice; in the first session, only behavioral data were collected whereas in the second session, behavioral and EEG data were recorded. The controls only completed the task once while scalp EEG was recorded.

A.R. exhibited a robust Stroop interference effect in both sessions. This effect, which was characterized by slower response times for incongruent faces than congruent faces, was not found with the controls. Incongruent faces were also found to be associated with a greater magnitude sustained N400 ERP component over frontal midline electrodes. This component has been repeatedly found in selective attention tasks and is widely regarded as a marker of response conflict (Carter, & Van Veen, 2007). These results indicate that incongruent faces are associated with increased response conflict in A.R.; the behavioral interference effects, in particular, are consistent with previous findings suggesting that synaesthesia is automatic (Hochel & Milán, 2008). Critically, A.R.'s behavioral interference effect disappeared in the posthypnotic condition in both sessions, as did the N400 effect in session 2; in all cases, there were no longer any significant differences between A.R. and the control participants. Finally, following the cancellation of the suggestion, the behavioral interference effect returned in both sessions, as did the N400 effect in session 2.

This study demonstrates that contrary to widely-held views held by synaesthesia researchers, synaesthesia can be temporarily abolished by cognitive control. This finding has important implications for the cognitive mechanisms underlying synaesthesia and provides further evidence for the instrumental utility of hypnosis in the study of cognitive and neurological phenomena.

Output

Presentations

The results of studies 1, 2, and 3 were presented at five conferences in 2009: the *Association for Psychological Science* (poster), the *Association for the Scientific Study of Consciousness* (poster), *Division 30 of the American Psychological Association* (oral), the *International Society of Hypnosis* (oral), and the *Society for Clinical and Experimental Hypnosis* (oral). The presentation of study 3 at the meeting of Division 30 was awarded the Nicholas P. Spanos graduate student award. In addition to presenting the cumulative results of the six studies

at the Bial Foundation's *Behind and Beyond the Brain* symposium in 2010, we presented the results of study 6 in oral form at the 2010 UK Synaesthesia Association conference.

Manuscripts

At the time of writing, the manuscript describing study 1 has been accepted by *Consciousness and Cognition* (see attached). Manuscripts describing studies 2, 3, and 6 are currently under review (see attached). A preliminary drafts of a paper describing study 4 has been completed (see attached); we anticipate submitting this papers in the next month. A paper describing study 5 will be written shortly with an aim of submitting it in the summer or autumn. We will inform the Bial Foundation and provide a copy of each paper once it is published.

Summary & Conclusions

In studies 1, 2, and 3, we consistently found evidence for two subtypes of HS participants. We found that these two subtypes vary in both hypnotic responding, phenomenological response to a hypnotic induction, and cognitive functioning. In addition, we found that the dissociative HS subtype reports an inflated level of anomalous perceptual experiences. Importantly, the two subtypes did not display different neurophysiological patterns in a resting condition or in response to stimuli of different valence. In the latter study, we found that LS participants exhibited a greater anomalous PSR to high affect stimuli, a finding that corroborates previous work on this phenomenon. Cumulatively, these studies provide preliminary support for the dissociative typological model of high hypnotic suggestibility and demonstrate how the investigation of these HS subtypes can greatly inform our understanding of both the incidence and phenomenology of anomalous perceptual experiences.

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Appendices:

1. Terhune, D. B., & Cardeña, E. (accepted). Differential patterns of spontaneous phenomenological response to a hypnotic induction: A latent profile analysis. *Consciousness and Cognition* [Study 1]
2. Terhune, D. B., Cardeña, E., Lindgren, M. (submitted). *Dissociation and individual differences in high hypnotic suggestibility*. Manuscript under review. [Study 2]
3. Terhune, D. B., Cardeña, E., Lindgren, M. (submitted). Dissociated control as a signature of typological variability in high hypnotic suggestibility. [Study 3]
4. Terhune, D. B., Cardeña, E., Lindgren, M. (submitted). *Disruption of synaesthesia by posthypnotic suggestion: An ERP study*. Manuscript under review. [Study 6]
5. Terhune, D. B., Cardeña, E., Lindgren, M. (in preparation). Hypnosis reduces resting state functional connectivity. [Study 4]

RUNNING HEAD: Resolving heterogeneity in hypnotic experience

Differential patterns of spontaneous experiential response to a hypnotic induction: A latent
profile analysis

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Abstract

A hypnotic induction produces different patterns of spontaneous experiences across individuals. The magnitude and characteristics of these responses covary moderately with hypnotic suggestibility, but also differ within levels of hypnotic suggestibility. This study sought to identify discrete phenomenological profiles in response to a hypnotic induction and assess whether experiential variability among highly suggestible individuals matches the phenomenological profiles predicted by dissociative typological models of high hypnotic suggestibility. Phenomenological state scores indexed in reference to a resting epoch during hypnosis were submitted to a latent profile analysis. The profiles in the derived four-class solution differed in multiple experiential dimensions and hypnotic suggestibility. Highly suggestible individuals were distributed across two classes that exhibited response patterns suggesting an inward attention subtype and a dissociative subtype. These results provide support for dissociative typological models of high hypnotic suggestibility and indicate that highly suggestible individuals do not display a uniform response to a hypnotic induction.

Keywords: hypnosis, hypnotic suggestibility, dissociation, fantasy-proneness, involuntariness, phenomenology, typology, latent profile analysis

Although considerable attention has been devoted to the striking distortions in agency induced by suggestions administered during hypnosis, a hypnotic induction alone is capable of producing profound alterations in a variety of dimensions of consciousness. A hypnotic induction consists of a set of instructions and suggestions to help a participant become absorbed in the experimenter's words and reduce their awareness of exogenous stimuli (e.g., Oakley & Halligan, 2009). Unusual spontaneous experiences following a hypnotic induction, omitting particular suggestions, are commonplace but remain understudied (Cardeña, 2005; Pekala & Kumar, 2007; Rainville & Price, 2003). Many individuals, in particular those of high hypnotic suggestibility, frequently report various types of alterations in core phenomenological dimensions of consciousness. Such experiences include vestibular perceptions of floating, marked changes in temporal perception, affect, and internal dialogue, and increased amounts of fantasy-based visual imagery. Some of the variance in these dimensions is attributable to participants' response expectancies (Henry, 1995, as cited in Kirsch, 1999; Pekala, Kumar, & Hand, 1993). However, alterations in these experiential dimensions are still reported among highly suggestible (HS) individuals when a neutral hypnotic induction, which excludes experience-specific suggestions (e.g., for relaxation), is used (Cardeña, 2005).

A consistently replicated finding is that variability in spontaneous experiences during hypnosis covaries with hypnotic suggestibility (Pekala & Kumar, 2007). For instance, HS individuals reliably report greater magnitude alterations in a variety of experiential dimensions than their medium and low suggestible counterparts (Kumar & Pekala, 1988, 1989). However, some studies have observed marked differences in this population (e.g., Barrett, 1996; Pekala & Kumar, 2007). For instance, Barrett (1996) presented evidence for two subtypes of HS individuals, one of which experienced greater alterations in awareness and increased involuntariness during hypnotic responding. HS individuals also exhibit considerable variability

in the types of suggestions to which they respond and the strategies they utilize to facilitate responding (e.g., McConkey & Barnier, 2004).

In order to resolve outstanding questions regarding heterogeneity in this population, various models have proposed that HS individuals are comprised of distinct types of respondents (e.g., Barber, 1999a; Brown & Oakley, 2004; Kunzendorf & Boisvert, 1996). These subtypes are hypothesized to experience hypnosis through different mechanisms and concomitantly exhibit dissimilar experiential response patterns following a hypnotic induction. Dissociative typological models of high hypnotic suggestibility propose that HS individuals are comprised of *dissociative* and *fantasy-prone* respondents (Barber, 1999a; Barrett, 1996; Cardeña, 1996; Carlson & Putnam, 1989; Perry, 2004); Barber (1999a) has also proposed a third type: *positively-set* respondents. According to these models, a hypnotic induction produces a state of experiential detachment in dissociative respondents that is characterized by reduced awareness, attention, episodic memory, imagery, and volitional control relative to other HS individuals. In contrast, fantasy-prone respondents are hypothesized to exhibit alterations in awareness during hypnosis of lower magnitude than dissociative respondents, but to experience greater attentional involvement (absorption), imagery, episodic memory, and volitional control. Positively-set respondents are hypothesized to exhibit relatively minor spontaneous alterations in experiential dimensions of consciousness that don't differ substantially from individuals of low hypnotic suggestibility. (For critical reviews of these models, see Barber [1999b] and accompanying commentaries).

Support for the experiential predictions of the typological models has been provided by cluster analysis studies (Forbes & Pekala, 1996; Pekala, 1991b; Pekala & Forbes, 1997; Pekala et al., 1995; for a review see Pekala & Kumar, 2007). In these studies, participants experienced a short resting epoch embedded within a standardized behavioral measure of hypnotic

suggestibility. Participants subsequently completed the *Phenomenology of Consciousness Inventory* (PCI; Pekala, 1991a) in reference to their spontaneous experiences during the resting epoch. The PCI taps a wide variety of experiential dimensions including body image, temporal perception, positive affect, attentional absorption, and visual imagery.

In four studies, Pekala and colleagues used *K*-means cluster analyses to derive discrete types of respondents at multiple levels of hypnotic suggestibility on the basis of PCI dimension scores (Pekala & Kumar, 2007). In the first study, Pekala (1991b) derived two types of HS participants, labelled *fantasy* and *classic* types, both of which were subsequently replicated by Pekala and Forbes (1997). The principal features of the fantasy type's experiential response were vivid imagery, positive affect, and mild reductions in awareness and memory, whereas the classic type experienced less vivid imagery, reduced control and memory, and greater alterations in awareness. In another study, Pekala et al. (1995) derived two types of HS participants, one that corresponded to the classic type and another labelled *compliant*, which was similar to the fantasy type except that it exhibited less imagery and positive affect and more internal dialogue. A final study replicated the classic type and found a second type interpreted as a hybrid of the fantasy and compliant types (Forbes & Pekala, 1996) and, in a separate seven-cluster solution, replicated the fantasy and classic types and observed a small percentage of HS participants classified in another cluster who exhibited minor alterations in the measured experiential dimensions.

These studies have been criticized for a lack of consistently derived cluster solutions (Lynn Meyer, & Schindler, 2004), but, collectively, provide evidence for distinct patterns of phenomenological response to a hypnotic induction among HS individuals. Further, they suggest that such patterns may be grounded in a latent typology. The classic type was consistently replicated, whereas the characteristics of a second (and possibly third) type are equivocal. Notwithstanding this issue, there are clear parallels between the phenomenological response of

the different clusters and the experiential profiles predicted by the dissociative typological models (e.g., Barber, 1999a). The results, however, appear to provide greater support for bifurcated (Barrett, 1996; Brown & Oakley, 2004; Carlson & Putnam, 1989; Kunzendorf & Boisvert, 1996) than trifurcated (Barber, 1999a) typological models.

Lack of consistency is neither the only nor most salient limitation of these studies. Although some of the analyses were undertaken on the entire sample, many of the derived cluster solutions were generated by cluster analyses performed on relatively small sample sizes of HS participants ($ns < 100$). The analyses could also have been strengthened by a validation check of the different types using an independent measure of theoretical significance. Furthermore, the hypnotic suggestibility of the derived types was not contrasted in order to identify their behavioral correlates. Barber (1999a), for instance, proposes that the dissociative subtype is more responsive to posthypnotic amnesia suggestions. A final limitation of these analyses is the use of *K*-means cluster analysis. Despite its pervasive use, there exists no consensus regarding analytic techniques for class enumeration, that is, the determination of an optimal number of clusters, in a sample using this method (Ruscio & Ruscio, 2008; Vermunt & Magidson, 2002). It follows that the reliability and validity of the derived cluster solutions in these studies may be suspect.

Many of the limitations of *K*-means cluster analysis are circumvented by latent variable modelling techniques such as latent profile analysis (LPA; Goodman, 2002; see also McCutcheon, 1987; 2002). LPA is a method for identifying homogeneous profiles in multivariate continuous data. The central assumption of LPA is that variability in a set of continuous indicator (observed) variables stems from a set of patterns determined by an underlying categorical latent (unobserved) variable comprised of multiple profiles (Vermunt & Magidson, 2002). The principal strength of LPA is that it allows for the computation of model fit statistics that render the process of class enumeration less arbitrary than *K*-means cluster analysis. In addition, LPA

enables the testing of more complex models, such as ones that free restrictions on indicator covariance (Vermunt & Magidson, 2002). In multiple comparative assessments, LPA consistently exhibited superior performance than *K*-means cluster analysis (Magidson & Vermunt, 2002).

The Present Study

There has been relatively little research on spontaneous phenomenological alterations during hypnosis and their underlying mechanisms (Rainville & Price, 2003). Spontaneous alterations in experiential dimensions of consciousness may reflect mind-wandering and a consequent weakening of executive functioning (Smallwood, Beach, Schooler, & Handy, 2008). Impaired executive functioning during hypnosis has been argued to modulate hypnotic suggestibility and play a critical role in mediating responsiveness to hypnotic suggestions (Egner, Jamieson, & Gruzelier, 2005; Woody & Bowers, 1994; Woody & Sadler, 2008). Accordingly, the examination of individual differences in spontaneous experiential response profiles among HS individuals and whether they exhibit a typological pattern represents a critically important endeavour for understanding the nature of hypnosis and hypnotic suggestibility.

This study used LPA to identify the optimal number and principal characteristics of different experiential response profiles following a hypnotic induction. Participants were administered a standardized group measure of hypnotic suggestibility within which was embedded a resting epoch. Following a de-induction, participants retrospectively completed the PCI (Pekala, 1991a) and the *Inventory Scale of Hypnotic Depth* (ISHD; Field, 1965). The ISHD is a measure of experiential involvement and involuntariness during hypnotic responding and was included to independently validate the dissociative typology because it has been argued to

discriminate dissociative and fantasy-prone HS individuals (Barrett, 1996). In addition to predicting that LPA would discern a poly-class solution of experiential profiles on the basis of PCI factor-based scores, we expected HS individuals to fall into two or three phenomenological classes that would exhibit dissimilar experiential profiles, suggesting a typological distribution. Finally, we tested the prediction that the experiential response patterns of the derived profiles would correspond to those predicted by the bifurcated and trifurcated dissociative typological models (Barber, 1999a; Barrett, 1996; Cardeña, 1996; Carlson & Putnam, 1989; Perry, 2004).

Method

Participants

Six hundred and forty individuals (375 females [59%]), whose ages ranged from 18 to 65 ($M = 23.71$, $SD = 5.62$), consented to participate in this study. Women ($M_{Age} = 23.55$, $SD = 5.56$) and men ($M_{Age} = 23.93$, $SD = 5.71$) didn't differ in age, $t < 1$. Participants were recruited through advertisements at Lund University and in the city of Lund or volunteered as part of an introductory psychology course. This study was approved by the local ethics committee.

Materials

Hypnotic Suggestibility. The Waterloo-Stanford Group Scale of Hypnotic Susceptibility, Form C (WSGC; Bowers, 1993, 1998) was used to measure responsiveness to hypnotic suggestions. The WSGC is a group adaptation of the individually-administered *Stanford Hypnotic Susceptibility Scale, Form C* (Weitzenhoffer & Hilgard, 1962) and consists of 12 dichotomously-scored items including direct ideomotor (e.g., arm heaviness), challenge motor (e.g., arm immobilization), and cognitive-perceptual (e.g., auditory hallucination) suggestions,

with scores ranging from 0 to 12. This measure has strong psychometric properties (Bowers, 1993, 1998).

Experiential Dimensions of Consciousness. The PCI (Pekala, 1991a) is a 53-item self-report scale measuring different dimensions of consciousness that is completed retrospectively in reference to a preceding interval. Each item consists of a pair of bipolar statements anchored on a seven-point Likert scale. The PCI consists of 12 dimensions (and 14 sub-dimensions): altered experience (body image, time sense, perception, and meaning); positive affect (joy, sexual excitement, and love); negative affect (anger, sadness, and fear); attention (direction and absorption); imagery (amount and vividness); self awareness; altered state of awareness; arousal; rationality; volitional control; memory; and internal dialogue. Kumar, Pekala, & Cummings (1996a) derived five PCI factors: attention to internal processes, dissociated control, negative affect, positive affect, and visual imagery.

Experiential Involvement & Involuntariness. The ISHD (Field, 1965) is a self-report scale composed of 38 dichotomous (true/false) items that measure alterations in awareness, perception, and volition during hypnosis. Representative items include: "At times I felt completely unaware of being in an experiment" and "Parts of my body moved without my conscious assistance." The scale exhibited strong internal consistency in this sample (Cronbach's $\alpha = .89$).

Procedure

Participants completed the WSGC in groups ranging in size from four to 40. A clinically-trained consultant was present during all sessions (see Cardeña & Terhune, 2009). A two-minute resting epoch was embedded within the WSGC prior to the administration of items 11 and 12. Prior to the epoch, participants were instructed to sit quietly with their eyes closed and continue

to experience hypnosis. Following the de-induction, participants completed the WSGC response booklet, the PCI in reference to the rest epoch, and the ISHD in reference to the whole session.

Statistical Analyses

The five PCI state factor-based scores (Kumar et al., 1996a) were used as the observable indicators for the derivation of the profiles using LPA. The fit of multiple models (two-class through five-class) was assessed. For each class solution, restricted and unrestricted models were evaluated. In the former, the covariance among indicators is restricted to zero, whereas in the latter it is allowed to be free. Restricted models commonly overestimate the number of profiles and provide less parsimonious solutions (Vermunt & Magidson, 2002). The selection of variables allowed to covary in the unrestricted models was made on the basis of the significance of the correlations among the indicator variables in Table 1. Statistical fit of the different models was evaluated using three information criterion indices: Akaike information criterion (AIC; Akaike, 1987), Bayesian information criterion (BIC; Schwarz, 1978), and the sample-size adjusted BIC (SSABIC; Sclove, 1987). In each case, lower values reflect superior model fit (Vermunt & Magidson, 2002). Two likelihood-ratio based tests were used: the Lo-Mendell-Rubin likelihood-ratio test (LMR-LRT; Lo, Mendell, & Rubin, 2001) and the Bootstrap likelihood-ratio test (BLRT; McLachlan & Peel, 2000). LMR-LRT and BLRT are used to adjudicate between nested models. For both, a non-significant value indicates that a model does not have superior fit than the corresponding model with one less class. The BLRT has consistently outperformed the LMR-LRT in comparative assessments (Nylund et al., 2007) and was given preference in class enumeration. Entropy values were calculated on the basis of each model's posterior probabilities for group membership and range from 0 to 1 with low values indicating poor classification of participants (Ramaswamy, Desarbo, Reibstein, & Robinson, 1993). The analyses were conducted

with MPLUS v. 5.0 (Muthén & Muthén, 1998-2007) with secondary analyses performed with SPSS v. 16.0. Non-parametric tests were used for many of the secondary analyses due to violations of the assumptions of homogeneity of variance. Outliers ($M \pm 2 SDs$) were excluded for contrasts among the different profiles.

Results

Intra-test Reliability

The PCI includes a set of items that allow for the computation of a reliability index (Pekala, 1991a). Twenty-five participants (4%) exhibited unacceptable values (> 2); this compares favorably to a previous study (9%; Kumar et al., 1996a). These individuals' data were excluded from the analyses, which thereafter included 615 participants.

Descriptive Statistics

Descriptive statistics and correlation coefficients for the research measures are presented in Table 1. All of the correlations were positive. WSGC scores were moderately correlated with ISHD scores and dissociated control, positive affect, and attention to internal processes, weakly correlated with visual imagery, and uncorrelated with negative affect. All other correlations were significant except for that between negative affect and visual imagery.

**** Insert Table 1 about here ****

Phenomenological Profiles

All models exhibited high entropy values, indicating acceptable participant classification. Unrestricted models exhibited superior fit to the data for all class solutions, as reflected by lower

information criteria values, than restricted models (see Table 2). The four-class unrestricted model had a comparable BIC value to the three-class unrestricted model and lower AIC and SSABIC values, indicating its superior fit. In addition, the former model had a significant BLRT value, indicating that it is a better model than the latter. The unrestricted five-class model had superior AIC and SSABIC values than the four-class unrestricted model. However, its BIC was lower and its BLRT value was not consistently replicated, indicating its instability and the unreliability of its p -value. Moreover, the replicability of BLRT values declined with the inclusion of increased starting values. Because of these replicability failures and for the sake of parsimony, we selected the four-class unrestricted model as the optimal model.

**** Insert Table 2 about here ****

Participants were assigned to a profile on the basis of posterior probabilities. Table 3 presents descriptive statistics for the different profiles. Profile 2 was the largest class, whereas the rest exhibited comparable sample sizes. The profiles did not differ in age, $F < 2.5$, but there was a significant relationship between sex and profile, $\chi^2(3, N = 615) = 25.20, p < .001$. Profile 2 had a greater proportion of women than the other profiles, profiles 1 and 3 had comparable sex distributions, and profile 4 had the largest proportion of males. The profiles were also found to differ as a function of categorical hypnotic suggestibility level (low, medium, high), $\chi^2(6, N = 615) = 87.27, p < .001$. Profiles 1 and 2 were primarily comprised of participants in the medium range of hypnotic suggestibility, whereas profiles 3 and 4 were primarily comprised of those in

the low range of hypnotic suggestibility. HS participants were distributed across profiles 1 and 2 with none in profile 3 and two in profile 4.²

**** Insert Table 3 about here ****

To identify their characteristic features, we first contrasted the four profiles on the five PCI state scores. Kruskal-Wallis tests yielded main effects of Profile for all five PCI state scores: dissociated control, $H(3) = 332.52, p < .001$, positive affect, $H(3) = 327.81, p < .001$, negative affect, $H(3) = 334.58, p < .001$, visual imagery, $H(3) = 67.38, p < .001$, and attention to internal process, $H(3) = 279.24, p < .001$. Bonferroni-corrected *post hoc* Mann-Whitney tests indicated a clear demarcation between the first two and last two profiles, that is, profiles 1 and 2 differed from 3 and 4, on all five PCI state scores. Profile 1 was found to have lower negative affect and greater attention to internal processes than profile 2, whereas profile 4 exhibited greater dissociated control, positive affect and negative affect than profile 3. These findings indicate that profiles 1 and 2 represent participants who exhibited marked experiential responses to a hypnotic induction, whereas profiles 3 and 4 were comprised of participants who experienced relatively moderate responses.

Next, we sought to further examine variability in PCI state scores between the first two profiles as a function of hypnotic suggestibility. We restricted this analysis to profiles 1 (inward attention) and 2 (dissociative), which were the only two profiles that included HS participants (see Table 4 for descriptive statistics). A 2 (Profile: inward attention v. dissociative) \times 3 (Hypnotic suggestibility: low, medium, high) multivariate analysis of variance on the five PCI

² In another study (Terhune, Cardeña, & Lindgren, 2010), the two HS participants in class 4 were both found to be false positives, that is, they failed to meet screening criteria for high hypnotic suggestibility as measured by individually-administered scales (Weitzenhoffer & Hilgard, 1967).

state factors revealed main effects of Profile, $F(5, 379) = 43.64, p < .001, \eta^2 = .37$, and Hypnotic suggestibility, $F(10, 758) = 4.93, p < .001, \eta^2 = .06$, but no interaction, $F < 2$. In addition to the main effects of Profile on negative affect and attention to internal processes reported above, main effects of Hypnotic suggestibility were found for dissociated control, positive affect, visual imagery, and attention to internal processes, all $F_s > 5$, all $p_s < .007$, η^2 range: .03 - .09. These effects were mediated by Profile \times Hypnotic suggestibility interactions for dissociated control, visual imagery, and attention to internal processes, all $F_s > 3$, all $p_s < .05$, all $\eta^2_s = .02$. In the inward attention profile, medium suggestible and HS participants exhibited greater dissociated control than low suggestible participants, but the former two did not differ from one another. HS participants in this profile also exhibited greater visual imagery than low suggestible participants, but did not differ from medium suggestible participants. No differences were found for attention to internal processes in this profile. In contrast, dissociated control and attention to internal processes increased in a significant linear fashion as a function of hypnotic suggestibility in the dissociative profile, whereas visual imagery increased from low to medium hypnotic suggestibility and did not differ between medium suggestible and HS participants. This indicates that variability in dissociated control, visual imagery, and attention to internal processes is differentially influenced by hypnotic suggestibility in the two profiles.

Assessment of the Typological Model

As profile 1 exhibited greater internally-directed attention and lower negative affect than profile 2, and the two profiles included all of the HS participants, we next examined whether they exhibited experiential response patterns consonant with the fantasy-prone and dissociative types, respectively. We tested specific directional predictions of the dissociative typological models in HS participants using PCI dimensions and sub-dimensions (see Table 5). The dissociative profile

was expected to exhibit *greater* distortions of awareness and *reduced* attention, imagery, memory, and volitional control than the inward attention profile. In line with these predictions, the dissociative profile exhibited greater scores on the altered experience dimension, $F(1, 55) = 4.35, p < .05, \eta^2 = .07$, and lower scores on attention, $F(1, 55) = 4.25, p < .05, \eta^2 = .07$, including direction of attention, $F(1, 55) = 4.27, p < .05, \eta^2 = .07$, but not absorption, $F < 1.5$. The inward attention profile displayed greater imagery vividness, $F(1, 54) = 4.88, p < .05, \eta^2 = .08$, but did not score higher on the general imagery dimension, nor amount of imagery, $F_s < 1$. The dissociative profile was also found to exhibit suggestively lower volitional control than the inward attention profile, $F(1, 55) = 3.84, p = .055, \eta^2 = .07$. However, in contrast with the predictions of some variants of the dissociative typological model (Barber, 1999a; Barrett, 1996), the two profiles did not differ in memory, $F < 2$.

Barrett (1996) presented evidence indicating that dissociative HS individuals exhibit greater ISHD scores than their non-dissociative counterparts. We next sought to test the effectiveness of the ISHD for discriminating the two profiles of HS participants. In line with Barrett's findings, HS participants in the dissociative profile exhibited significantly greater ISHD scores ($M = 24.77, SD = 5.10$) than those in the inward attention profile ($M = 21.76, SD = 4.55$), $F(1, 54) = 5.21, p < .05, \eta^2 = .09$. This finding was followed up with a 2 (Profile) \times 3 (Hypnotic suggestibility) analysis of variance (ANOVA) on ISHD scores to examine whether the relationship between involuntariness and hypnotic suggestibility differs across profiles. There was no main effect of Profile, $F < 1.5$, but a main effect of Hypnotic suggestibility, $F(2, 383) = 26.10, p < .001, \eta^2 = .12$, which was qualified by a Profile \times Hypnotic suggestibility interaction, $F(2, 383) = 4.18, p < .05, \eta^2 = .02$. Subsidiary one-way ANOVAs revealed main effects of Hypnotic suggestibility in the inward attention, $F(2, 128), p < .001, \eta^2 = .10$, and dissociative, $F(2, 255) = 29.41, p < .001, \eta^2 = .19$, profiles. Although low suggestible participants ($M = 17.35$,

$SD = 4.45$) in the inward attention profile exhibited lower ISHD scores than medium ($M = 20.51$, $SD = 4.74$) and HS participants, $ps < .01$, the latter two didn't differ, $p > .05$. In contrast, low ($M = 13.63$, $SD = 7.57$) and medium ($M = 19.00$, $SD = 6.61$) suggestible participants in the dissociative profile differed from one another as well as HS participants, $ps < .001$. This indicates that the relationship between hypnotic suggestibility and involuntariness during hypnotic responding is linear in the dissociative profile but plateaus in the inward attention profile in medium to high levels of hypnotic suggestibility.

**** Insert Table 4 about here ****

We next report analyses examining differential affective response between the two subtypes of HS participants. A mixed-model ANOVA with Affect as a repeated-measures variable (positive vs. negative) and Profile (inward attention vs. dissociative) as a between-groups variable using Z -score transformed values for the PCI dimension scores revealed main effects of Affect, $F(1, 55) = 7.85$, $p < .01$, $\eta^2 = .13$, Profile, $F(1, 55) = 27.60$, $p < .001$, $\eta^2 = .33$, and an Affect \times Profile interaction, $F(1, 55) = 9.06$, $p < .01$, $\eta^2 = .14$. Follow-up repeated measures ANOVAs revealed a main effect of Affect in the inward attention profile, with lower negative than positive affect, $F(1, 23) = 26.91$, $p < .001$, $\eta^2 = .54$, but no effect in the dissociative profile, $F < 0.5$. These findings indicate that the dissociative profile exhibits an elevated level of *general* affect, relative to participants in profiles 3 and 4, whereas the inward attention profile only exhibits elevated positive affect.

Hypnotic Suggestibility as a Function of Profile

We finally undertook a series of exploratory analyses to discern differences in hypnotic suggestibility between the two profiles. The inward attention profile exhibited significantly greater WSGC total scores ($M = 5.41$, $SD = 2.14$) than the dissociative profile ($M = 4.94$, $SD = 2.14$), $F(1, 387) = 4.20$, $p < .05$, but the magnitude of this difference was negligible: $\eta^2 = .01$. After a Bonferroni correction ($\alpha = .004$), the inward attention profile was found to more frequently respond to the direct ideomotor (arm heaviness) suggestion (90%) than the dissociative profile (74%), $\chi^2(1, N = 389) = 13.16$, $p < .001$, $phi = .18$. There were also trends for the inward attention profile (44%) to exhibit greater responsiveness than the dissociative profile (34%) on the posthypnotic drawing item, $\chi^2(1, N = 389) = 3.83$, $p = .050$, $phi = .10$, but less responsiveness to the negative visual hallucination item (inward attention: 17%, dissociative: 25%), $\chi^2(1, N = 389) = 3.24$, $p = .072$, $phi = .09$. The two profiles did not differ on WSGC total scores or any individual WSGC items when the analyses were restricted to HS participants.

Discussion

This study sought to identify discrete experiential profiles in response to a hypnotic induction and examine whether the profiles of HS participants corresponded to the patterns predicted by dissociative typological models of high hypnotic suggestibility (e.g., Barber, 1999a). The results indicate that phenomenological response to hypnosis can be classified in terms of four experiential profiles. Two involve marked alterations in a variety of experiential dimensions, whereas the other two are characterized by relatively minor experiential shifts. All HS participants fell into the first two profiles, whereas medium and low suggestible participants were distributed among the four profiles. The first two profiles differed in endogenous attention and negative affect, suggesting that they corresponded to the fantasy-prone and dissociative subtypes, respectively, predicted by the dissociative typological models (e.g., Barber, 1999a; Barrett,

1996). Upon closer inspection, HS participants in these two profiles were found to exhibit differential levels of awareness, affect, attention, imagery, and volitional control. All observed findings were in the direction predicted by the dissociative typological models (Barber, 1999a; Barrett, 1996; Carlson & Putnam, 1989). Critically, in replication of a previous finding (Barrett, 1996), the two subtypes were also found to differ in involuntariness during hypnotic responding, as measured by the ISHD. In particular, the fact that the ISHD correlated strongly with dissociated control, but only weakly with imagery scores provides further support for the utility of this measure for discriminating the two subtypes (Barrett, 1996). The results also corroborate many of the findings of previous cluster analyses on spontaneous experiential response to a hypnotic induction (Pekala & Kumar, 2007), as well as the relationships between hypnotic suggestibility and the PCI state scores (Kumar et al., 1996). In sum, the results provide strong support for the proposal that HS individuals are comprised of two distinct subtypes of respondents (Barber, 1999a).

Despite the support found for the dissociative typological models, our results diverge from the models' predictions in multiple respects that are worth considering. First, no evidence was found for a third HS subtype, positively-set respondents (Barber, 1999a). It is plausible that the inward attention and dissociative profiles had members with minimal alterations in awareness that correspond to the positively-set subtype but which were either too few in number or not sufficiently unique in their displayed experiential response patterns to be classified as a discrete phenomenological profile. This possibility notwithstanding, the results favor bifurcated variants of the dissociative typological model (Barrett, 1996; Cardeña, 1996; Carlson & Putnam, 1989; Perry, 2004) rather than the trifurcated version (Barber, 1999a). In addition, the dissociative profile did not exhibit reduced episodic memory during hypnosis, as predicted by Barber (1999a; see also Barrett, 1996), and found in previous cluster analyses (Pekala & Kumar, 2007). Further,

despite reporting less vivid imagery than the inward attention profile, the dissociative profile still exhibited greater vividness of imagery than profiles 3 and 4. This finding is inconsistent with the hypothesis that this subtype experiences minimal imagery following a hypnotic induction (Barber, 1999a; see also Pekala & Kumar, 2007). These disparities may stem from cultural differences (e.g., expectancies) in our sample, relative to previous North American samples. Alternatively, a large proportion of cognitive-perceptual suggestions in the measure of hypnotic suggestibility that we used (Bowers, 1993, 1998) may have invoked greater amounts of imagery, which carried over into the resting epoch. At the very least, these disparities suggest that HS individuals are comprised of two distinct subtypes and that spontaneous episodic memory deficits during hypnosis should not be regarded as a critical marker of typological variability in high hypnotic suggestibility.

A novel finding of this study is that the strongest discriminator of the experiential response profiles of the two types of HS participants was negative affect. Specifically, the dissociative profile exhibited greater negative affect following a hypnotic induction than the inward attention profile. Although previous cluster analyses of PCI dimension scores during hypnosis did not observe greater negative affect in the dissociative subtype of HS participants (Pekala & Kumar, 2007), dissociative tendencies have been found to predict negative affect during hypnosis (Kumar, Pekala, & Marcano, 1996b; Pekala, Kumar, Maurer, Elliott-Carter, Moon, & Mullen, 2009). More broadly, this may suggest a greater proneness to psychopathology in this profile (Pekala et al., 2009), as has been argued elsewhere (e.g., Lynn, Lilienfeld, & Rhue, 1999). One explanation for this finding is that the distortions in awareness produced by the hypnotic induction induced state-dependent memory intrusions in dissociative participants corresponding to negative events to which the participants had previously responded with experiential detachment (e.g., Spiegel & Cardeña, 1990). A second possibility is that greater

negative affect may have resulted from participants' response expectancies (Kirsch, 1999; Lynn, Kirsch, & Hallquist, 2008). However, a recent study, which found that expectations for negative affect during hypnosis were unrelated to its occurrence during hypnosis after controlling for baseline negative affect (Cardeña, Jönsson, Terhune, & Lehmann, 2009), casts doubt on this interpretation.

A final explanation for increased negative affect during hypnosis in the dissociative profile is that the participants in the two profiles experienced increased general affect during hypnosis, but the dissociative profile was unable to sufficiently regulate negative affect due to weakened executive control. For instance, both profiles of HS participants experienced elevated positive affect, but only the dissociative profile experienced elevated negative affect. A finding in another study, that high dissociative HS participants displayed impaired cognitive control during hypnosis relative to a control condition, whereas low dissociative HS participants exhibited marginally superior cognitive control (Terhune, Cardeña, & Lindgren, 2009), clearly supports this interpretation. Increased involuntariness during hypnotic responding among the dissociative profile is also consistent with weakened control during hypnosis in this subtype. In non-hypnotic contexts, a negative mood has been found to increase mind wandering (Smallwood, Fitzgerald, Miles, & Phillips, 2009), which is associated with attentional lapses (Smallwood et al., 2008). Future work should attempt to directly link impaired cognitive control during hypnosis in the dissociative profile with increases in negative affect.

Importantly, the present study failed to identify unequivocal behavioral signatures of the two subtypes of HS individuals. The only robust behavioral difference between the two profiles was the increased level of responsiveness to the direct ideomotor suggestion of the WSGC in the inward attention profile. This difference may have been caused by the fact that this suggestion was administered first, as dissociative HS individuals may require a longer hypnotic induction

before achieving an optimal level of hypnotic suggestibility (Barber, 1999a; Barrett, 1996; Brown & Oakley, 2004). More broadly, the WSGC (and a group environment) may be insufficient for discerning differences among HS individuals. Measures of hypnotic suggestibility with larger proportions of cognitive-perceptual suggestions may be better suited to this task (Weitzenhoffer & Hilgard, 1967; Woody & Barnier, 2008). In addition, future research may consider measuring factorial invariance, that is, equivalence of factor structures, of hypnotic suggestibility scales across the two profiles. Another suitable place to look for differences between the two subtypes may be in their utilization of cognitive strategies during hypnotic responding. Studies on response strategy utilization have provided evidence for distinct subtypes of respondents (Danziger et al., 1998; Kunzendorf & Boisvert, 1996; Winkel, Younger, Tomcik, Borckardt, & Nash, 2006). For instance, Kunzendorf and Boisvert (1996) found that suggestions for negative hallucinations and hyperaesthesia modulated brainstem evoked potentials in only a subset of HS individuals despite the fact that all reported the phenomenal impression of responding to the suggestions. The reconciliation of individual differences in phenomenological response to a hypnotic induction with differential response strategy utilization should be afforded greater attention in future research (see also Brown & Oakley, 2004).

A question raised by critics of the typological models is whether the different subtypes are dimensional, that is, extending from low to high hypnotic suggestibility or taxonic, that is, reflective of a discrete subtype of HS respondent (e.g., Lynn et al., 1999). Barber's (1999a) model is somewhat equivocal in this regard (see commentaries accompanying Barber [1999b]). Although by no means conclusive, the present results suggest that typological variability in experiential response is dimensional rather than taxonic. HS individuals were classified into two profiles, which also included participants of low and medium suggestibility, whereas a taxonic typological pattern would predict that HS individuals would form two or more distinct profiles.

In so far as many of the participants in the dissociative profile exhibited low or medium hypnotic suggestibility, the present findings are also broadly consistent with previous research that demonstrated that high dissociative individuals uniformly experience high experiential involvement during hypnotic responding, but only some display high hypnotic suggestibility (Kumar et al., 1996b). However, the dimensional structure of each profile and in particular, its relationship to hypnotic responding, may differ. For instance, involuntariness during hypnotic responding, and dissociated control and attention to internal processes during the resting epoch, increased linearly as a function of hypnotic suggestibility in the dissociative profile, but did not increase from medium to high hypnotic suggestibility in the inward attention profile. These results could be interpreted as reflecting a taxonic distribution in the dissociative profile and a dimensional distribution in the inward attention profile. Dimensional and taxonic variants of the typological models, and their attendant predictions, require closer inspection in future studies.

An alternative to the typological models is the *componential model* (Woody & Barnier, 2008; Woody, Barnier, & McConkey, 2005). According to this account, hypnotic suggestibility is determined by a single latent factor and individual differences at specific levels of hypnotic suggestibility, in particular those among HS individuals, are modulated by ancillary ‘componential’ abilities. For instance, imagery ability may not correlate with general hypnotic suggestibility but may facilitate responsiveness to particular types of suggestions among HS individuals (see, e.g., Laurence, Beaulieu-Prévost, & du Chéné, 2008). On this account, the two experiential profiles of HS individuals observed in this study do not constitute discrete subtypes *per se*, but rather different ancillary aptitudes (e.g., for altering awareness and agency) that, in turn, affect particular features of hypnotic responding (e.g., involuntariness), but which are not indicative of differential underlying mechanisms. Although the componential model is a valuable alternative to the typological models and warrants greater attention, the different abilities that

contribute to individual differences among HS individuals remain underspecified (Woody et al., 2005; see also Laurence et al., 2008). This model requires refinement before it can generate testable predictions that clearly diverge from those of the typological models.

The present study is limited in at least four respects. First, insofar as the results are dependent upon self-reports, some participants, particularly those in the dissociative profile, who exhibited greater distortions in awareness during hypnosis, may have had greater difficulty quantifying their experiential responses. Although the high level of inter-item reliability speaks against this limitation, it would be useful to corroborate self-reported lapses in attention with performance on a behavioral task (e.g., Smallwood et al., 2008; Terhune et al., 2009). Second, because there are no Swedish-language equivalents of the measures included in this study, all of the measures were administered in English. However, previous work indicates that deflation of hypnotic suggestibility because of English measurement with a Swedish sample is negligible (Cardeña, Kallio, Terhune, Buratti, & Lööf, 2007). Furthermore, our measures exhibited strong internal consistency and reliability and the observed WSGC scores are comparable to those of a recent study with a British sample (Dienes, Brown, Hutton, Kirsch, Mazzoni, & Wright, 2009). This renders unlikely the possibility that English-language administration of the measures represents a serious confound. A third potential limitation stems from the selection of an LPA model that allowed for class-dependent unrestricted covariance matrices. Allowing local dependencies between indicator variables possesses a number of strengths, such as the prevention of selecting a model with too many profiles, but it may also function to hide additional meaningful profiles (Vermunt & Magidson, 2002). A final limitation concerns the small number of experiential dimensions included as indicator variables in the LPA models. The success of any clustering technique is dependent upon the extent to which the selected indicator variables measure the dimensions of interest. As a result, the present analyses may not have included all

relevant experiential dimensions that could discriminate among the different profiles. Future research should consider including a wider variety of experiential dimensions.

Conclusions

This study used LPA to identify discrete experiential profiles in response to a hypnotic induction to test the prediction that there are distinct subtypes of HS individuals (e.g., Barber, 1999a). We identified a homogeneous subset of dissociative HS participants who exhibit pronounced distortions in awareness, affect, and volitional control and reduced attention and imagery during hypnosis relative to a second profile of HS participants who were primarily characterized by endogenously-directed attention. The former was also found to exhibit increased involuntariness during hypnotic responding. We maintain that these experiential responses can be understood as reflecting a weakening of executive functioning following a hypnotic induction that is isolated to the dissociative profile (see also Barber, 1999a; Brown & Oakley, 2004). Insofar as there is consensus that involuntariness is the core phenomenological feature of hypnotic responses and the primary explanandum of experimental hypnosis research (Kihlstrom, 2008; Kirsch & Lynn, 1998; Weitzenhoffer, 1980), these findings have critical implications. They indicate that the relationship between involuntariness and hypnotic suggestibility is modulated by (typological) experiential response to a hypnotic induction. That is, increased hypnotic suggestibility among HS, relative to low and medium suggestible individuals, appears to only be coupled with increased involuntariness among the dissociative profile. These findings further suggest that the mechanisms underlying hypnotic responding in dissociative HS individuals are either different from or more pronounced than those underlying the responses of individuals in the inward attention subtype.

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Table 1

Descriptive statistics and correlation matrix for the research measures

Variable	<i>M (SD)</i>	1	2	3	4	5	6	7
1. WSGC	4.41 (2.18)		.57**	.53**	.42**	.07	.29**	.49**
2. ISHD	15.26 (7.83)			.80**	.53**	.15**	.30**	.74**
3. Dissociated control	- 8.43 (5.21)				.63**	.25**	.35**	.77**
4. Positive affect	4.24 (3.26)					.21**	.38**	.58**
5. Negative affect	1.30 (2.16)						.08	.10*
6. Visual imagery	3.32 (1.94)							.28**
7. Attention to internal processes	6.47 (2.33)							

Note. WSGC = Waterloo Stanford Group Scale of Hypnotic Susceptibility, Form C; ISHD

= Inventory Scale of Hypnotic Depth.

* $p < .05$. ** $p < .001$.

Table 2

Evaluation indices and model comparison tests for the latent profile analysis of experiential dimensions during hypnosis

Model	AIC	BIC	SSABIC	LMR LRT	<i>p</i>	BLRT	<i>p</i>	Entropy
2-class R	14263	14334	14283	760.92	< .001	780.67	< .001	.82
2-class UR	13903	14018	13936	110.26	< .04	113.12	< .001	.82
3-class R	14049	14146	14076	220.74	< .001	226.47	< .001	.80
3-class UR	13489	13719	13554	166.85	.03	169.21	< .001	.81
4-class R	13920	14044	13955	137.29	.08	140.85	< .001	.81
4-class UR	13445	13724	13524	174.36	.11	176.83	< .001	.77
5-class R	13851	14001	13893	79.11	.05	81.16	< .001	.83
5-class UR	13404	13731	13496	62.72	.12	-	-	-

Note. AIC = Akaike information criterion; BIC = Bayesian information criterion; SSABIC

= sample-size adjusted BIC; LMR-LRT = Lo-Mendell-Rubin likelihood-ratio test; BLRT =

Bootstrap likelihood-ratio test; R = restricted; UR = unrestricted; BLRT values for the 5-

class unrestricted model failed to replicate and are not provided; the optimal model is in

bold.

Table 3

Distributional data and descriptive statistics for PCI state factor scores in the four profiles:

Number or Mean (Percentage or Standard Deviation)

Variable	Profile			
	Inward attention 1 (n = 131)	Dissociative 2 (n = 258)	Minimal response 3 (n = 127)	Moderate response 4 (n = 99)
Sex (female)	70 (53%)	177 (69%)	65 (51%)	42 (42%)
Hypnotic suggestibility				
Low	29 (22%)	68 (26%)	78 (61%)	55 (56%)
Medium	78 (60%)	157 (61%)	49 (39%)	42 (42%)
High	24 (18%)	33 (12%)	0 (0%)	2 (2%)
Dissociated control	-5.42 (3.07) ^a	-5.73 (4.58) ^a	-13.89 (2.91) ^b	-12.44 (2.25) ^c
Positive affect	5.44 (3.06) ^a	5.99 (3.01) ^a	0.66 (0.53) ^b	2.67 (1.00) ^c
Negative affect	-0.33 (0.29) ^a	2.94 (2.32) ^b	-0.04 (0.70) ^c	0.86 (1.15) ^d
Visual imagery	3.88 (2.02) ^a	3.80 (1.82) ^a	2.43 (1.79) ^b	2.47 (1.61) ^b
Attention to internal processes	8.25 (1.23) ^a	7.26 (2.05) ^b	4.34 (1.68) ^c	4.78 (1.68) ^c

Note. Different superscripted letters indicate cell means significantly differ according to

Mann Whitney Tests after a Bonferroni correction ($\alpha = .002$).

Table 4

Descriptive statistics (Mean and Standard Deviation) for PCI state factor scores in the inward attention and dissociative profiles as a function of hypnotic suggestibility

PCI state factor	Profile					
	Inward attention			Dissociative		
	Low	Medium	High	Low	Medium	High
Dissociated control	-7.08 (2.72) ^a	-4.97 (3.12) ^b	-4.86 (2.69) ^b	-8.22 (4.75) ^a	-5.29 (4.07) ^b	-2.75 (4.20) ^c
Positive affect	4.75 (2.73)	5.60 (3.20)	5.74 (2.99)	4.79 (2.91)	6.26 (2.95)	7.17 (2.74)
Negative affect	-0.34 (0.24)	-0.33 (0.31)	-0.29 (0.31)	3.07 (2.28)	2.90 (2.29)	2.86 (2.59)
Visual imagery	3.90 (2.00) ^{a,b}	3.58 (2.01) ^a	4.85 (1.86) ^b	3.17 (1.83) ^a	3.98 (1.77) ^b	4.23 (1.78) ^b
Attention to internal processes	7.79 (1.51) ^a	8.34 (1.10) ^a	8.48 (1.18) ^a	6.27 (2.03) ^a	7.43 (1.88) ^b	8.52 (2.02) ^c

Note. Different superscripted letters indicate cell means in each profile significantly differ according to Tukey HSD tests.

Table 5

Descriptive statistics (Mean and Standard Deviation) for the PCI dimensions and sub-dimensions in the two profiles of highly suggestible participants

Variable	Profile	
	Inward attention (<i>n</i> = 24)	Dissociative (<i>n</i> = 33)
Altered experience	2.42 (0.70)	2.93 (1.02)
Attention	4.58 (0.80)	4.00 (1.19)
Direction	4.76 (0.80)	4.07 (1.50)
Absorption	4.31 (1.04)	3.91 (1.41)
Imagery	3.40 (1.29)	3.06 (1.25)
Amount	3.60 (1.51)	3.53 (1.53)
Vividness	3.33 (1.19)	2.59 (1.25)
Memory	3.83 (1.15)	3.53 (1.05)
Volitional control	2.91 (1.10)	2.30 (1.18)
Positive affect	0.38 (1.01)	0.70 (0.90)
Negative affect	- 0.70 (0.09)	0.74 (1.19)

RUNNING HEAD: Heterogeneity in high hypnotic suggestibility

Dissociative tendencies and individual differences in high hypnotic suggestibility

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Keywords: hypnosis, hypnotic suggestibility, dissociation, involuntariness, executive functioning, imagery

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Abstract

Introduction: Inconsistencies in the relationship between dissociation and hypnosis may result from heterogeneity among highly suggestible individuals. One reason for such heterogeneity may be the existence of distinct highly suggestible subtypes. This study contrasted highly suggestible subtypes high or low in dissociation in measures of hypnotic responding, cognitive functioning, and psychopathology.

Methods: Eleven high dissociative highly suggestible (HDHS), 19 low dissociative highly suggestible (LDHS), and 21 low suggestible (LS) participants were administered hypnotic suggestibility scales and completed measures of free recall, working memory capacity, imagery, fantasy-proneness, and psychopathology.

Results: HDHS participants were more responsive to positive and negative hallucination suggestions and experienced greater involuntariness during hypnotic responding. They also exhibited impaired working memory capacity and elevated pathological fantasy and dissociative symptomatology. In contrast, LDHS participants displayed superior object visual imagery.

Conclusions: These results provide further evidence for two highly suggestible subtypes: a dissociative subtype that exhibits greater involuntariness during hypnotic responding, deficits in executive functioning, and a predisposition to psychopathology and a subtype that exhibits superior imagery and no observable deficits in functioning.

High hypnotic suggestibility has been argued to be a predisposing factor for dissociative psychopathology (Butler, Duran, Jasiukaitis, Koopman, & Spiegel, 1996). Dissociative experiences and responses to hypnotic suggestions share many features including pronounced phenomenal distortions in agency and awareness (Kirsch, & Lynn, 1998). On the basis of these similarities, it has been proposed that the two phenomena share similar mechanisms (Woody, & Sadler, 2008). Attempts to test the hypothesized relationship between dissociative tendencies and hypnotic suggestibility in non-clinical samples have been mixed (Butler, & Bryant, 1997; Dienes, Brown, Hutton, Kirsch, Mazzoni, & Wright, 2009), whereas patients with dissociative symptomatology have consistently been found to exhibit high hypnotic suggestibility (Bryant, Guthrie, & Moulds, 2001; Roelofs, Hoogduin, Keijsers, Naring, Moene, & Sandijck, 2002; Spiegel, Hunt, & Dondershine, 1988; but see Litwin & Cardeña, 2000). These disparities may reflect the circuitous route by which dissociative tendencies influence hypnotic responding.

Heterogeneity among highly suggestible (HS) individuals may partly account for the inconsistent relationship between dissociation and hypnotic suggestibility (Dell, 2009). HS participants display marked variability in responsiveness to cognitive-perceptual suggestions (e.g., positive hallucinations) as well as involuntariness during hypnotic responses (McConkey, & Barnier, 2004). Individual differences in cognitive functioning among HS individuals may account for some of this variability. For instance, the capacity for generating and manipulating imagery has been found to vary among HS participants (Sheehan & Robertson, 1996) and to predict responsiveness to particular suggestions (Laurence, Beaulieu-Prévost, & du Chéné, 2008). Moghrabi (2004) similarly found that working memory capacity negatively correlated with responsiveness to cognitive-perceptual suggestions, suggesting that impaired working memory facilitates hypnotic suggestibility in HS participants. Insofar as working memory is critical for online attributions of agency (i.e., intention-action matches), working memory deficits may also

contribute to involuntariness during hypnotic responding. In addition, individual differences in executive functioning among HS individuals (Brown, & Oakley, 2004; Terhune, Cardeña, & Lindgren, 2009) may further contribute to individual differences in hypnotic responding in this population.

Heterogeneity in high hypnotic suggestibility and the relationship between dissociation and hypnotic responding are jointly addressed by dissociative typological models (e.g., Barber, 1999; Barrett, 1996; Cardeña, 1996; Carlson, & Putnam, 1989; Kunzendorf, & Boisvert, 1996; Perry, 2004). These models propose that there is a dissociative subtype among HS participants. This group is hypothesized to experience hypnotic responses through dissociative mechanisms such as the inhibition of information from awareness, impaired monitoring of response intentions, or the weakening of executive control (e.g., Brown, & Oakley, 2004; see also Woody, & Sadler, 2008). In contrast, the responses of a second subtype are argued to be facilitated by superior imagery and flexible utilization of cognitive strategies (Barber, 1999; Brown, & Oakley, 2004; Carlson, & Putnam, 1989; Kunzendorf, & Boisvert, 1996).

Although these models have been afforded relatively little attention, a number of studies have corroborated their central predictions. For instance, King and Council (1998) found that responding to a hypnotic suggestion impaired performance on a secondary attentional task in low dissociative HS (LDHS) participants, but not high dissociative HS (HDHS) participants. This indicates that responding to hypnotic suggestions taxes the attentional resources of LDHS participants but has little effect on those of HDHS participants. We recently demonstrated that a hypnotic induction attenuates cognitive control in HDHS participants, but marginally augments control in LDHS participants (Terhune et al., 2009). This finding is consistent with the hypothesis that HDHS participants experience deficits in executive control during hypnosis, whereas LDHS participants maintain flexible use of effortful strategies (Barber, 1999; Brown, &

Oakley, 2004). We have also found support for bifurcated dissociative typological models on the basis of spontaneous phenomenological response to a hypnotic induction (Terhune, & Cardeña, 2010). Using latent profile analysis, we found evidence for a dissociative HS subtype that experiences marked distortions in volition during hypnosis and for an inward-attention subtype that experiences greater endogenously-directed attention and vivid imagery (see also Pekala, & Kumar, 2007). Other studies analyzing response strategy utilization during hypnotic responding have also provided evidence for different respondents that closely match the HDHS and LDHS subtypes (Brown, & Oakley, 2004; McConkey, Glisky, & Kihlstrom, 1989; see also Kunzendorf, & Boisvert, 1996; Winkel, Younger, Tomcik, Borckardt, & Nash, 2006).

The possibility of a dissociative subtype among HS participants may shed further light on the relationship between hypnotic suggestibility and psychopathology (Barber, 1999; Lynn, Lilienfeld, & Rhue, 1999). Hypnotic suggestibility has previously been found to correlate with various pathological symptoms such as perceptual distortions (Gruzelier, De Pascalis, Jamieson et al., 2004; Jamieson, & Gruzelier, 2001). Dissociative tendencies are present in the general population, but their extreme manifestations are reflective of psychopathology. Research has suggested that individuals exhibiting pathological dissociation may form a taxon or latent subtype (Waller, Putnam, & Carlson, 1996; Waller, & Ross, 1997; see also Watson, 2003). Lynn and colleagues (1999) speculated that the dissociative HS subtype proposed in the typological models of high hypnotic suggestibility (e.g., Barber, 1999) may correspond to this dissociative taxon. Crucially, in our previous study, the dissociative subtype exhibited more spontaneous negative affect during hypnosis (Terhune, & Cardeña, 2010). This finding may point to impaired emotion regulation and a predisposition to psychopathology in this subtype.

The dissociative typological models possess considerable overlap but they vary in the phenomena that differentiate the subtypes as well as their principal characteristics. For instance,

Barber (1999) places emphasis on episodic memory deficits in the dissociative subtype, which he identifies as ‘amnesia-prone’, arguing that this subtype is characterized by pronounced spontaneous posthypnotic amnesia. This prediction is controversial insofar as it is difficult to reconcile with the repeated finding that spontaneous posthypnotic amnesia is rare (Hilgard, & Cooper, 1965; Kihlstrom, & Schachter, 1995). Furthermore, we found no difference in the frequency of spontaneous amnestic episodes during hypnosis between the two HS subtypes (Terhune, & Cardeña, 2010). Other typological models (e.g., Brown, & Oakley, 2004; Kunzendorf, & Boisvert, 1996) focus on executive functions and argue that the dissociative subtype exhibits impairments in executive monitoring and/or control (see also Woody, & Sadler, 2008). The principal features of the non-dissociative subtype also differ across the models. Whilst all of the models agree that this subtype will display superior imagery abilities (e.g., Barber, 1999; Kunzendorf, & Boisvert, 1996), only some of the models explicitly identify this subtype as being fantasy-prone (Barber, 1999; Barrett, 1996). However, the position that the dissociative and fantasy-prone subtypes represent distinct groups is challenged by the association between dissociation and fantasy-proneness (Giesbrecht, Lynn, Lilienfeld, & Merckelbach, 2008). These divergent predictions allow for refined tests of the characteristic features of the purported HS subtypes.

The present study sought to examine whether dissociative tendencies modulate individual differences in high hypnotic suggestibility by stratifying HS participants on the basis of dissociative tendencies and comparing LDHS and HDHS participants in hypnotic responding, cognitive functioning, and psychopathology.

LS and HS participants were administered two indices that measure five hypnotic suggestion *profiles*: agnosia and cognitive distortions, dreams and regressions, negative hallucinations, positive hallucinations, and posthypnotic compulsions (Weitzenhoffer & Hilgard,

1967). If HDHS participants possess a greater propensity for automatizing behavior and compartmentalizing information (Barber, 1999), they would be expected to exhibit greater responsiveness to the posthypnotic compulsion profile, which may depend on the execution of implementation intentions outside of awareness. In a similar fashion, hypothesized superior inhibitory abilities among HDHS participants (Barber, 1999) should support increased responsiveness to the negative hallucination and agnosia and cognitive distortion profiles, which require the inhibition of sensory and semantic information and motor representations, respectively. In contrast, LDHS participants have been argued to be more responsive to dream and regression profiles, which may require greater utilization of fantasy and imagery and depend upon strong episodic retrieval strategies (Barber, 1999; Hilgard, 1964). LDHS participants' superior imagery abilities may also facilitate responsiveness to positive hallucinations. An alternative prediction is provided by Kunzendorf and Boisvert (1996), who maintain that the dissociative subtype is characterized by a monitoring deficit during hypnosis (Barber [1999] similarly argues that this subtype is more likely to accept the reality of a hallucination). Accordingly, HDHS participants may be more responsive to hallucination suggestions due to impaired monitoring of the source of suggestion-specific perceptual representations and the concomitant misattribution of the content to the environment (Bentall, 1990; see also Brown, & Oakley, 2004).

Our previous finding of attenuated cognitive control among HDHS participants during hypnosis in the same sample as the present study (Terhune et al., 2009) points to the depletion of flexible strategy utilization following a hypnotic induction in this subtype (Brown, & Oakley, 2004). Insofar as expending cognitive effort during a task facilitates self-agency attributions (Johnson, Hashtroudi, & Lindsay, 1993), HDHS participants were expected to experience greater involuntariness during hypnotic responding (Carlson, & Putnam, 1989; Terhune, &

Cardeña, 2010). This prediction is also in keeping with the close relationship between dissociation and involuntariness (Dell, 2010).

Our investigation of individual differences in cognitive functioning focused on memory and imagery. We first tested Barber's (1999) prediction of spontaneous posthypnotic amnesia by examining posthypnotic recall of hypnotic suggestions and recall organization, which has previously been observed to be disorganized in HS participants (Evans, & Kihlstrom, 1973; Radtke, & Spanos, 1981). This represents a critical test of Barber's (1999) model because participants were administered two separate hypnotic suggestibility scales by different experimenters. In line with our previous study and the extant literature, we expected that in contrast with Barber (1999), the two HS subtypes wouldn't differ in spontaneous amnesia. We also sought to replicate Farvolden and Woody's (2004) finding of impaired free recall among HS participants, but expected it to be isolated to HDHS participants. We assumed that this finding was reflective of weakened executive functioning in this subtype and included a measure of working memory capacity to further corroborate this supposition. Finally, we sought to replicate the previous finding of a non-dissociative, HS imagery subtype (Kunzendorf, & Boisvert, 1996; Terhune, & Cardeña, 2010) by administering a behavioral measure of object visual imagery with the expectation that LDHS participants would display superior imagery.

Our third series of analyses focused on different forms of psychopathology. Participants completed measures of normal and pathological fantasy-proneness to test the prediction that LDHS participants represent a fantasy-prone subtype (Barber, 1999; Carlson, & Putnam, 1989). Participants also completed measures of global and dissociative psychopathology to examine whether HDHS participants correspond to the pathological dissociative taxon (Lynn et al., 1999).

Method

Participants

Sixty-four individuals (48 females) ranging in age from 18 to 33 ($M = 23.47$, $SD = 3.02$) with normal or corrected-to-normal vision were recruited from a larger group hypnosis study ($N = 640$; Terhune, & Cardeña, 2010). Hypnotic suggestibility was measured in group sessions using the *Waterloo-Stanford Group Scale of Hypnotic Susceptibility, Form C* (WSGC; Bowers, 1993; high ≥ 8 ; $n = 42$; low ≤ 4 ; $n = 22$) and in individual sessions with the *Revised Stanford Profile Scales of Hypnotic Susceptibility* (RSPS I and II; Weitzenhoffer, & Hilgard, 1967). Eleven HS participants were excluded for not meeting the inclusion criterion (mean RSPS score ≥ 10)², and two participants (one LS, one HS) dropped out of the study. The HS participants ($M = 8.67$, $SD = 0.99$) exhibited higher WSGC scores than the LS participants ($M = 2.52$, $SD = 0.68$), $F(1, 49) > 100$, $p < .001$. Participants provided informed written consent and were compensated for their participation. This study was approved by the local ethics committee.

High dissociation was established through a cut-off criterion of 20 on the *Swedish Dissociative Experiences Scale* (S-DES; Körlin, Edman, & Nyback, 2007), corresponding to the 75th percentile for the sample. This criterion is commonly used (Cardeña, 2008; Chiu, Yeh, Huang, Wu, & Chiu, 2009; Giesbrecht, & Merckelbach, 2009) and yielded 11 HDHS ($M = 35.29$, $SD = 14.58$) and 19 LDHS ($M = 11.62$, $SD = 5.24$) participants. As in other studies, dissociative tendencies and hypnotic suggestibility were correlated in the sample, resulting in only 2 (10%) LS participants meeting the criterion for high dissociation as compared with 11 (37%) of HS participants. HDHS participants exhibited greater S-DES scores than LS participants ($M = 10.36$,

2 This criterion was established prior to data collection on the basis of the scale norms (Weitzenhoffer & Hilgard, 1967) and our previous use of the scales (e.g., Cardeña, 2005).

$SD = 7.90$) and LDHS participants, $Us < 12$, $Zs > 4$, $ps < .001$, but the latter two didn't differ, $t < 1$. The three groups did not differ in age (HDHS: $M = 23.82$, $SD = 3.60$; LDHS: $M = 23.68$, $SD = 3.11$; LS: $M = 22.86$, $SD = 2.33$), $F < 1$, or sex distributions (HDHS: 9 females; LDHS: 13 females; LS: 16 females), $\chi^2(2) < 1$. HDHS ($M = 8.73$, $SD = 1.01$) and LDHS ($M = 8.63$, $SD = 1.01$) did not differ on an 'omnibus' measure of hypnotic suggestibility (WSGC), $t < 0.5$.

Questionnaires

Participants completed the S-DES (Körlin, et al., 2007), a 28-item scale in which they rated the percentage of the time they had different dissociative experiences. Using taxometric analysis, Waller and colleagues presented evidence that an eight-item subset (DES-T) provide an index of membership in a pathological dissociative taxon (Waller et al., 1996), although later research has qualified this proposal (Cardeña, 2008). Individuals falling into the taxon are argued to experience, or have a heightened predisposition to, dissociative psychopathology. Average DES scores, DES-T scores, and the Bayesian probability of membership in the taxon (Waller, & Ross, 1997) were computed. We used a categorical probability cut-off of .5 (e.g., Watson, 2003) for nominal inclusion in the taxon.

We administered the *Inventory of Childhood Memories and Imaginings* (ICMI; Wilson, & Barber, 1983) to participants as a measure of fantasy-proneness. The 52-item ICMI has two subscales; the first is associated with a variety of forms of psychopathology, in particular difficulty monitoring the boundaries between fantasy and reality, whereas the second measures non-pathological imaginative involvement (Klinger, Henning, & Janssen, 2009).

Participants also completed the 53-item *Brief Symptom Inventory* (Derogatis, 1993). The mean value, with a range of 0 to 4, was used as a global measure of psychopathology.

All of the measures have recognized psychometric properties and exhibited strong internal consistency in this sample (Cohen's α ; S-DES: .94, ICMI: .94; BSI: .95).

Behavioral Materials

Hypnotic suggestibility was measured using the RSPS I and II (Weitzenhoffer, & Hilgard, 1967). Their combined 18 items comprise five response profiles (scoring range and Cohen's α): agnosia and cognitive distortions (0 - 12; $\alpha = .89$), dreams and regressions (0 - 12; $\alpha = .91$), negative hallucinations (0 - 12; $\alpha = .75$), positive hallucinations (0 - 12; $\alpha = .85$), and posthypnotic compulsions (0 - 6; $\alpha = .72$).

Free recall was measured with Farvolden and Woody's (2004) modified version of the *Auditory Verbal Learning Test* (AVLT; Crawford, Stewart, & Moore, 1989; Lezak, 1995). In the AVLT, an experimenter recited fifteen words at a rate of one per second. Following completion of the list, participants were given thirty seconds to recall as many of the words as possible. Five study and recall trials were completed, with number of words recalled on the fifth trial acting as the dependent measure. This task was included in the battery of cognitive measures to examine whether Farvolden and Woody's (2004) finding of impaired AVLT performance was isolated to HDHS participants.

Working memory capacity was measured with the counting span (CSPAN) task (Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004). In the CSPAN, participants viewed visual displays consisting of geometric targets (dark blue circles) presented amongst distracters (dark blue squares and light green circles) on a gray background. Participants counted the targets in each successive display and repeated the sum, after which there was a 500 ms inter-stimulus interval. Following a variable number of displays, participants recalled the successive sums of targets in serial order. The number of targets per display varied from 3 to 9 and the number of displays per trial varied from 2 to 6. Participants completed two practice and 15 experimental trials. Stimuli were presented with E-Prime v. 1.2 (Psychology Software Tools, Pittsburgh, PA) on a PC computer. The dependent measure was the mean percentage of correct

responses in the correct serial position per trial (Kane, et al., 2004).

Object visual imagery was measured with the *Degraded Films Task*. This task consists of one-minute films depicting a single common object (e.g., an acoustic guitar) embedded within visual white noise becoming progressively *less* degraded over time. Participants were instructed to name each object as quickly as possible and completed one practice trial and 15 experimental trials administered randomly with inter-stimulus intervals of 5000 ms. Stimulus presentation and response recording were done using MATLAB v. 7.3 (The Mathworks, Natick, MA) on a PC computer. The dependent measures for this task were mean response time for correct trials and error percentage. The *Degraded Films Task* is based on the *Degraded Pictures Task* (Kozhevnikov, Kosslyn, & Shephard, 2005), a measure of object visual imagery comprised of static degraded objects. In a pilot study, we found that response times on the *Degraded Films Task* were negatively correlated with a measure of object visual imagery, but not spatial visual imagery (Blajenkova, Kozhevnikov, & Motes, 2006), thereby demonstrating the specificity of this task as a measure of object visual imagery.

Procedure

Different experimenters, who were masked to participants' group, administered the RSPS I and II on separate days. Following the de-induction in both sessions, participants were administered a surprise recall test in which they were given two minutes to report everything that occurred during the session. The mean spearman *rho* between the recall order and actual order of the suggestions across the two sessions was used as an index of recall organization. Participants subsequently rated the involuntariness with which they experienced each suggestion to which they responded according to the following scale: 1: 'completely voluntary' to 5: 'completely involuntary' (Bowers, 1981).

Participants completed the CSPAN, AVLT, and *Degraded Films Task*, in randomized order in a third session for which they were recruited separately. The experimenter was masked to group status and the hypotheses under test and no mention of hypnosis was made. The questionnaire measures were given to participants during this session and they returned them to the experimenter at a later date.

Statistical Analyses

Analyses of variance (ANOVAs) and independent (two-tailed) *t*-tests were used for between-group analyses. ANOVAs were followed up with planned comparisons for directional predictions and Tukey HSD tests for *post hoc* contrasts. Kruskal-Wallis and Mann-Whitney tests were used for analyses in which data violated the assumption of homogeneity of variance across groups.

Results

Hypnotic Responding

As can be seen in Figure 1A, main effects of Group were found for each of the five RSPS profiles: agnosia and cognitive distortions: $H(2) = 32.27, p < .001$; dreams and regressions: $H(2) = 37.68, p < .001$; negative hallucinations: $H(2) = 32.76, p < .001$; positive hallucinations: $F(2, 48) = 41.89, p < .001$; and posthypnotic compulsions: $H(2) = 22.00, p < .001$. LS participants scored lower on all of the profiles relative to HDHS and LDHS participants, all $U_s < 70$, all $Z_s > 4$, all $p_s < .001$, d_s : 1.91 to 3.33. HDHS participants were more responsive than LDHS participants to the negative hallucination, $t(28) = 2.99, p = .006, d = 1.17$, and positive hallucination, $t(28) = 3.11, p = .004, d = 1.22$, profiles, but to none of the other profiles, $t_s < 1.6$.

**** Figure 1 about here ****

Mean involuntariness differed across groups, $H(2) = 19.83, p < .001$ (see Figure 1B). HDHS participants experienced greater involuntariness than LDHS participants, $t(28) = 2.86, p = .008, d = 1.11$, and both reported greater involuntariness than LS participants, $Us < 70, Zs > 3, ps < .005, ds = 1.27$ to 1.73 . Analyses of involuntariness for individual profiles revealed group effects for positive hallucinations, $F(2, 35) = 9.39, p < .001, \eta_p^2 = .35$, and dreams and regressions, $F(2, 41) = 16.78, p < .001, \eta_p^2 = .45$, but none of the other profiles, $Fs < 2.5$. HDHS and LDHS participants exhibited greater involuntariness than LS participants for both profiles, $ps < .02$, but the two HS groups only differed in involuntariness during the dream and regressions profile, $p < .03$. HDHS participants also exhibited greater involuntariness than LDHS participants during the posthypnotic compulsion profile, $F(1, 17) = 5.14, p = .037, \eta_p^2 = .23$; LS participants were not included in this analysis because of their low level of responding;

Cognitive Functioning

In contrast with the prediction of elevated spontaneous posthypnotic amnesia in HDHS participants (Barber, 1999), but in line with other studies, posthypnotic recall didn't differ across groups (HDHS: $M = 6.14, SD = 1.38$; LDHS: $M = 6.55, SD = 1.36$; LS: $M = 6.74, SD = 1.32$), $F < 1$. A marginal main effect of Group was found for posthypnotic recall order, $F(2, 48) = 3.07, p = .056, \eta_p^2 = .11$, with HDHS participants ($M = 0.25, SD = 0.38$) displaying greater disorganization of recall than LS participants ($M = 0.59, SD = 0.32$), $p = .045$. LDHS participants ($M = 0.45, SD = 0.41$) didn't differ from either group, $ps > .3$.

There were main effects of Group for both the AVLT, $F(2, 48) = 3.50, p = .038, \eta_p^2 = .13$, and CSPAN, $F(2, 48) = 3.39, p = .042, \eta_p^2 = .12$ (see Table 1). HDHS participants exhibited

lower scores on both tasks than LDHS, AVLT: $p = .079$; CSPAN: $p = .042$, and LS participants, AVLT: $p = .011$; CSPAN: $p = .015$. LDHS and LS participants did not differ on either measure, $ps > .5$. The three groups exhibited comparable response accuracy on the *Degraded Films Task*, $F < 1$, but differed in response latency, $F(2, 48) = 5.71, p = .006, \eta_p^2 = .19$. As predicted, LDHS participants displayed faster response times (indicating superior performance) than HDHS, $p = .004$, and LS participants, $p = .012$, whereas the latter two groups did not differ, $p = .65$. These results indicate that HDHS participants exhibit deficits in working memory capacity and free recall, whereas LDHS participants have superior object visual imagery.

**** Table 1 about here ****

Fantasy-proneness and Psychopathology

In order to examine whether the LDHS represent a fantasy-prone subtype and the HDHS participants a pathological group, we next examined measures of fantasy-proneness, and general and dissociative psychopathology. The three groups differed on ICMI component 1 (pathological fantasy), $F(2, 47) = 12.91, p < .001, \eta_p^2 = .36$. Contrary to the central prediction of some dissociative typological models, the HDHS participants exhibited higher scores than LDHS and LS participants, $ps < .001$; the latter two didn't differ, $p > .5$. The three groups didn't differ on ICMI component 2 (imaginative involvement), $F < 3$, nor the *Brief Symptom Inventory*, $H(2) < 1.5$. The three groups, however, differed in dissociative psychopathology (DES-T), $H(2) = 21.38, p < .001$. HDHS participants exhibited higher scores than LDHS, $U = 6.50, Z = 4.23, p < .001$, and LS participants, $U = 15, Z = 4.01, p < .001$, who didn't differ, $t < 0.5$. Five of the HDHS participants were classified as members of the dissociative taxon, whereas none of the LDHS and LS participants were, $\chi^2(2, N = 51) = 20.16, p < .001, phi = .63$. These findings counter the claim

that fantasy-proneness is unique to LDHS participants and point to elevated pathological symptomatology among HDHS participants.

Dissociative Tendencies and Low Hypnotic Suggestibility

Exploratory analyses examined whether dissociative tendencies covaried with individual differences in LS participants. S-DES scores correlated with responsiveness to the RSPS dreams and regressions profile and posthypnotic recall organization in the LS sample, $r_s(21) > .45$, $p_s < .04$, but not with any other measure, $r_s < .4$, $p_s > .05$. These results suggest that dissociative tendencies don't modulate individual differences in the same variables among LS participants as in HS participants.

Discussion

This study helps to clarify the relationship between hypnosis and dissociation by demonstrating that dissociative tendencies modulate individual differences among HS participants. HDHS participants were more responsive to hallucination suggestions, experienced greater involuntariness during hypnotic responding, and exhibited impaired working memory capacity and greater pathological (dissociative and fantasy-prone) symptomatology. LDHS participants, in contrast, were found to display superior object visual imagery. These findings add to a growing literature indicating that high hypnotic suggestibility is not a uniform condition. In particular, this study provides further evidence for a bifurcated HS typology comprised of a dissociative subtype and an imagery subtype (Barber, 1999; Kunzendorf, & Boisvert, 1996; Terhune, & Cardeña, 2010).

Our findings are consistent with a number of previous studies as well as predictions derived from different dissociative typological models. For instance, the features of HDHS

participants in this study closely correspond to our previous study, in which the dissociative HS subtype experienced greater involuntariness, increased negative affect, and pronounced distortions in awareness, but no alterations in memory (Terhune, & Cardeña, 2010). Elevated involuntariness in this subtype has important consequences because involuntariness is commonly regarded as the core phenomenological feature of hypnotic responses (Weitzenhoffer, 1980). The finding of superior object visual imagery in the LDHS participants is consistent with the proposal that the non-dissociative subtype displays superior imagery (Barber, 1999; Carlson, & Putnam, 1989; Kunzendorf, & Boisvert, 1996). Finally, elevated fantasy-prone and dissociative psychopathology among the HDHS participants supports the hypothesis that this subtype displays greater psychopathology (Lynn et al., 1999). However, insofar as the reliability and validity of the DES-T is inconsistent (Cardeña, 2008; Merritt, & You, 2008; Waller, Ohanian, Meyer, Everill, & Rouse, 2001; Watson, 2003), this finding should be interpreted with caution.

Despite the support for bifurcated dissociative typological models, our results are inconsistent with multiple predictions from certain versions of these models. First, HDHS participants did not display pronounced spontaneous posthypnotic amnesia (Barber, 1999). Although this finding is at odds with Barber's (1999) prediction, it is consistent with the results of our previous study (Terhune, & Cardeña, 2010) and the extant literature (Kihlstrom, & Schachter, 1995). Spontaneous posthypnotic amnesia may be either extremely rare and/or artifactual of demand characteristics (Wagstaff, 1999), at least among non-clinical groups. In either case, it should not be interpreted as a signature of the dissociative subtype. Second, in contrast with predictions derived from Barber's (1999) typological model, the two HS subtypes differed in only two of the five suggestion profiles. However, the finding of superior responsiveness to negative and positive hallucinations in the HDHS subtype is arguably consistent with Kunzendorf and Boisvert's (1996) typological model, which maintains that this

subtype experiences deficient monitoring during hypnosis. Finally, counter to a number of the typological models (e.g., Barber, 1999; Carlson, & Putnam, 1989), LDHS participants did not exhibit greater fantasy-proneness than HDHS participants. The three groups didn't differ in normal fantasizing and, in fact, HDHS participants displayed greater pathological fantasy-proneness. These findings stand in stark contrast with bifurcated typological models that distinguish between fantasy-prone and dissociative HS subtypes (Barber, 1999; Barrett, 1996).

We propose that the present findings can be explained by a disruption in executive functioning among HDHS participants. This hypothesis is broadly in keeping with other dissociation theories (Woody, & Sadler, 2008), but we diverge from such accounts by maintaining that this deficit is isolated to HDHS participants (Brown, & Oakley, 2004; Kunzendorf, & Boisvert, 1996). Impaired source monitoring in HDHS participants may explain this group's greater responsiveness to hallucination suggestions (Bentall, 1990) as well as their inflated levels of pathological fantasy, which may reflect an impaired ability to discriminate fantasy from reality (Klinger et al., 2009). By systematically impairing participants' awareness of intentions, a monitoring deficit among HDHS participants also helps account for their greater involuntariness during hypnotic responding (Woody, & Sadler, 2008). The working memory deficit observed in HDHS participants provides further evidence for impaired executive functioning in this group and may also point to a deficit in the awareness of inner speech, which is dependent upon the articulatory loop in working memory (Shergill, Bullmore, Brammer, Williams, Murray, & McGuire, 2001). This deficit may contribute to the hypothesized reduction of inner speech following a hypnotic induction in this subtype (Miller, Galanter, & Pribram, 1960), an effect that been argued to provide the basis for weakening of executive functions during hypnosis (Hilgard, 1986; see also Brown, & Oakley, 2004). Deficient executive functioning in this subtype may further contribute to elevated psychopathological

symptomatology in this subtype, in particular impaired emotion regulation (Terhune, & Cardeña, 2010). Although this study provides little information on the mechanisms underlying hypnotic responding among LDHS participants, these respondents may achieve high hypnotic suggestibility through their superior imagery abilities and flexible use of attentional resources during hypnosis (Brown, & Oakley, 2004; King, & Council, 1998; Kunzendorf, & Boisvert, 1996; Terhune et al., 2009).

A limitation of this study is the near absence of high dissociative LS participants from our sample, because of the correlation between dissociation and hypnotic suggestibility. The structure of this study opens the possibility that the observed differences between LDHS and HDHS participants are not unique to HS individuals and reflect broader covariates of dissociation. Importantly, this limitation doesn't apply to the effects observed with the measures of hypnotic responding, as LS participants display floor effects on these measures due to their low level of hypnotic suggestibility. Furthermore, correlational analyses in the LS participants revealed that dissociative tendencies did not covary with *any* of the variables that differed across the two HS subtypes. In addition, the finding of impaired working memory capacity among HDHS is actually at odds with the repeated demonstration of superior working memory capacity in highly dissociative individuals (De Ruiter, Phaf, Elzinga, & Van Dyck, 2004; Veltman, de Ruiter, Rombouts et al., 2005). This clearly indicates that this observed effect is not reflective of a broader modulatory influence of dissociation.

Two alternative interpretations of the present results are worth considering. First, it could be argued that the observed differences between HDHS and LDHS participants are caused by greater hypnotic suggestibility in the former group. However, the two groups did not differ on a general group measure of hypnotic suggestibility (Bowers, 1993). Furthermore, they differed on only two of the five suggestion profiles in the RSPS (Weitzenhoffer, & Hilgard, 1967). We

maintain that these results indicate that HDHS participants possess a superior ability for responding to hallucination suggestions, but display otherwise similar levels of hypnotic suggestibility to LDHS participants (for a related discussion, see Woody, Barnier, & McConkey, 2005).

A second interpretation of the present results is provided by the *componential* model (Laurence et al., 2008; Woody et al., 2005). This account maintains that HS participants represent a uniform population but that individual differences therein result from variability in ancillary ‘componential’ abilities (see also Lynn et al., 1999). According to this account, the findings of this study could be interpreted as reflecting the modulatory influence of dissociative tendencies on individual differences in an otherwise homogeneous group and not the existence of distinct subtypes among HS participants. It needs to be acknowledged that the componential approach was developed to account for the factorial structure of standard hypnotic suggestibility scales and not to address heterogeneity among HS participants. Accordingly, further development of the model is needed to develop specific predictions regarding heterogeneity in this population. Discerning points at which the componential and dissociative typological models diverge in their predictions represents a task of paramount importance for future work on heterogeneity in this population. Irrespective of which approach possesses greater strength, our results clearly indicate that an examination of the modulatory influence of dissociative tendencies on individual differences in high hypnotic suggestibility will be more fruitful than the conventional approach of attempting to establish a linear association between these two variables. We also are intrigued by the possibility that such an orientation may assist in reconciling seemingly incompatible hypotheses in the experimental hypnosis literature (Barber, 1999; Brown, & Oakley, 2004; King, & Council, 1998).

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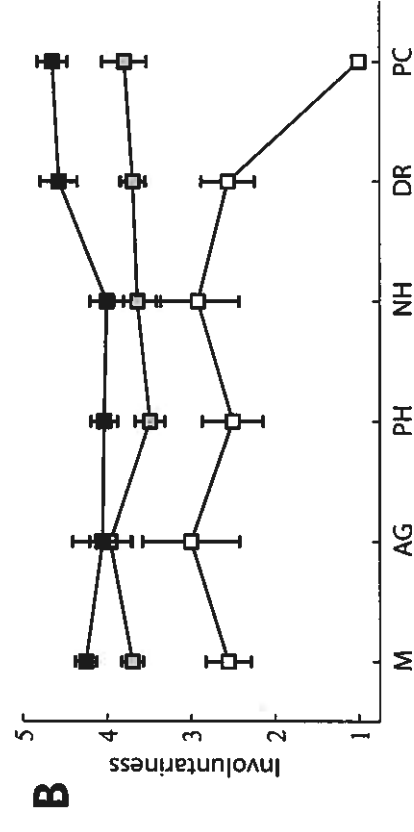
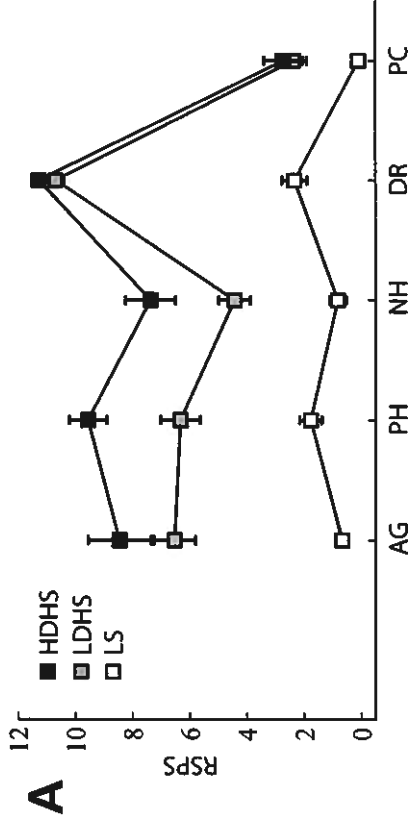
Table 1

Descriptive statistics for the cognitive and psychometric measures as a function of group

Variable	Group		
	LS	LDHS	HDHS
AVLT	11.76 (1.81)	11.11 (1.85)	9.64 (3.11)
CSPAN	0.73 (0.10)	0.71 (0.14)	0.61 (0.15)
DFT accuracy	0.09 (0.13)	0.12 (0.14)	0.13 (0.13)
DFT latency	39.38 (2.15)	37.45 (2.38)	40.14 (2.51)
DES-T	5.71 (6.57)	5.86 (3.80)	26.13 (15.82)
DES-T membership (%)	0/21 (0)	0/19 (0)	5/11 (45)
ICMI 1: Pathological fantasy	2.19 (1.91)	2.68 (2.08)	5.90 (1.79)
ICMI 2: Imaginative involvement	3.52 (1.81)	4.10 (1.10)	4.90 (1.52)
Brief Symptom Inventory	0.47 (0.30)	0.51 (0.46)	0.74 (0.59)

Figure 1.

Hypnotic responding as a function of group. A: RSPS profiles. B: Involuntariness scores. M = Mean; AG = Agnosia and cognitive distortions; PH = Positive hallucinations; NH = Negative hallucinations; DR = Dreams and regressions; PC = Posthypnotic compulsions. Error bars represent standard errors of the mean.



RUNNING HEAD: Dissociated control in high hypnotic suggestibility

Dissociated control as a signature of typological variability in high hypnotic suggestibility.¹

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Abstract

This study tested the prediction that a hypnotic induction differentially impacts cognitive control in different subtypes of highly suggestible individuals. Low suggestible (LS), low dissociative highly suggestible (LDHS), and high dissociative highly suggestible (HDHS) participants completed the Stroop color-naming task in control and hypnosis conditions. HDHS participants exhibited superior baseline cognitive control, as reflected in stronger sequential congruency effects, relative to LDHS and LS participants. LS and LDHS participants displayed marginally superior up-regulation of cognitive control following a hypnotic induction, whereas HDHS participants' performance declined during hypnosis. Both HS subtypes reported greater utilization of an experiential response strategy, characterized by increased effortless responding, during hypnosis, but only HDHS participants displayed a corresponding increase in response automatization. These findings indicate that dissociative tendencies modulate the impact of a hypnotic induction on cognitive control in high hypnotic suggestibility and suggest that HS individuals are comprised of distinct subtypes with different cognitive profiles.

Keywords: hypnosis, hypnotic suggestibility, Stroop, cognitive control, conflict monitoring, dissociation

Responses to hypnotic suggestions are frequently accompanied by marked distortions in highly suggestible (HS) individuals' perceived control over their actions and the availability of information to consciousness (Kihlstrom, 2008). This experience of involuntariness is widely regarded as the core phenomenological property of hypnotic responding (Kirsch, & Lynn, 1998; Weitzenhoffer, 1980). An influential theory of hypnosis – *dissociated control theory* – argues that responses to hypnotic suggestions are facilitated by a breakdown in executive control over contention scheduling (Norman & Shallice, 1986) in HS individuals following a hypnotic induction (E. Woody, & Farvolden, 1998; Woody, & Bowers, 1994). On the basis of neuroimaging evidence (Egner, Jamieson, & Gruzelier, 2005), a revised version of this theory specifically proposes that hypnosis triggers a decoupling of executive monitoring and control functions (Egner, & Raz, 2007; Jamieson, & Woody, 2007; Woody, & Sadler, 2008). On this account, executive control can still bias contention scheduling, but no longer consistently receives feedback from the executive monitor and thus exhibits difficulty selectively adjusting cognitive control to meet task demands. In contrast, 'sociocognitive' theories of hypnosis argue that a hypnotic induction does not have a deleterious impact on executive functions in HS individuals (Lynn, Kirsch, & Hallquist, 2008).

Experimental investigations of baseline executive attention in low suggestible (LS) and HS individuals have produced conflicting results (for a review see Dienes, Brown, Hutton, Kirsch, Mazzoni, & Wright, 2009). Studies using selective attention tasks have alternately reported superior attention (David, King, & Borkardt, 2001; Rubichi, Ricci, Padovani, & Scaglietti, 2005), or poorer attention (Palmer, & Field, 1971), among HS individuals, or no group differences across individuals of different levels of hypnotic suggestibility (Baribeau, LeBeau, Roth, & Laurence, 1994; Dienes, et al., 2009; Iani, Ricci, Gherri, & Rubichi, 2006). Studies using other measures of executive functioning (e.g., Wisconsin Card Sorting Task, random number

generation) have found parallel inconsistencies (Aikins, & Ray, 2001; Crawford, Brown, & Moon, 1993; Graham, & Evans, 1977; Stroop, 1935).

Multiple experiments have found poorer selective attention, as measured by the Stroop color-naming task (Stroop, 1935), among HS individuals *following* a hypnotic induction (Gruzelier, Gray, Kaiser, & Barker, 1997; Jamieson, & Sheehan, 2004; Kaiser, Barker, Haenschel, Baldeweg, & Gruzelier, 1997; Sheehan, Donovan, & Macleod, 1988). These results are in line with the predictions of dissociated control theory (Jamieson, & Woody, 2007; Woody, & Bowers, 1994). Similar effects have been reported for letter fluency (Gruzelier, & Warren, 1993; Kallio, Revonsuo, Hamalainen, Markela, & Gruzelier, 2001). However, these effects have not been observed in all studies (Egner, et al., 2005). Moreover, HS individuals have been found to exhibit prominent heterogeneity in at least one study (Nordby, Hugdahl, Jasiukaitis, & Spiegel, 1999). Nordby et al. (1999) found that HS participants' error rates on the Stroop color-naming task during hypnosis varied from approximately 2% to 24%, whereas their error rates in the control condition, and LS participants' error rates across conditions, varied only from 1% to 5%.

Variability in attentional functioning among HS individuals between and within experiments is strikingly consistent with other studies demonstrating heterogeneity in this population. HS individuals exhibit marked variability in multiple dimensions of hypnotic responding including spontaneous phenomenological response to a hypnotic induction (Pekala, & Kumar, 2007), behavioral and experiential hypnotic suggestibility (McConkey, & Barnier, 2004), and the cognitive and neurophysiological mechanisms underlying responses to hypnotic suggestions (Galea, Woody, Szechtman, & Pierrynowski, in press; King, & Council, 1998; Kunzendorf, & Boisvert, 1996; Sadler, & Woody, 2006; Winkel, Younger, Tomcik, Borckardt, & Nash, 2006).

One interpretation of heterogeneity in this population is that HS individuals are comprised of distinct subtypes with dissimilar cognitive and phenomenological profiles (Barber, 1999; Brown, & Oakley, 2004; Carlson, & Putnam, 1989; Kunzendorf, & Boisvert, 1996; Perry, 2004). These models vary in the demarcation criteria used to discriminate different HS subtypes but they agree that there is a subtype that exhibits weakened executive functioning following a hypnotic induction (henceforth high dissociative highly suggestible [HDHS] individuals), in a similar fashion to that predicted by second-order dissociated control theory (Brown, & Oakley, 2004), whereas the remainder (low dissociative highly suggestible [LDHS] individuals) maintain flexible executive control in accordance with sociocognitive theories of hypnosis (Lynn, et al., 2008). For example, Brown and Oakley (2004) argue that a hypnotic induction produces an absorbed attentional state in HDHS participants that is characterized by reduced supervisory control and metacognition (see also Dienes, & Perner, 2007). A corollary of dissociative typological models is that HDHS participants will display deficits on selective attention tasks following a hypnotic induction, whereas LDHS participants will not. Brown and Oakley (2004) further address heterogeneity in baseline attention among HS participants by arguing that insofar as the phenomenological state achieved by the HDHS subtype during hypnosis is facilitated in part by attentional focusing, this subtype may exhibit superior baseline attention than the LDHS subtype. Similarly, proponents of dissociated control theory have noted that not all HS participants may experience hypnotic suggestions through weakened cognitive control (Woody, & Sadler, 1998) and have recently allowed for the possibility of discrete HS subtypes that experience hypnosis through different dissociative mechanisms (Woody, & Sadler, 2008).

A number of studies have yielded evidence in support of bifurcated dissociative typological models. King and Council (1998) found that LDHS participants exhibited impaired performance on a secondary attentional task whilst responding to a posthypnotic suggestion, as

would be predicted by sociocognitive theories (Lynn, et al., 2008), whereas HDHS participants' ability to respond to the suggestion did not have a detrimental impact on their performance on the attentional task, as would be predicted by dissociated control theory (Woody, & Bowers, 1994). In two studies of HS participants with different methodologies, we also found evidence for a dissociative subtype that experiences greater spontaneous alterations in agency and more pronounced involuntariness during hypnotic responding, and a second subtype that displays superior object visual imagery (Terhune, & Cardeña, 2010; Terhune, Cardeña, & Lindgren, 2010).

The present study aimed to resolve previous inconsistencies regarding the modulatory influence of hypnotic suggestibility on attention by reconsidering this relationship within the context of dissociative typological models. We tested the prediction that disruptions in cognitive control following a hypnotic induction would be restricted to HDHS participants. Cognitive control can be understood as the ability to selectively adjust attention in accordance with environmental demands. This form of control is necessary for optimal performance in selective attention tasks such as the Stroop (1935) task, in which individuals have to identify the color of congruently- and incongruently-colored words. Greater selective attention is required on incongruent trials in which participants have to identify a stimulus color (e.g., red) that is different from the stimulus word (e.g., 'GREEN') than on congruent trials when the two stimulus dimensions match. This task has been repeatedly noted to provide a suitable means for testing the predictions of dissociated control theory (Egner, et al., 2005; Kirsch, & Lynn, 1998), although it has been argued that impaired performance among HS participants on this task during hypnosis may reflect increased relaxation rather than a weakening of executive control (Kirsch, & Lynn, 1998). In the present study, LS and HS participants completed the Stroop task in control and hypnosis conditions and provided self-reports of relaxation and strategy utilization (Jamieson, &

Sheehan, 2004; Sheehan, et al., 1988). Our analyses focused on the sequential congruency effect (Egner, 2007) and response automatization (Laurence, Beaulieu-Prévost, & du Chéné, 2008; Segalowitz, & Frenkiel-Fishman, 2005).

The sequential congruency effect refers to a reduction in Stroop interference following incongruent relative to congruent trials (Egner, 2007; Gratton, Coles, & Donchin, 1992). Incongruent trials that are preceded by an incongruent trial (II) are associated with faster and more accurate responses than those preceded by a congruent trial (CI). This effect remains even when feature integration effects (Hommel, Proctor, & Vu, 2004) are excluded (Notebaert, Gevers, Verbruggen, & Liefoghe, 2006). The sequential congruency effect has been argued to reflect the up-regulation of cognitive control in the wake of response conflict (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Specifically, increased response conflict between competing behavioral representations on incongruent trials is hypothesized to be gauged by conflict monitoring, which in turn communicates the requisite need for context-dependent adjustments in cognitive control. Up-regulation of cognitive control is subsequently implemented by increasing selective attention to relevant stimulus dimensions (stimulus color) and reducing processing of irrelevant stimulus dimensions (stimulus name) (Botvinick, et al., 2001; Egner, 2007). These ‘micro adjustments’ in cognitive control (Botvinick, 2007) are the hypothesized mediator of faster response times on II relative to CI trials. We expected that HDHS participants would exhibit weaker sequential congruency effects following a hypnotic induction, whereas LDHS and LS participants would exhibit no changes or stronger effects.

Response automatization refers to the extent to which behavioral responses become automatic. Previous research suggests that HS participants may have a heightened capacity for automaticity. For instance, Moghrabi (2004) reported a positive relationship between hypnotic suggestibility and the Stroop facilitation effect. HS individuals have also been found to exhibit

faster response times in a simple reaction time task (Braffman, & Kirsch, 2001) and when identifying a stimulus in a backward masking task (Ingram, Saccuzzo, Mcneill, & McDonald, 1979). Dixon and Laurence (1992) similarly reported that HS individuals displayed greater baseline behavioural automaticity than LS individuals in response to color-word primes in a color-naming task. Finally, Laurence et al. (2008) observed that HS individuals displayed lower inter-trial response time variability, as measured by the coefficient of variability (CV) in a cognitive inhibition task than LS individuals, which they interpreted as reflecting an enhanced propensity for automatizing behavioral responses (Segalowitz, & Frenkiel-Fishman, 2005). A notable feature of these studies is that none examined the impact of a hypnotic induction on response automatization. To further examine this relationship, we tested the prediction that HDHS participants would exhibit reduced CVs following a hypnotic induction, whereas LS and LDHS participants' CVs would not differ across conditions.

Method

Participants

Three groups of individuals took part in this experiment: LS ($n = 19$), LDHS ($n = 18$), and HDHS ($n = 11$) participants. Hypnotic suggestibility was measured in group sessions using the *Waterloo-Stanford Group Scale of Hypnotic Susceptibility, Form C* (WSGC; Bowers, 1993, 1998) and individually-administered *Revised Stanford Profile Scales of Hypnotic Susceptibility* (RSPS I & II; Weitzenhoffer, & Hilgard, 1967), where LS: WSGC: ≤ 4 ; RSPS ≤ 6 ; HS: WSGC ≥ 8 ; RSPS ≥ 20 . HS subtypes were stratified according to the Swedish version (Körlin, Edman, & Nybäck, 2007) of the *Dissociative Experiences Scale* (Bernstein, & Putnam, 1986; Carlson, & Putnam, 1993) using a cut-off criterion of 20, corresponding to the 75th percentile for the sample (Terhune, et al., 2010). The three groups were matched for age (LS: $M = 22.89$, $SD = 2.40$;

HDHS: $M = 23.82$, $SD = 3.60$; LDHS: $M = 23.39$, $SD = 2.91$), $F < 1$, and sex distributions (LS: 12 [67%] female; HDHS: 9 [82%] female; LDHS: 14 [74%] female)), $\chi^2 < 1$. The two HS subtypes exhibited equivalent hypnotic suggestibility on the WSGC and three out of five subscales of the RSPS, whereas LS participants scored lower on all measures (Terhune, et al., 2010). All participants were right-handed (Oldfield, 1971) and had normal or corrected-to-normal vision. Participants provided informed consent and the study was approved by a local ethics committee.

Materials

Stimuli & Task. The Stroop task was administered on a PC computer using E-Prime v. 1.2 (Psychological Software Tools, Pittsburgh, PA). Participants were seated at a distance of 75 cm from the computer monitor. Stimuli, subtending a visual angle of $5.3^\circ \times 1.5^\circ$, consisted of one of three color words (RÖD [RED], GRÖN [GREEN], BLÅ [BLUE]) printed in one of the three corresponding ink colors and were presented in quasi-random fashion with 67% of trials being incongruent. Stimuli were centered on the vertical and horizontal axes of a 33 cm monitor and were presented for 1200 ms. Interstimulus intervals consisted of a centrally-presented white fixation cross for condition-matched durations randomly varying from 1500 to 1900 ms.

Procedure

Participants completed the Stroop task in control and hypnosis conditions in counterbalanced order. The experimenter was masked to group identity. Participants were instructed to identify the *color* of the word, while ignoring the *word* itself, by depressing one of three keys on a manual response box. They completed one practice block of 82 trials and seven

blocks in each condition. Prior to task onset, participants provided a self-report of current relaxation level (1 = completely agitated or excited to 5 = completely relaxed) to control for differential relaxation across groups (Kirsch, & Lynn, 1998). Following completion of the task, participants rated the frequency with which they used three different strategies (rehearsal [repetition of instructions], experiential [allowing responses to occur effortlessly], and positional [focusing attention on a single letter or portion of a letter]) on five-point Likert scales (1 = none of the time to 5 = all of the time; Jamieson, & Sheehan, 2004; Sheehan et al., 1988). The hypnotic induction and de-induction were drawn from the RSPS II (Weitzenhoffer, & Hilgard, 1967), which was modified to exclude all references to relaxation, sleep, and posthypnotic amnesia.

Data Analysis

CVs (SD/M) were computed on the entire data set and were analyzed with Condition (control vs. hypnosis) acting as a within-groups variable and Group (LS vs. LDHS vs. HDHS) acting as a between-groups variable. Sequential congruency effects were computed on RT data trimmed of outliers ($M \pm 2$ SDs) and restricted to complete alternation trials in which neither the same color word or ink color was repeated; all error, post-error and negative priming trials were also excluded, resulting in 42 trials per condition. Analyses of variance (ANOVAs) on error rates were performed on arcsine-transformed error percentages. Data were analyzed using mixed-model ANOVAs with Condition, Previous trial (congruent vs. incongruent), and Current trial (congruent vs. incongruent) acting as within-groups variables and Group acting as a between-groups variable. When main effects of Group, or interactions involving Group, were not observed, we used exploratory ANOVAs collapsing across HS subtypes in the Group variable (LS vs. HS); only novel effects are reported for these analyses. Significant main effects and

interactions were supplemented with *post hoc* Tukey HSD tests or independent or paired-samples *t*-tests. Pearson correlation coefficients were computed in order to assess the relationship among variables.

Results

Relaxation

As can be seen in Table 1, a Condition main effect was found for relaxation, with participants reporting greater relaxation during hypnosis relative to the control condition, $F(1, 45) = 62.43, p < .001, \eta_p^2 = .58$. Crucially, the Groups did not differ in relaxation, nor was there a Condition \times Group interaction, $F_s < 3$. These results indicate that increased relaxation during hypnosis did not differ across groups.

**** Table 1 about here ****

Strategy utilization

Utilization of the rehearsal, $F(1, 45) = 9.78, p = .003, \eta_p^2 = .18$, and positional strategies, $F(1, 45) = 7.20, p = .010, \eta_p^2 = .14$, decreased during hypnosis. In both cases, there were no main effects of Group, nor Condition \times Group interactions, $F_s < 2.5$. In contrast, participants reported greater use of the experiential strategy during hypnosis, $F(1, 45) = 23.01, p < .001, \eta_p^2 = .34$, but again there was no main effect of Group, nor a Condition \times Group interaction, $F_s < 2.5$.

Exploratory analyses pooling the two HS subtypes found no new effects other than a marginal Condition \times Group interaction on utilization of the experiential strategy, $F(2, 45) = 3.85, p = .056, \eta_p^2 = .08$. HS participants displayed a significant increase in utilization of this strategy from the control to the hypnosis condition, $t(28) = 4.43, p < .001, d = 0.85$, whereas LS participants did

not differ across conditions, $t < 1.5$. These results indicate that utilization of the rehearsal and positional strategies uniformly decreased in all groups following a hypnotic induction, whereas utilization of the experiential strategy increased only in HS participants.

Response automatization

Analysis of CVs revealed a main effect of Condition, $F(1, 45) = 4.65, p = .036, \eta_p^2 = .09$, with reduced scores (i.e., greater automatization) following a hypnotic induction (see Table 2). There was no main effect of Group nor a Condition \times Group interaction, $F_s < 2.5$. An exploratory ANOVA collapsing across HS subtypes, failed to replicate the main effect of Condition, but revealed a marginal Condition \times Group interaction, $F(1, 46) = 3.91, p = .054, \eta_p^2 = .08$. Subsidiary analyses revealed that CVs did not differ across conditions in the LS participants, $t < 0.5$, but were lower during hypnosis in HS participants, $t(28) = 3.08, p = .005, d = 0.36$. Further analyses revealed that decreases in CV following a hypnotic induction were present in HDHS, $t(10) < 2.68, p = .023, d = 0.66$, but not LDHS, $t < 1.90$, participants. These findings indicate that a hypnotic induction facilitates narrowing of RT variability among HDHS participants, but not LS and LDHS participants.

Sequential congruency effects

No differences in sequential congruency effects were observed according to the order in which the conditions were completed, so data were collapsed across order condition orders. Descriptive statistics for sequential congruency effects are presented in Table 2. No evidence for differential speed-accuracy tradeoffs, as reflected in negative correlations between RTs and error rates, was found across conditions or groups. A main effect of Current trial was found for error

rates, $F(1, 45) = 17.14, p < .001, \eta_p^2 = .28$, with fewer errors on congruent than incongruent trials.

No other main effects or interactions on error rates were found, all $F_s < 3$.

**** Table 2 about here ****

A mixed model ANOVA on RTs revealed a main effect of Condition, $F(1, 45) = 12.47, p = .001, \eta_p^2 = .22$, with slower RTs during hypnosis. A main effect of Current trial, $F(1, 45) = 125.33, p < .001, \eta_p^2 = .74$, reflecting the Stroop interference effect, was qualified by a Previous trial \times Current trial interaction, $F(1, 45) = 39.58, p < .001, \eta_p^2 = .47$, reflecting the sequential congruency effect (i.e., reduced Stroop interference following incongruent than congruent trials). Two three-way interactions were observed: Condition \times Previous \times Group, $F(2, 45) = 6.07, p = .005, \eta_p^2 = .21$, and Previous \times Current \times Group, $F(2, 45) = 4.14, p = .022, \eta_p^2 = .16$. These interactions were further mediated by the predicted Condition \times Previous \times Current \times Group interaction, $F(2, 45) = 4.59, p = .015, \eta_p^2 = .17$. This interaction indicates that the impact of the hypnotic induction on sequential congruency effects differed across groups (see Figure 1).

**** Figure 1 about here ****

Subsidiary analyses focused on differences between CI and II trials as an index of conflict-mediated adjustment in cognitive control. HDHS participants' RTs were significantly faster for II than CI trials in the control condition, $t(10) = 3.38, p = .007, d = 1.05$, but non-significantly slower during hypnosis, $t < 0.5$. The RT reduction for II, relative to CI, trials in the control condition ($M = -48.18, SD = 47.32$) was significantly greater than in the hypnosis condition ($M = 4.55, SD = 32.27$), $t(10) = 2.43, p = .035, d = 1.37$. This finding supports our

central prediction that a hypnotic induction produced a significant decline in cognitive control among HDHS participants.

The performance of LDHS and LS participants was very similar. Among LDHS participants, II RTs were not faster than CI RTs at baseline, $t < 0.5$, but were marginally faster during hypnosis, $t = 1.97$, $p = .066$, $d = 0.17$. The RT differences between the control ($M = 1.17$, $SD = 30.53$) and hypnosis ($M = -18.61$, $SD = 40.15$) conditions in this subtype exhibited a weak trend toward significance, $t(17) = 1.94$, $p = .069$, $d = 0.57$. Among LS participants, RTs did not differ between CI and II trials at baseline, $t < 0.5$, but II trials were marginally faster than CI trials during hypnosis, $t(18) = 2.09$, $p = .051$, $d = 0.25$. Improved performance from baseline ($M = 1.95$, $SD = 33.64$) to hypnosis ($M = -19.37$, $SD = 40.31$), however, was not significant, $t < 2$. When LS and LDHS participants were pooled, performance significantly improved from baseline ($M = 1.57$, $SD = 31.72$) to hypnosis ($M = -19.00$, $SD = 39.67$), $t = 2.51$, $p = .017$, $d = 0.58$. These results indicate that LS and LDHS participants displayed weak trends toward superior cognitive control following the hypnotic induction.

RT differences between baseline CI and II trials differed as a function of Group, $F(2, 45) = 8.06$, $p = .001$, $\eta_p^2 = .26$. HDHS participants exhibited superior performance in the control condition than LDHS and LS participants, Tukey HSD $ps = .002$, who did not differ, $p > .95$. In contrast, RT differences did not differ across groups during hypnosis, $F < 2$. Changes in the RT differences between CI and II trials from the control to the hypnosis condition also differed across groups, $F(2, 45) = 7.26$, $p = .002$, $\eta_p^2 = .24$. Whereas HDHS participants' performance declined ($M = 52.73$, $SD = 71.99$), that of LS ($M = -21.32$, $SD = 56.54$) and LDHS ($M = -19.78$, $SD = 43.27$) participants improved. This performance change in conflict adaptation from the control to the hypnosis condition was significantly worse in the HDHS participants relative to the LS, Tukey HSD $p = .003$, and LDHS, Tukey HSD $p = .004$, participants, who did not differ, $p >$

.9. These results indicate that HDHS participants exhibited superior cognitive control than LS and LDHS participants at baseline and that a hypnotic induction differentially impacted performance in HDHS participants relative to LS and LDHS participants.

Correlational analyses were undertaken to examine the relationship between performance across conditions in the three groups. RT differences between CI and II trials at baseline and hypnosis were unrelated in LDHS, $r(18) = .27, p = .27$, and LS, $r(19) = -.16, p = .51$, but were negatively correlated in the HDHS participants, $r(11) = -.62, p = .041$. The correlations of LDHS and HDHS participants were significantly different, $Z = 2.31, p = .021$, whereas those of LS and HDHS participants, $Z = 1.32, p > .1$, and LS and LDHS participants, $Z = 1.22, p > .1$, were not. Crucially, this indicates that magnitude of cognitive control at baseline among HDHS participants is associated with the magnitude of deterioration in cognitive control during hypnosis, with those individuals exhibiting the greatest conflict adaptation at baseline displaying the poorest adaptation during hypnosis. Insofar as the decline in performance from the control to the hypnosis condition in HDHS participants paralleled the increase in response automatization, as measured by the CV, an additional correlational analysis was performed to assess the relationship between the two measures. Changes in conflict adaptation from the control to the hypnosis condition were significantly correlated with changes in response automatization, $r(48) = -.35, p = .015$, with poorer conflict adaptation during hypnosis associated with increased response automatization.

Correlational analyses were further undertaken to assess the influence of dissociative tendencies on performance among LS participants. Dissociation, as measured by the S-DES, was non-significantly positively correlated with RT changes scores from CI to II trials in the control condition, $r = .34$, and non-significantly negatively correlated in the hypnosis condition, $r = -.14$. The directions of these correlations suggest that high dissociation in LS participants was

associated with poorer and greater conflict adaptation in control and hypnosis conditions, respectively.

Discussion

Analysis of sequential congruency effects in the Stroop task demonstrates that a hypnotic induction differentially impacts cognitive control in different subtypes of HS individuals. Specifically, we found that whereas LS and LDHS participants displayed marginal improvements in conflict adaptation following a hypnotic induction, HDHS participants exhibited a marked deterioration in conflict-mediated adjustment of cognitive control. Crucially, this effect cannot be attributed to differential relaxation levels across groups, as was previously suggested (Kirsch, & Lynn, 1998), nor differences in strategy utilization. These results are consistent with other studies demonstrating that HS individuals are comprised of distinct subtypes with dissimilar cognitive profiles (Galea et al., in press; King, & Council, 1998; Kunzendorf, & Boisvert, 1996; Winkel et al., 2006).

In addition to differential modulation of cognitive control by the hypnotic induction, the two HS subtypes displayed another important difference. Specifically, HDHS participants exhibited more pronounced sequential congruency effects at baseline than LDHS and LS participants, who didn't differ from one another. This result indicates that HDHS individuals are better at adjusting cognitive control following response conflict and is consistent with Brown and Oakley's (2004) prediction of superior attention in this subtype. Differential baseline cognitive control across the two subtypes may explain previous inconsistencies in baseline attention in this population (for a review, see Dienes, et al., 2009).

The present results are broadly consistent with the position that HS participants are comprised of two subtypes with distinct cognitive and phenomenological profiles (Barber, 1999;

Brown, & Oakley, 2004; Carlson, & Putnam, 1989; Kunzendorf, & Boisvert, 1996). In particular, they corroborate the prediction that HDHS participants display impaired cognitive control during hypnosis, whereas LDHS participants maintain flexible use of executive attention (Brown, & Oakley, 2004). This impairment may specifically point to a disruption in the integrative communication between conflict monitoring, as supported by the anterior cingulate, and cognitive control, as supported by the lateral prefrontal cortex, leading to a weakened ability to flexibly adjust control in the wake of response conflict (Egner, & Raz, 2007; Jamieson, & Woody, 2007). Impaired cognitive control in HDHS individuals following a hypnotic induction plausibly contributes to inflated involuntariness during hypnotic responding in this subtype relative to LDHS participants (Terhune, & Cardeña, 2010; Terhune, et al., 2010).

A limitation of this study is the near absence of high dissociative low suggestible participants. As in other studies (Butler, & Bryant, 1997), dissociation and hypnotic suggestibility were moderately correlated in this sample even though they were measured in independent contexts (see Terhune, et al., 2010). The absence of this group reduces our ability to discern whether the observed differences between the two subtypes reflect the modulatory influence of dissociative tendencies on individual differences among HS participants or whether they reflect broader correlates of dissociation. However, a number of findings go against the latter interpretation. First, HDHS participants exhibited superior cognitive control, whereas high dissociative individuals commonly exhibit attentional deficits in control conditions (DePrince, & Freyd, 1999; Giesbrecht, & Merckelbach, 2009; Giesbrecht, Merckelbach, Geraerts, & Smeets, 2004). This is commensurate with the observed positive, albeit non-significant, correlation demonstrating poorer baseline conflict adaptation among high dissociative LS participants. Second, the deterioration in cognitive control among HDHS participants following a hypnotic induction is also unlikely to reflect a broader covariate of dissociation. Dissociation was non-

significantly associated with improved cognitive control during hypnosis, the converse of what was observed with the HDHS participants. Importantly, in other studies high dissociative LS participants have performed differently than HDHS participants (King, & Council, 1998; Terhune, & Cardeña, 2010). Finally, even if the observed results are due to broader covariates of dissociation, they still indicate that dissociation modulates individual differences in cognitive control in significant ways and provide robust support for dissociative typological models.

Although we have emphasized the dissimilarities of the two HS subtypes, they exhibited uniformity in their increased utilization of an effortless response strategy (Jamieson, & Sheehan, 2004) following a hypnotic induction. This increase may tap into the hypothesized ‘experiential response set’, a cognitive set characterized by a willingness to allow experiences to occur with minimal effort (Tellegen, 1981). Increased utilization of the experiential response set following a hypnotic induction may be a strategic marker of high hypnotic suggestibility. This finding lends partial support to a componential interpretation of heterogeneity in high hypnotic suggestibility (Laurence, et al., 2008; Woody, Barnier, & McConkey, 2005), an alternative to the typological models. This account assumes that HS participants are homogeneous with regard to the core mechanisms underlying high hypnotic suggestibility, but vary in ancillary componential abilities, which contribute to individual differences in cognitive functioning and hypnotic responding. According to this account, the uniform heightened adoption of the experiential set by HS participants during hypnosis may partly reflect the core ability underlying high hypnotic suggestibility, whereas differential cognitive control at baseline and following a hypnotic induction may represent an ancillary componential ability that mediates other features of hypnotic responding such as involuntariness. It should be noted however that the effect sizes for the differences in experiential strategy utilization between LS and HS participants are small in comparison to those for the differential sequential congruency effects between LDHS and HDHS

participants, whereas the converse would be expected by this account. Nevertheless, the componential model remains a viable alternative to the typological models and is worthy of further theoretical development and investigation.

In demonstrating differential impact of a hypnotic induction on cognitive control in HS participants, the present findings may help to reconcile a number of competing views in contemporary experimental hypnosis research. First, the performance of the LDHS participants closely corresponds to what would be predicted by response set theory (Lynn, et al., 2008), which maintains that a hypnotic induction will not have a deleterious effect on attention. In contrast, the performance of HDHS participants corresponds to what would be predicted by dissociated control and second-order dissociated control theories (Jamieson, & Woody, 2007; Woody, & Bowers, 1994). Second, in a similar fashion, the present results may take us one step closer to reconciling the competing positions that hypnosis facilitates (Horton, & Crawford, 2004) or impairs (Woody, & Sadler, 2008) attention (the marginal improvement among LS participants corroborates a previous finding (Egner, et al., 2005)). Whether a hypnotic induction has a facilitative or detrimental effect on cognitive control appears to depend on the participants' subtype. More broadly, this experiment adds to a series of studies that have documented evidence for two subtypes, one which displays performance that corresponds to the predictions of dissociated control theory and another which displays performance that corresponds to the predictions of sociocognitive theories (Galea, et al., in press; King, & Council, 1998; Terhune, et al., 2010; Winkel, et al., 2006). Further identification of these subtypes and the mechanisms by which they respond to hypnotic suggestions represents an endeavour of critical importance for contemporary hypnosis research.

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Table 1

Descriptive Statistics for Relaxation and Strategy Utilization

Variable	Group					
	LS		LDHS		HDHS	
	Control	Hypnosis	Control	Hypnosis	Control	Hypnosis
Relaxation	2.89 (0.66)	4.21 (0.63)	3.28 (0.90)	4.06 (1.00)	3.27 (0.65)	4.82 (0.41)
Rehearsal	2.26 (1.15)	2.05 (1.22)	2.44 (1.38)	1.94 (1.06)	3.09 (1.38)	2.09 (1.22)
Positional	2.32 (1.11)	1.84 (0.77)	2.28 (1.32)	2.28 (1.23)	2.36 (1.69)	1.55 (0.93)
Experiential	3.37 (1.38)	3.68 (1.42)	3.39 (1.10)	4.17 (0.99)	2.55 (1.21)	3.73 (1.10)

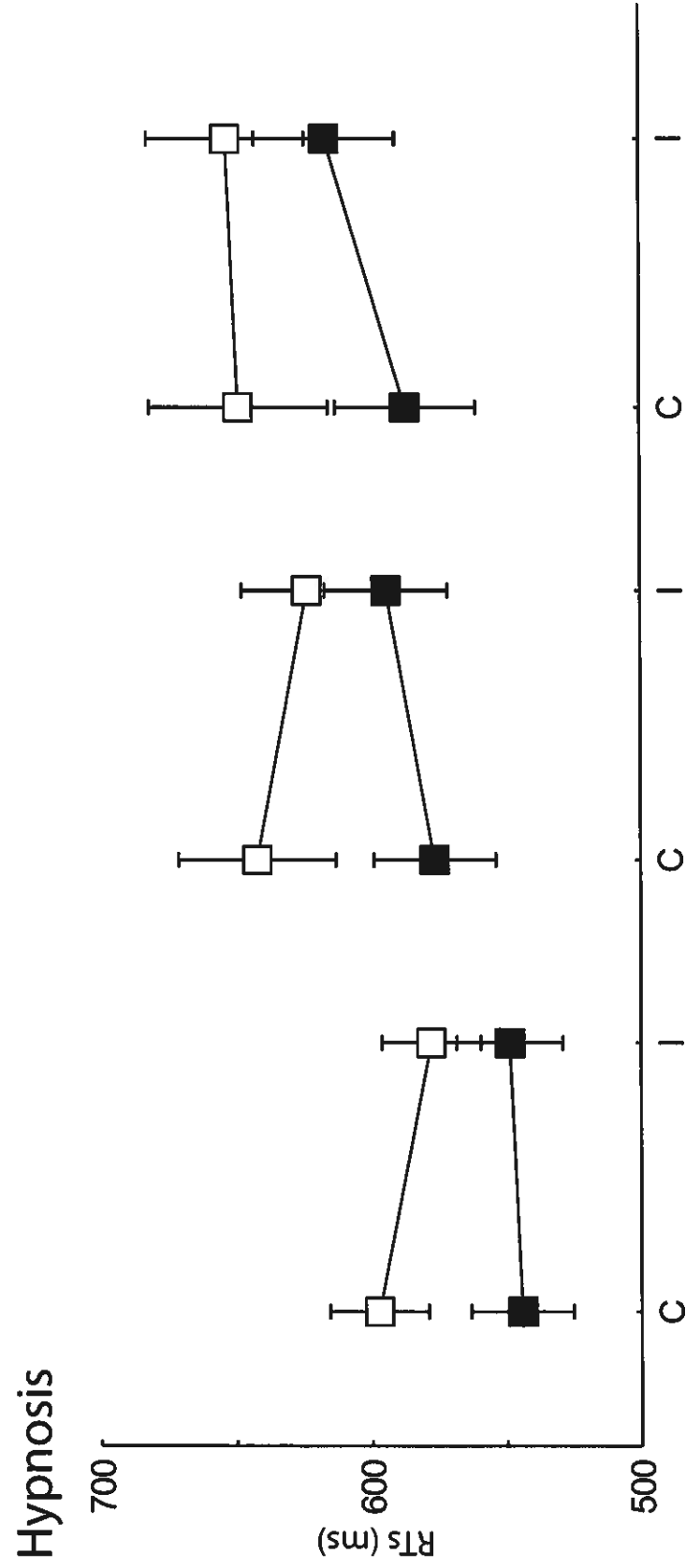
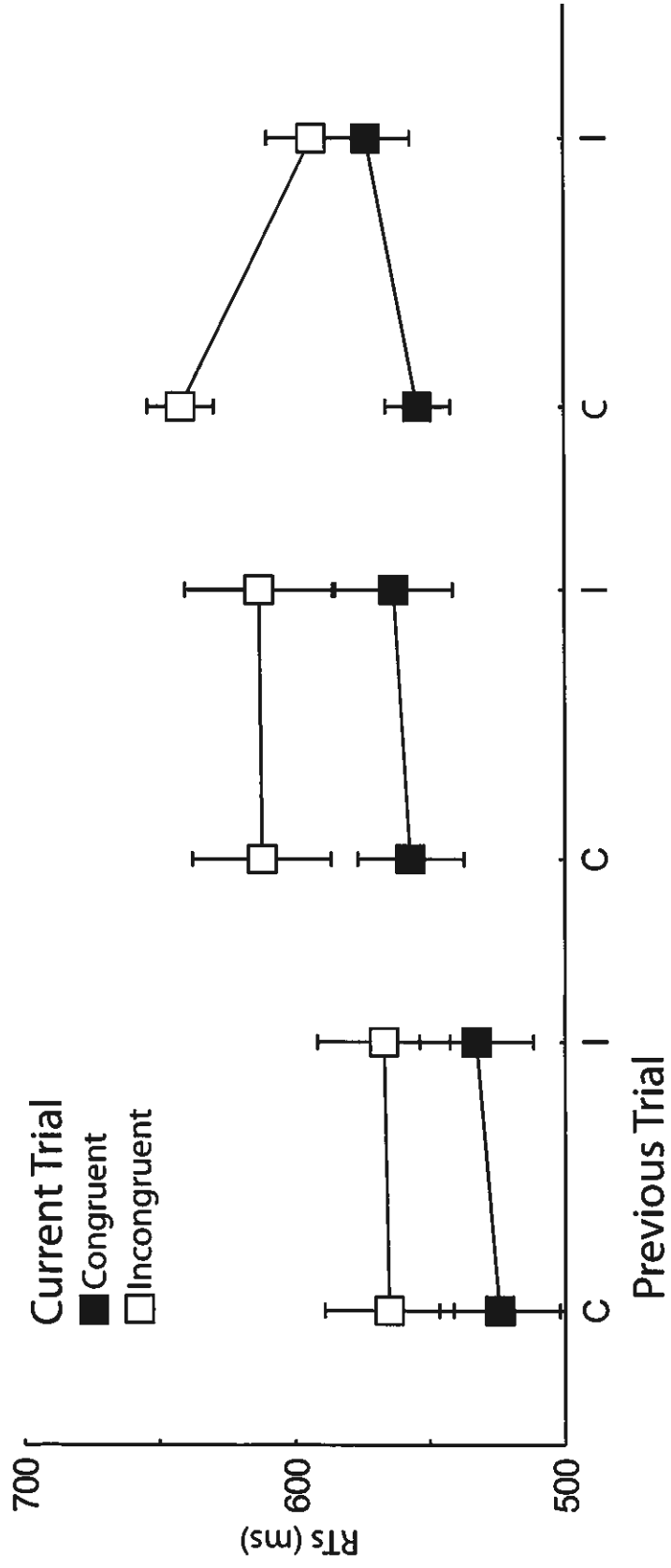
Table 2

Descriptive statistics for the Stroop Color-Naming Task

Variable	Group					
	LS		LDHS		HDHS	
	Control	Hypnosis	Control	Hypnosis	Control	Hypnosis
CV	0.25 (0.03)	0.25 (0.03)	0.25 (0.04)	0.25 (0.03)	0.27 (0.02)	0.25 (0.03)
RTs (ms)						
CC	524 (97)	544 (82)	557 (84)	576 (96)	554 (40)	587 (86)
CI	565 (105)	597 (79)	612 (108)	642 (124)	642 (40)	649 (110)
IC	533 (92)	549 (85)	563 (93)	594 (96)	574 (55)	617 (87)
II	567 (108)	578 (80)	613 (116)	624 (103)	594 (55)	653 (97)
Errors (%)						
CC	0.04 (0.04)	0.04 (0.03)	0.04 (0.04)	0.05 (0.04)	0.03 (0.04)	0.05 (0.04)
CI	0.05 (0.04)	0.05 (0.05)	0.08 (0.08)	0.05 (0.06)	0.05 (0.05)	0.06 (0.05)
IC	0.04 (0.04)	0.03 (0.04)	0.04 (0.04)	0.04 (0.04)	0.04 (0.04)	0.04 (0.06)
II	0.04 (0.03)	0.04 (0.03)	0.05 (0.04)	0.04 (0.04)	0.05 (0.04)	0.05 (0.04)

Figure 1.

Mean RTs (\pm SEM) in the Stroop color-naming task as a function of Condition, Group, Previous trial congruency (C = Congruent, I = Incongruent), and Current trial congruency.



RUNNING HEAD: Hypnosis and functional connectivity

Hypnosis reduces resting state functional connectivity¹

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Abstract

Previous research has suggested that a hypnotic induction produces changes in resting state functional connectivity among highly suggestible individuals, but no comprehensive studies have been undertaken to date. We recorded resting state EEG and self-reported state dissociation in control and hypnosis conditions in two separate experiments with low suggestible and highly suggestible individuals. The hypnotic induction reliably produced an increase in state dissociation and a reduction in neural synchrony over a wide range of frequency bands in both anterior and posterior regions, although only anterior reductions were found with two different measures of synchronization. Observed effects were more pronounced among highly suggestible individuals, who displayed uniform phenomenological and neurophysiological responses. These findings demonstrate that increased state dissociation following a hypnotic induction is associated with reduced resting state functional connectivity.

Keywords: hypnosis, hypnotic suggestibility, dissociation, neural synchrony, omega complexity, synchronization likelihood

A hypnotic induction consists of instructions and suggestions for reducing awareness of exogenous stimuli and becoming 'absorbed' in (i.e., effortlessly attentive to) the words of the operator. These features frequently lead to a reduction in metacognition and conceptual thought among highly suggestible (HS) individuals, as well as increases in self-reported lapses in attention, mind-wandering, and spontaneous vivid imagery (Cardeña, 2005; Oakley, & Halligan, 2010; Pekala, & Kumar, 2007; Rainville, & Price, 2003). These spontaneous experiences are of considerable import because they reflect changes in the background (resting) state of consciousness during hypnosis and may relate to observed deficits in executive functioning among HS individuals following a hypnotic induction (Gruzelier, & Warren, 1993; Jamieson, & Sheehan, 2004; for reviews see Egner, & Raz, 2007; Jamieson, & Woody, 2007) and contribute to the distortions in agency that often characterize responses to hypnotic suggestions (Weitzenhoffer, 1980). Insofar as distinct contents of consciousness are presumed to have corresponding unique neural signatures, spontaneous phenomenological distortions during hypnosis should be reflected in changes in oscillatory activity or functional connectivity. However, the neurophysiological mechanisms underlying hypnosis remain poorly understood.

A common approach to the study of the phenomenal state produced by a hypnotic induction has been the application of spectral analysis to resting state EEG recorded during hypnosis (see Crawford, & Gruzelier, 1992; Oakley, & Halligan, 2010; Williams, & Gruzelier, 2001). Spectral analyses have produced largely inconsistent results. Moreover, in many cases, the results have often not been predicted by, or subsequently incorporated into, a theoretical framework. Oscillatory activity in the theta frequency band (4 – 8 Hz) was repeatedly observed as a marker of hypnosis or a trait-like correlate of hypnotic suggestibility (Akpınar, Ulett, & Itil, 1971; Galbraith, London, Leibovitch, Cooper, & Hart, 1970; Graffin, Ray, & Lundy, 1995; Sabourin, 1982), although these findings have not been consistently replicated and may reflect other variables such as increased relaxation (Williams, & Gruzelier, 2001; see also Jacobs, & Friedman, 2004). Similar inconsistencies have been found with activity in the alpha band (8 – 12 Hz; Akpınar, Ulett, & Itil, 1971; Perlini, & Spanos, 1991; Williams,

& Gruzelier, 2001), although there is evidence to suggest that a hypnotic induction may selectively increase posterior upper alpha (~ 10-12 Hz) in HS individuals (Williams, & Gruzelier, 2001).

Inconsistent findings across spectral analyses may be attributable to methodological shortcomings such as low power, improper measurement of hypnotic suggestibility, and confounding of a hypnotic induction with content-specific suggestions (e.g., for relaxation; for reviews see Cardeña, 2005; Fingelkurts, Fingelkurts, Kallio, & Revonsuo, 2007; Lynn, Kirsch, Knox, Fassler, & Lilienfeld, 2007).

The assessment of changes in functional connectivity following a hypnotic induction may be a more promising approach to investigating the neurophysiological basis of spontaneous experiential distortions during hypnosis (Gruzelier, 2006). The electrical activity of the brain as recorded by surface electrodes reflects the dynamic interplay between and among distributed neural assemblies that exhibit transient quasi-stationary microstates that are interrupted by changes in the functional integrity of the assemblies and their coordination with other assemblies. Functional connectivity can be understood as the temporal correlation among two or more neurophysiological events and thus applies to both synchronous oscillatory activity underlying neural assemblies (local connectivity) as well as coordination between distributed assemblies (remote connectivity; Fingelkurts, Fingelkurts, & Kahkonen, 2005). There is consensus that the functional integration of information in the thalamocortical system plays a fundamental role in shaping the level and content of consciousness (Salinas, & Sejnowski, 2001; Tononi, 2003; Tononi, & Edelman, 1998; Vaitl, et al., 2005) and, in particular, in giving rise to coherent cognition and perception and the phenomenal unity of consciousness (Fries, 2005; Varela, Lachaux, Rodriguez, & Martinerie, 2001; Varela, & Thompson, 2003; for a review, see Seth, Dienes, Cleeremans, Overgaard, & Pessoa, 2008). Integration of neural information between pairs of EEG channels can be quantified using measures of synchronization (Fingelkurts, et al., 2005; Stam, & van Dijk, 2002; Varela, et al., 2001), which index the statistical interdependency between two time series. The functional coordination of distributed large-scale networks, as reflecting in synchronous oscillatory activity, has been shown to be associated with a wide

variety of cognitive functions including attention and working memory (Varela, et al., 2001; Ward, 2003) and has proven useful in discriminating psychiatric and neurological patients from healthy controls (Saito, et al., 1998; Stam, et al., 2006; Uhlhaas, & Singer, 2006), as well as distinguishing different states of consciousness (Wackermann, 1999).

An examination of the content of spontaneous phenomenological distortions among HS individuals following a hypnotic induction provides a clear link with neural synchrony. The constellation of spontaneous experiences reported during hypnosis, ranging from alterations in temporal perception to volition, can be collectively classified as 'dissociative' insofar as they reflect disruptions between normally integrated systems underlying awareness, control, and perception (Spiegel, & Cardeña, 1991). The weakening of integration that characterizes dissociative experiences maps remarkably well onto a disturbance in neural synchrony, such that reduced synchronization in prefrontal regions and elsewhere in the cortex may provide a useful neurophysiological operational definition of state dissociation (for a related position, see Bob, 2007). A corollary of this hypothesis is that a hypnotic induction will produce a disruption in the functional coordination of neural networks supporting a wide variety of cognitive functions that is isolated to, or augmented among, HS individuals, and that this will in turn produce spontaneous dissociative experiences. This account is in keeping with dissociation theories of hypnosis, which have specifically proposed that a hypnotic induction triggers a reduction in the functional coordination of executive control and monitoring in the lateral prefrontal cortex and anterior cingulate (Jamieson, & Woody, 2007).

A number of studies have provided preliminary evidence for the position that hypnosis reduces resting state functional connectivity. In a study with a single HS individual, Fingelkurts, Fingelkurts, Kallio, et al. (2007a) found that a hypnotic induction produced a decrease in local and remote functional connectivity, as measured by the index of structural synchrony (Fingelkurts, Fingelkurts, Rytasala, Suominen, Isometsa, & Kahkonen, 2007b), across multiple frequency bands. The decrease in functional connectivity was more predominant for connections involving anterior regions of the cortex,

as would be predicted by dissociation theories (Jamieson, & Woody, 2007; Woody, & Farvolden, 1998) and frontal inhibition models (Crawford, & Gruzelier, 1992; Gruzelier, 1998) of hypnosis. Moreover, there were a number of new connections that emerged during hypnosis, the majority of which were in posterior regions and in the beta frequency band (Fingelkurts et al., 2007a). Crucially, these findings were replicated one year later with the same participant, thereby demonstrating their reliability. However, generalizations from this study should be tempered because of the single-case study design. In addition, insofar as no LS individuals participated in the study, it is unclear whether the observed effects are unique to HS individuals. These two limitations were circumvented in a study by Cardeña and colleagues (Cardeña, Lehmann, Jönsson, Terhune, & Faber, 2008) which found that a hypnotic induction reduced global functional connectivity, as measured by omega complexity (Wackermann, 1996), in HS individuals relative to LS and medium suggestible individuals. In addition, Cardeña et al. found that decreased functional connectivity during hypnosis was related to spontaneous imagery and perceptual distortions. This study was limited because only global synchronization in a broad frequency band, as opposed to topographical analyses in multiple frequency bands, was the dependent measure. In another study, Egner and colleagues found reduced coherence in the gamma band between two anterior electrode channels during hypnosis relative to a control condition in HS, but not LS, participants during completion of a Stroop task (Egner, Jamieson, & Gruzelier, 2005). A related experiment by Isotani et al. (2001) also found that HS individuals exhibit reduced global synchronization, as measured by omega complexity, in an eyes-closed resting state control condition. Finally, two other studies using fractal analysis of single channel EEG have found increased independence of anterior neural assemblies among HS individuals at baseline (Ray, 1997) and in all regions in HS individuals following a hypnotic induction (Lee, et al., 2007). Although these studies did not examine synchronization between different electrodes (i.e., functional connectivity), they point to increased temporal independence of neural assemblies in HS individuals. Taken together, these studies suggest that a hypnotic induction produces changes in functional connectivity across a variety of

cortical areas and in multiple frequency bands and that decreased functional connectivity may be a baseline marker of high hypnotic suggestibility.

A critical issue that has been neglected by previous neurophysiological studies of hypnosis is whether a hypnotic induction produces a uniform state of consciousness among HS individuals. HS individuals have been repeatedly observed to display marked variability in a variety of dimensions of hypnotic responding (McConkey, & Barnier, 2004) and in their spontaneous phenomenological response patterns to a hypnotic induction (Pekala, & Kumar, 2007; Terhune, & Cardeña, 2010). Using latent profile analysis, Terhune and Cardeña (2010) found that HS participants were comprised of two discrete subtypes, a *dissociative* subtype that experienced pronounced distortions in awareness and volitional control and greater negative affect, and an *inward attention* subtype whose experience was characterized by endogenously-directed attention and vivid imagery. The characteristic features of these two subtypes were replicated in a subsequent behavioural study (Terhune, Cardeña, & Lindgren, 2010). The presence of heterogeneity among HS individuals represents a potential confound in the search for the neural correlates of spontaneous phenomenological distortions during hypnosis (for related points, see Barnier, & McConkey, 2003; Woody, & McConkey, 2003). An alternative to typological models of high hypnotic suggestibility (Barber, 1999; Carlson, & Putnam, 1989) is provided by the componential model (Woody, Barnier, & McConkey, 2005). This account assumes that HS individuals exhibit uniformity on the core mechanisms underlying hypnosis and hypnotic responding, but differ in ancillary componential abilities (e.g., imagery), which, in turn, modulate individual differences (see also Laurence, Beaulieu-Prévost, & du Chéné, 2008). On the assumption that the background neurophenomenological state produced by a hypnotic induction is functionally linked with the mechanisms underlying hypnosis, the componential model would predict that the two HS subtypes will exhibit similar neurophysiological responses to hypnosis, i.e. reduced functional connectivity during hypnosis, whereas the typological models predict that such an effect is isolated to, or augmented in, the dissociative subtype.

In this study we measured changes in resting state functional connectivity following a hypnotic induction across individuals of different levels of hypnotic suggestibility. To isolate reliable effects, the same design was employed in two separate sessions (e.g., Fingelkurts et al., 2007). Participants experienced brief resting epochs in control and hypnosis conditions whilst EEG was recorded. State dissociation was measured by self-report in reference to the resting epochs in order to further clarify the phenomenological concomitants of the hypnotic induction. In addition, we addressed the issue of heterogeneity among HS individuals by comparing low dissociative HS and high dissociative HS subtypes. As in other studies (Cardeña, et al., 2008; Isotani, et al., 2001), we used omega complexity (OC; Wackermann, 1996) as a measure of synchronization. OC is a linear measure derived from spatial principal components analysis that has been used to document reduced synchronization in schizophrenic patients than controls (Irisawa, et al., 2006; Saito, et al., 1998), and to reliably discriminate different sleep stages (Szelenberger, Wackermann, Skalski, Niemcewicz, & Drojewski, 1996; for a review, see Wackermann, 1999). Insofar as OC is not sensitive to nonlinear synchronization and in previous studies has failed to detect apparently nonlinear effects, synchronization likelihood (SL; Stam, & van Dijk, 2002; see also Micheloyannis, et al., 2006; Stam, et al., 2006), was computed for resting epochs.

Method

Participants

Participants were 47 individuals (34 females) ranging in age from 18 to 33 ($M = 23.36$, $SD = 2.85$) who had previously been screened in group sessions using the *Waterloo Group Scale of Hypnotic Susceptibility, Form C* (WSGC; Bowers, 1993; $HS \geq 8$, $LS \leq 4$; see Terhune, & Cardeña, 2010) and in two individual sessions with the *Revised Stanford Profile Scales of Hypnotic Susceptibility* (RSPS I and II; Weitzenhoffer, & Hilgard, 1967; $HS > 10$; $LS < 4$; see Terhune, et al., 2010). The sample was comprised of 19 LS (13 females; $M_{Age} = 23.26$, $SD = 2.47$) and 28 HS (21 females; $M_{Age} = 23.43$, $SD =$

3.12) participants, who didn't differ in age, $t < 0.5$, or sex distributions, $\chi^2 < 0.5$. Among HS individuals, high dissociation was established with a cut-off criterion of 20 on the *Swedish Dissociative Experiences Scale* (S-DES; Körlin, Edman, & Nybäck, 2007; see Terhune, et al., 2010), yielding 11 high dissociative HS ($M = 35.29$, $SD = 14.58$) and 17 low dissociative HS ($M = 11.95$, $SD = 5.41$) participants. The 19 LS participants displayed low levels of dissociation ($M = 10.62$, $SD = 8.28$). Participants provided informed written consent and were compensated for their participation.

Instrument

State dissociation was measured with the eight-item version of the *Peritraumatic Dissociative Experiences Questionnaire* (PDEQ; Marshall, Orlando, Jaycox, Foy, & Belzberg, 2002). The PDEQ is a state measure that is completed retrospectively in reference to a preceding epoch. Items are scored on a five-point Likert scale with anchors at 0 ('not at all true') and 5 ('extremely true'), with the outcome score being the mean across items. A representative item is "I 'blanked out' or 'spaced out' or in some way felt that I was not part of what was going on." The PDEQ has a unidimensional structure and robust psychometric properties (Marshall et al., 2002) and exhibited strong internal consistency in all conditions of the current study (α range: .82 - .91; $M = .87$, $SD = .04$).

Procedure

Participants took part in two sessions with equivalent experimental designs that were separated by approximately one week (LS: $M_{\text{Days}} = 8.47$, $SD = 6.10$; HS: $M_{\text{Days}} = 8.46$, $SD = 8.86$, $t < .01$). Following the application of the EGI sensor net and instrument calibration, participants were seated in a semi-reclined position in a quiet, dimly-lit room. Each session involved the recording of EEG during three three-minute eyes-closed resting state epochs (pre-hypnosis control, hypnosis, post-hypnosis control). The hypnotic induction and de-induction were drawn from the RSPS (Weitzenhoffer, &

Hilgard, 1967), but were modified to exclude all references to sleep, relaxation, and superfluous suggestions. Participants retrospectively completed the PDEQ in reference to each resting epoch.

EEG recording and processing

EEG was recorded with a 128-channel Geodesic Sensor Net (Electrical Geodesics, Eugene, OR), sampled at 500 Hz, and filtered online between 0.3 and 100 Hz. Amplified EEG data were filtered offline with a 0.5 Hz high-pass filter and a 50 Hz low-pass filter and segmented into two-second epochs. Epochs containing artifacts ($\pm 80 \mu\text{V}$) were automatically removed as were those with artifacts detected by visual inspection. Artifact-free epochs were converted to ASCII files for offline analyses. The number of acceptable two-second epochs per condition varied from 64 to 89 ($M = 82.50$, $SD = 3.47$) and did not differ across conditions or groups in either session, $F_s < 1.5$.

Analyses

OC and SL values were computed using the program DIGEEG, with permission of C.J. Stam (Department of Clinical Neurophysiology, VU University Medical Center, Amsterdam). In each case, the values were computed for each two-second epoch in four regions comprised of 20 channels (left anterior, right anterior, left posterior, right posterior; see Figure 1) in the following frequency bands: delta (0.5 – 4), theta1 (4.5 – 6), theta2 (6.5 – 8), alpha1 (8.5 – 10), alpha2 (10.5 – 12), beta (15 – 25), and gamma (35 – 45). Epoch values in each condition were subsequently averaged.

**** Figure 1 about here ****

Omega Complexity

OC is a linear measure of the spatial complexity of multichannel EEG data (Wackermann, 1996, 1999) and indexes the magnitude of functional independence among the set of signals. OC is a single

measure derived from the spatial principal components analysis of a covariance matrix comprised of data from the EEG channels in a montage in which the entropy (i.e., loss of information) of the normalized eigenvalues of the derived components is the logarithm of omega (Wackermann, 1996). As sources of electrical activity exhibit greater independence, or complexity, OC increases; reduced synchronization is reflected in *greater* OC values, which range from 1 (absolute synchrony) to k (absolute independence), where k represents the total number of electrodes in the data set, or in the present analyses, 20.

Synchronization Likelihood

SL is a measure of the statistical interdependence of two time series and provides a measure of synchronization that is sensitive to both linear and non-linear dependencies (Stam, & van Dijk, 2002). SL is computed by using time delay embedding to construct two series of state space vectors ($X_i \dots X_j$, $Y_i \dots Y_j$) from two time series, X and Y . SL is defined as the likelihood that the occurrence of the same state at times i and j in time series X will be matched by its occurrence at times i and j in time series Y (for further details, see Montez, Linkenkaer-Hansen, van Dijk, & Stam, 2006; Stam, & van Dijk, 2002). SL values range from a selected value P_{ref} (independent signals) to 1 (maximally synchronous time series). P_{ref} was 0.01 for all analyses whereas other parameters included in the analyses were selected on the basis of the different frequency bands (see Montez et al., 2006). SL is computed for each electrode pair in a regional montage and then averaged across pairs to reflect overall synchronization in the epoch.

Statistical analyses

PDEQ scores were submitted to mixed-model analyses of variance (ANOVAs) for each experimental session, with Condition (pre-hypnosis control vs. hypnosis vs. post-hypnosis control) acting as a within-groups variable and Group (LS vs. low dissociative HS vs. high dissociative HS)

acting as a between-groups variable. OC and SL values for each frequency band were submitted to mixed-model ANOVAs with Condition and Group and two additional within-groups variables: Region (anterior vs. posterior) and Hemisphere (left vs. right). Group was collapsed across HS subtypes (i.e., LS vs. HS) when no differences between the two HS subtypes were observed. The Greenhouse-Geisser correction was used whenever the assumption of sphericity was violated; original degrees of freedom are reported. Subsidiary analyses were performed with independent and dependent *t*-tests for between- and within-group contrasts, respectively. Unequal-variance *t*-tests were used when the assumption of homogeneity of variance was violated. Pearson correlations were used to measure the relationship between variables. Analyses were performed using MATLAB v. 7.6 (The Mathworks, Natick, MA) and SPSS v. 16 (SPSS Inc., Chicago, IL). We only report effects that were replicated (statistically significant and in the same direction) across sessions.

Results

Sample Characteristics

Two HS participants, one in each subtype, exhibited too few (< 10) artifact-free epochs in one or more conditions and were excluded from the data set. The two HS subtypes did not differ in state dissociation, OC, or SL in any of the conditions and were pooled into one group. The analyses henceforth included 19 LS and 26 HS participants.

Reliability of Measures

Correlation coefficients were computed for OC and SL values (averaged across regions) and PDEQ scores in the pre-hypnosis control conditions across the two sessions to assess the reliability of these measures. PDEQ values across the two sessions were significantly correlated, $r = .84$, $p = .001$. Similarly, in each frequency band, OC (range: .64 - .94, $M = .81$, $SD = .13$, all $ps < .001$) and SL (range: .75 - .93, $M = .85$, $SD = .07$, all $ps < .001$) exhibited strong reliability.

State dissociation

State dissociation scores across conditions and groups are presented in Figure 2. Across sessions, there were main effects of Condition, S1: $F(2, 86) = 101.90, p < .001, \eta^2 = .70$, S2: $F(2, 86) = 90.15, p < .001, \eta^2 = .68$, Hypnotic suggestibility, S1: $F(1, 43) = 39.28, p < .001, \eta^2 = .48$, S2: $F(1, 43) = 26.92, p < .001, \eta^2 = .39$, and Condition \times Hypnotic suggestibility interactions, S1: $F(2, 86) = 26.14, p < .001, \eta^2 = .38$, S2: $F(2, 86) = 35.54, p < .001, \eta^2 = .45$.

**** Figure 2 about here ****

Across sessions, LS and HS participants did not consistently differ in PDEQ scores in the pre-hypnosis control and post-hypnosis control conditions, but HS participants exhibited greater state dissociation than LS participants during hypnosis, S1: $t(43) = 6.98, p < .001, d = 2.16$, S2: $t(43) = 6.89, p < .001, d = 2.12$. Among the LS participants, the increase in PDEQ scores from the pre-hypnosis control to the hypnosis condition was significant, S1: $t(18) = 4.77, p < .001, d = 1.44$, S2: $t(18) = 3.15, p < .01, d = .97$, as was the decrease from the hypnosis to the post-hypnosis control condition, S1: $t(18) = 4.24, p < .001, d = 1.34$, $t(18) = 3.25, p < .005, d = 1.00$. HS participants also reported significant increases in state dissociation from the pre-control to the hypnosis condition, S1: $t(25) = 10.10, p < .001, d = 2.48$, S2: $t(25) = 10.43, p < .001, d = 2.34$, and decreases from the hypnosis to the post-hypnosis control condition, S1: $t(25) = 11.07, p < .001, d = 3.00$, S2: $t(25) = 10.57, p < .001, d = 2.49$. Critically, the increase in PDEQ scores from the pre-hypnosis control to the hypnosis condition was significantly greater in the HS participants than the LS participants, $t(43) = 4.77, p < .001, d = 1.47$, S2: $t(43) = 6.07, p < .001, d = 1.88$, as was the decrease from the hypnosis to the post-hypnosis condition, S1: $t(43) = 5.64, p < .001, d = 1.73$, S2: $t(43) = 6.14, p < .001, d = 1.89$. These results indicate that state

dissociation increased following the hypnotic induction and returned to baseline levels following the de-induction, but that these effects were more pronounced among HS participants.

Omega Complexity

Descriptive and inferential statistics for OC are presented in Tables 1 and 2, respectively. Main effects of Hemisphere were found for delta and theta2, reflecting greater OC among right hemisphere electrodes for delta and greater OC among left hemisphere electrodes for theta2. However, there were no replicable interactions involving Hemisphere for any of the frequency bands. Condition main effects in the delta band were mediated by Condition \times Group interactions with HS participants exhibiting greater OC in the hypnosis condition than LS participants. As can be seen in Figure 3, OC patterns across conditions and regions were equivalent in the theta1 and theta2 bands. In both cases, Region \times Condition interactions were qualified by Region \times Condition \times Group interactions. LS participants did not differ across conditions in theta1, but exhibited lower OC in the post-hypnosis control condition than the pre-hypnosis control condition in theta2. Among the HS participants, OC increased during hypnosis over anterior regions and returned to baseline levels in the post-hypnosis control condition. Region \times Condition \times Group interactions were also found for alpha1 and alpha2. In alpha1, LS participants exhibited increased OC during hypnosis relative to the pre-hypnosis and post-hypnosis control conditions over both anterior and posterior sites. HS participants displayed the same pattern over anterior sites, but exhibited no condition differences over posterior sites. In alpha2, LS participants did not differ across conditions, whereas HS participants exhibited increased anterior OC during hypnosis relative to the control conditions. In the beta band, there was a main effect of condition; OC increased during hypnosis, $t_s > 4$, $p < .001$, $d_s > 0.5$, and decreased to baseline levels in the post-hypnosis control condition, $t_s > 4.2$, $p_s < .001$, $d_s > 0.7$. As can be seen in Table 1, OC changes in the beta band were restricted to anterior regions. Crucially, changes in anterior OC from the pre-hypnosis control to the hypnosis condition were significantly greater in HS participants, $t_s (43) >$

2.9, $ps < .007$, $ds > 0.8$, as were reductions in OC from the hypnosis to the post-hypnosis control condition, $ts(43) > 2.7$, $ps < .05$, $ds > 0.8$. In the gamma band, there was a Region \times Condition interaction. Across groups, anterior OC increased in the hypnosis condition, $ts > 3.7$, $ps < .002$, $ds > 0.5$, and returned to baseline levels in the post-hypnosis control condition, $ts > 2.8$, $ps < .01$, $ds > 0.4$, but did not change over posterior regions. As can be seen in Table 1 and Figure 3, these effects were only present in HS participants, whereas LS participants didn't differ across conditions. No between-group differences were found, but increases in anterior OC from the pre-hypnosis control to the hypnosis condition were significantly greater in HS participants, $ts > 2.2$, $ps < .03$, $ds > 0.6$. In summary, LS participants exhibited increased OC during hypnosis over both anterior and posterior regions in alpha1 and over anterior regions in beta, whereas HS participants consistently displayed increased anterior OC during hypnosis in all frequency bands, but only exhibited increased posterior OC in the delta band. The only differences in *changes* in OC from the control to the hypnosis condition across groups were in the beta and gamma bands, with greater increases displayed by HS participants.

**** Table 1 about here ****

**** Table 2 about here ****

**** Figure 3 about here ****

Synchronization Likelihood

Descriptive and inferential statistics for SL are presented in Tables 3 and 4, respectively. No main effects of Group or Hemisphere on SL were found. Main effects of Region were replicated for multiple frequency bands, in all cases reflecting lower SL over posterior regions, thus replicating the Region effects on OC. Main effects of Condition were found for all frequency bands and in all cases, these

effects were qualified by Condition \times Group interactions. In all frequency bands, SL decreased in the hypnosis condition and increased again in the post-hypnosis control condition. Increased SL during hypnosis was found over anterior regions for both groups, all posterior regions for HS participants, and all posterior regions for LS participants except in the delta and alpha1 bands.

**** Table 3 about here ****

**** Table 4 about here ****

Subsidiary *t*-tests revealed that LS and HS participants did not differ in SL in the control conditions in any of the frequency bands, whereas HS participants consistently exhibited lower SL during hypnosis than LS participants in anterior and posterior regions of all frequency bands except anterior alpha1. Following the de-induction, SL only returned to baseline levels in LS participants in delta, theta2, alpha2, and beta bands. Among HS participants, SL increased following the de-induction but only to baseline levels in the delta (anterior and posterior) and alpha1 (anterior) bands. Collectively, these findings indicate that the hypnotic inductions reduced SL in a broad range of frequency bands and regions in both LS and HS participants. In addition, SL increased again following the de-induction but only returned to baseline levels in delta and alpha1 bands in both groups and theta2 and beta in LS participants.

Crucially, SL changes associated with the induction and de-induction were greater in HS participants (see Figure 4). In both sessions, decreases in SL from the pre-hypnosis control to the hypnosis condition were greater in HS participants over both anterior and posterior regions in the delta ($ts > 3.5, ps \leq .001, ds > 1.2$), theta1 ($ts > 5.3, ps < .001, ds > 1.6$), theta2 ($ts > 5, ps < .001, ds > 1.5$), alpha1 ($ts > 2.4, ps < .03, ds > 0.7$), alpha2 ($ts > 4.7, p < .001, ds > 1.5$), beta ($ts > 3.7, ps < .001, ds > 1.2$), and gamma ($ts > 2.9, ps < .006, ds > 0.8$) bands. Similarly, increases in SL from the hypnosis to post-hypnosis control condition were greater in HS participants over both anterior and posterior regions

in delta ($ts > 2.5$, $ps \leq .01$, $ds > 0.6$), theta1 ($ts > 4.7$, $ps < .001$, $ds > 1.5$), theta2 ($ts > 3.8$, $ps < .001$, $ds > 1.2$), alpha2 ($ts > 4$, $ps < .001$, $ds > 1.5$), beta ($ts > 3.1$, $ps < .004$, $ds > 1.1$), and gamma ($ts > 3.5$, $ps \leq .001$, $ds > 0.9$), but only over posterior regions in alpha1 ($ts > 3.5$, $ps < .001$, $ds > 1$). These findings indicate that changes in SL associated with the hypnotic induction and de-induction were more pronounced among HS participants.

**** Figure 4 about here ****

Synchronization and State Dissociation

Correlational analyses examined the relationship between changes in the synchronization measures and state dissociation following the hypnotic induction. In both sessions, increases in state dissociation from the pre-hypnosis control to the hypnosis condition in the entire sample were negatively correlated with decreases in SL in the delta (anterior: $rs > .3$, $ps < .05$), theta1 (anterior: $rs > .39$, $ps < .01$; posterior: $rs > .38$, $ps < .01$), theta2 (anterior: $rs > .43$, $ps < .005$; posterior: $rs > .34$, $ps < .05$), alpha2 (posterior: $rs > .33$, $ps < .05$), and beta (anterior: $rs > .34$, $ps < .05$) bands. No replicable effects were found for alpha1 or gamma. Changes in OC across conditions were unrelated to changes in state dissociation in any of the frequency bands.

Discussion

Following a hypnotic induction, HS participants exhibited increased state dissociation and reduced electrocortical synchronization in all measured frequency bands relative to LS participants. Reductions in neural synchrony over anterior sites were found with two different measures (OC and SL), whereas reductions in posterior regions were only consistently found with one measure (SL). Crucially, LS and HS individuals displayed similar patterns in state dissociation and neural synchrony across the conditions, but the impact of the hypnotic induction on both measures was more pronounced

among HS individuals. These findings strongly suggest that the disruptions in awareness, control, and perception that characterize spontaneous episodes of state dissociation during hypnosis are grounded in a widespread disruption of neural synchrony.

Our results directly or conceptually replicate a number of previous findings. Reliable reductions in neural synchrony in a wide range of frequency bands were previously found by Fingelkurts et al. (2007a). In particular, we found convergent evidence from both synchronization measures for reduced neural synchrony in anterior regions, as reported by Fingelkurts et al. (2007a). This seems to suggest that the impact of a hypnotic induction on cortical functioning has greater effect over frontal regions of the cortex and is in accordance with models that maintain that frontal functioning is attenuated among HS individuals during hypnosis (Dietrich, 2003; Gruzelier, 1998; Jamieson, & Woody, 2007; Muzur, 2006; Woody, & Sadler, 2008). Our results also replicate the finding of our own previous study in which global increases in OC (i.e., reduced synchronization) occurred following a hypnotic induction in HS individuals (Cardeña, et al., 2008), but indicate that this reduction, as measured by OC, is more pronounced over anterior regions of the cortex and that changes in functional connectivity across groups are only present in the beta and gamma bands. That reductions in anterior beta and gamma synchronization, as measured by OC, during hypnosis were greater among HS individuals conceptually replicates Egner et al.'s (2005) finding of reduced gamma coherence during hypnosis among HS individuals. Our results also resonate with those of a recent fMRI study that found that a hypnotic induction reduced activity in the anterior default mode (i.e., resting state) network (McGeown, Mazzoni, Venneri, & Kirsch, 2009); an effect that has since been replicated (Deeley et al., 2008, as cited in Oakley, & Halligan, 2010). Disruption of neural synchrony during hypnosis may mediate the reduction of activity in the default network. One inconsistency with the extant literature is that we failed to replicate the finding that HS individuals exhibit attenuated baseline neural synchrony, as measured by OC (Isotani, et al., 2001). However, this finding may have resulted from inadequate

screening of participants in Isotani et al.'s study. Our results indicate that LS and HS individuals do not exhibit baseline differences in functional connectivity.

The divergence of the two synchronization measures is worth examining. Whilst both measures pointed to reductions in neural synchrony over anterior regions during hypnosis, similar reductions over posterior regions were only found in SL. Other studies have also found that SL is sensitive to effects that go undetected by OC (e.g., Molnar, et al., 2009). Discrepancies between the results garnered by the two measures are likely because OC is a linear measure (Wackermann, 1999), whereas SL is sensitive to both linear and nonlinear interdependencies (Stam, Breakspear, van Walsum, & van Dijk, 2003; Stam, & van Dijk, 2002). In addition, whereas SL reflects the average level of synchronization among all pairs in an electrode montage, OC measures synchronization among all the electrodes in a montage and thus may be more sensitive to higher-order interactions involving a diverse array of neural assemblies. A second important difference between the two measures is that changes in state dissociation across conditions were associated with corresponding changes in SL, but not OC. Taken together, the findings suggest that whilst changes in neural synchrony, as measured by SL, may underlie changes in state dissociation, OC may reflect other higher-order processes and their corresponding phenomenological dimensions such as deficient executive functioning or greater imagery (Cardeña, et al., 2008; see also Ray, 1997). In any case, it is apparent that OC and SL are measuring different, albeit overlapping, processes. Comprehensive research on the relationship between these and other measures of synchronization is needed (cf. Horwitz, 2003).

The present results provide strong support for the position that disruption in neural synchrony during hypnosis represents the neurophysiological basis for state dissociation. Widespread reductions in neural synchrony across frequencies and regions, as measured by SL, may point to a generalized reduction in cortical arousal and concomitant increase in disorientation and inability to form coherent percepts that is more pronounced in HS individuals; the latter two phenomenological features are hallmark components of state dissociation. Support for this interpretation is provided by a PET study of

hypnosis, which found that reduced vigilance was associated with decreased activation of the brainstem and thalamus (Rainville, Hofbauer, Bushnell, Duncan, & Price, 2002; see also Rainville, & Price, 2003). Increased state dissociation and reduced neural synchrony may result from an induced *irregularity* of oscillations generated in these regions, which would attenuate the establishment of reliable phase relationships between neural assemblies (Fries, 2005). A similar mechanism may apply at the assembly level, leading to a reduction in the formation of functionally coherent assemblies or the ability of assemblies to entrain additional neurons and incorporate them into the assembly (see also Engel, Fries, & Singer, 2001). A hypnotic induction appears to reduce the ability of cortical networks and thalamocortical loops to generate synchronous oscillatory activity and, thereby, for the brain to integrate information, resulting in state dissociation. These effects may have nonlinear components and hence go undetected by principal components analysis of the EEG (Wackermann, 1999). In contrast, reductions in neural synchrony measured by OC were only found over anterior regions and were only greater among HS than LS participants in the beta and gamma frequencies. These effects may reflect disruptions in local cortico-cortical connections in higher-order regions (Uhlhaas, & Singer, 2006) and reflect weakened executive functioning (see also Egner et al., 2005). More broadly, the current results provide strong support for the position that disruptions in information processing underlying state dissociation are based in corresponding reductions in neural synchrony (e.g., Bob, 2007). Insofar as state dissociation is characterized by disruptions in the phenomenal unity of consciousness, we also provide indirect support for theories of consciousness that maintain that the integration of information by synchronized neural assemblies plays a fundamental role in the unified experience of consciousness (Tononi, & Edelman, 1998; Varela, & Thompson, 2003).

It is significant that LS individuals exhibited similar, albeit less pronounced, reductions in neural synchrony and increases in state dissociation during hypnosis as HS individuals. However, the observed effects were more pronounced in the latter. Differences among individuals in their conscious states depend on the repertoire of possible states that an individual can experience (e.g., Tononi, 2003).

In this regard, it may be that HS individuals have a greater capacity for transitions between states with different levels of functional connectivity (see also Gruzelier, 2006). Whether HS individuals are capable of such transition states outside of a hypnotic context is worth pursuing.

Whereas previous studies have suggested that HS individuals are comprised of distinct subtypes with discrete experiential profiles following a hypnotic induction (Pekala, & Kumar, 2007; Terhune, & Cardeña, 2010), these individuals displayed uniform patterns of neurophysiological and phenomenological response across conditions. Accordingly, the current results are inconsistent with models proposing that HS individuals are comprised of distinct subtypes (Barber, 1999; Cardeña, 1996; Carlson, & Putnam, 1989) and provide support for a componential model (Laurence, et al., 2008; Woody, et al., 2005; Woody, & McConkey, 2003). Insofar as high dissociative HS participants displayed greater, albeit non-significant, increases in state dissociation during hypnosis than low dissociative HS participants, the current findings may be the result of insufficient power. Moreover, previous studies discriminated HS subtypes on the basis of a diverse set of experiential dimensions including affect, awareness, control, imagery, and perception (Pekala, 1991); accordingly, state dissociation may not provide sufficient sensitivity in discriminating the two subtypes. Finally, previous studies identified subtypes on the basis of their first experience of hypnosis, whereas the participants in the present study had previously experienced hypnosis twice before participating. Accordingly, HS subtypes may exhibit different experiential profiles initially, but display greater experiential homogeneity in later sessions. At first glance, homogeneity in neurophysiological response among HS individuals may be difficult to reconcile with our previous finding that a hypnotic induction differentially impacts cognitive control in low dissociative and high dissociative HS subtypes (Terhune, Cardeña, & Lindgren, 2009). One possibility is that a hypnotic induction produces a uniform neurophysiological state in HS individuals, but that low dissociative HS individuals have greater control over their attentional states and maintain the ability to flexibly recruit cognitive resources to meet task demands whereas high dissociative HS individuals' ability to do so is diminished. This

speculation is consistent with the claim that state dissociation during hypnosis is less involuntary among low dissociative HS individuals than high dissociative HS individuals (Cardeña, 1999; Carlson, & Putnam, 1989) as well our own findings that high dissociative HS individuals experience greater involuntariness during hypnotic responding (Terhune, & Cardeña, 2010; Terhune, et al., 2010). In their study of the impact of a hypnotic induction on activity in the default mode network, McGeown et al. (2009) found that activation differences between control and hypnosis conditions in HS individuals decreased when participants had to complete tasks of increasing difficulty. We might speculate that such reductions in condition differences will be more pronounced among low dissociative HS individuals.

A number of alternative interpretations for our results are worth considering. It could be argued that the reduction in neural synchrony observed during hypnosis results from increased relaxation. However, suggestions for relaxation were omitted from the induction in this study. The value of this omission was demonstrated in another study that took place during the first session of this study, in which increases in relaxation from the control to the hypnosis condition did not differ across LS and HS participants (Terhune, et al., 2009). This finding strongly suggests that the observed effects reflect correlates of increased state dissociation, not relaxation. A second interpretation is that the observed results reflect spurious correlations resulting from volume conduction (cf. Horwitz, 2003). Whilst volume conduction can lead to erroneous correlations between electrodes of close spatial proximity that may record signals from common sources, it is highly improbable that the observed effects, which involve condition-specific changes that differed across groups, are the product of such an artifact. Although the results present strong evidence for reductions in neural synchrony during hypnosis, the problem of volume conduction and the concomitant poor spatial resolution of EEG do reduce our ability to make sound inferences regarding the regions contributing to observed changes in neural synchrony and render any conclusions tentative. In this regard, utilizing magnetoencephalography,

which has comparable temporal resolution to EEG but superior spatial resolution, in future studies of resting state functional connectivity changes during hypnosis will be particularly advantageous.

One of the defining features of hypnosis is the profound distortions in agency that accompany responses to hypnotic suggestions among HS individuals. An important step in understanding the neurophysiology of hypnosis will be the examination of whether disruptions in functional connectivity, and concomitant increases in state dissociation, following a hypnotic induction exhibit a causal influence on hypnotic suggestibility. Specifically, future research should investigate whether decreases in functional connectivity following a hypnotic induction predict increases in suggestibility from the control to the hypnosis condition (see also Lynn, et al., 2007; cf. Kallio, & Revonsuo, 2003). A related question is whether disruption of neural synchrony in the prefrontal cortex (and elsewhere) of LS and medium suggestible individuals will increase hypnotic suggestibility. A recent study with medium suggestible individuals found that rapid transcranial magnetic stimulation applied to the left dorsolateral prefrontal cortex increased experiential responsiveness to a set of hypnotic suggestions (Semmens-Wheeler, & Dienes, 2009), thereby providing preliminary support for this conjecture. A further consideration for future research is the distance of connections examined. Our analyses were restricted to local synchrony within topographical regions (anterior or posterior) within each hemisphere. Future research should examine remote functional connectivity over distributed networks (e.g., fronto-parietal networks). Fingelkurts et al. (2007) present preliminary evidence that long-distance connectivity is also disrupted during hypnosis, but further research is needed to clarify the consistency of these disruptions across HS individuals, as well as their cognitive and phenomenological consequences.

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Table 1.

Descriptive statistics (*M* and *SD*) for omega complexity as a function of Group, Condition, Region, Frequency, and Session

Frequency	Group	Region										
		Anterior						Posterior				
		Session 1			Session 2			Session 1			Session 2	
C	H	C	C	H	C	C	H	C	C	H	C	
Delta												
LS	2.18 (0.46)	2.37 (0.43)	2.23 (0.49)	2.24 (0.58)	2.36 (0.49)	2.09 (0.37)	3.31 (0.39)	3.35 (0.43)	3.33 (0.63)	3.23 (0.57)	3.36 (0.54)	3.07 (0.36)
HS	2.12 (0.36)	3.04 (0.62)	2.20 (0.50)	2.08 (0.30)	2.97 (0.66)	1.98 (0.31)	3.23 (0.55)	3.91 (0.57)	3.36 (0.54)	3.18 (0.29)	3.92 (0.85)	3.15 (0.27)
Theta1												
LS	2.58 (0.48)	2.63 (0.49)	2.50 (0.55)	2.48 (0.39)	2.47 (0.38)	2.36 (0.47)	3.57 (0.71) ^a	3.36 (0.66) ^{a,b}	3.35 (0.69) ^b	3.35 (0.63) ^a	3.20 (0.65) ^{a,b}	3.15 (0.60) ^b
HS	2.72 (0.57) ^a	2.97 (0.68) ^b	2.68 (0.58) ^a	2.65 (0.55) ^a	3.06 (0.68) ^b	2.47 (0.44) ^a	3.79 (0.89)	3.57 (0.77)	3.73 (0.81)	3.86 (0.93)	3.64 (0.87)	3.65 (0.86)
Theta2												
LS	1.93 (0.33) ^{a,b}	2.07 (0.39) ^a	1.88 (0.45) ^b	1.86 (0.32) ^{a,b}	1.93 (0.33) ^a	1.75 (0.37) ^b	3.12 (0.61) ^a	3.19 (0.66) ^a	2.88 (0.64) ^b	2.86 (0.63) ^a	2.98 (0.71) ^a	2.66 (0.49) ^b
HS	2.20 (0.63) ^a	2.38 (0.76) ^b	2.15 (0.63) ^a	2.14 (0.59) ^a	2.41 (0.72) ^b	2.02 (0.57) ^a	3.50 (1.04)	3.41 (0.90)	3.40 (0.97)	3.54 (1.07)	3.34 (0.87)	3.29 (0.96)
Alpha1												
LS	1.60 (0.37) ^a	1.87 (0.51) ^b	1.61 (0.43) ^a	1.53 (0.30) ^a	1.78 (0.45) ^b	1.55 (0.38) ^a	2.55 (0.51) ^a	2.87 (0.68) ^b	2.48 (0.50) ^a	2.46 (0.42) ^a	2.72 (0.62) ^b	2.35 (0.34) ^a
HS	1.96 (0.80) ^a	2.28 (0.95) ^b	1.94 (0.88) ^a	1.90 (0.80) ^a	2.16 (0.99) ^b	1.80 (0.76) ^a	3.05 (1.17)	3.20 (1.11)	2.92 (1.14)	3.02 (1.32)	2.90 (0.87)	2.86 (1.21)
Alpha2												
LS	1.97 (0.51)	2.17 (0.53)	2.02 (0.51)	1.97 (0.46)	2.11 (0.46)	2.02 (0.45)	2.94 (0.68)	3.17 (0.75)	2.85 (0.53)	2.85 (0.67)	3.01 (0.69)	2.81 (0.53)
HS	2.21 (0.73) ^a	2.63 (0.77) ^b	2.25 (0.75) ^a	2.12 (0.67) ^a	2.41 (0.91) ^b	2.08 (0.64) ^a	3.18 (1.12)	3.43 (1.07)	3.12 (1.09)	3.10 (0.97)	2.92 (0.91)	3.02 (0.91)
Beta												
LS	2.07 (0.30) ^a	2.41 (0.51) ^b	2.18 (0.60) ^{a,b}	2.10 (0.44) ^a	2.33 (0.58) ^b	2.13 (0.50) ^{a,b}	3.53 (0.62)	3.63 (0.65)	3.49 (0.87)	3.34 (0.69)	3.49 (0.73)	3.17 (0.46)
HS	2.22 (0.58) ^a	3.14 (1.16) ^b	2.26 (0.54) ^a	2.12 (0.58) ^a	2.89 (1.03) ^b	2.09 (0.45) ^a	3.46 (0.77) ^{a,b}	4.29 (0.98) ^a	3.48 (0.66) ^b	3.46 (0.90) ^{a,b}	3.90 (1.14) ^a	3.33 (0.70) ^b
Gamma												
LS	3.68 (1.20)	4.02 (1.24)	3.83 (1.55)	3.96 (1.12)	4.15 (1.26)	4.02 (1.11)	4.77 (1.93)	4.42 (1.98)	4.28 (1.76)	5.25 (1.90)	4.54 (1.82)	4.77 (1.57)
HS	3.52 (0.96) ^a	4.61 (1.65) ^b	3.62 (1.07) ^a	3.59 (0.98) ^a	4.64 (1.40) ^b	3.51 (0.95) ^a	4.19 (2.10)	4.55 (2.04)	4.55 (1.92)	5.29 (1.85)	5.07 (1.93)	4.54 (1.55)

Note. Values in bold are significantly different across groups, $p < .05$; different super-scripted letters among two conditions in a session indicate different cell means, $p < .05$; LS = low suggestible; HS = highly suggestible

Table 2
Inferential statistics (F and η^2) for omega complexity

Frequency Session	Main effects and interactions					
	Hemisphere (1, 43)	Region (1, 43)	Condition (2, 86)	Region \times Condition (2, 86)	Condition \times Group (2, 86)	Region \times Condition \times Group (2, 86)
Delta						
1	9.55**, .18	198.76***, .82	21.91***, .34		12.97***, .23	
2	12.24**, .22	355.16***, .89	38.91***, .48		14.30***, .25	
Theta1						
1		129.04***, .75		16.26***, .27		3.23*, .07
2		195.35***, .82		16.96***, .28		9.23**, .18
Theta2						
1	10.46**, .20	292.94***, .87	10.23***, .19	5.54**, .11		5.10*, .11
2	6.86*, .14	362.62***, .89	13.06***, .23	6.84**, .14		12.59***, .23
Alpha1						
1		292.55***, .87	20.18***, .32			3.42*, .07
2		338.37***, .89	11.12***, .21			4.59*, .10
Alpha2						
1		134.95***, .76				3.59*, .08
2		184.71***, .81				10.06**, .19
Beta						
1		241.45***, .85	20.96***, .33			
2		261.16***, .86	14.70***, .26			
Gamma						
1		7.23*, .14		6.08**, .12		
2		22.75***, .35		22.47***, .34		

Note. Degrees of freedom are reported in brackets for each analysis.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 3

Descriptive statistics (*M* and *SD*) for synchronization likelihood as a function of Group, Condition, Region, Frequency, and Session

Frequency	Group	Region										
		Anterior						Posterior				
		Session 1		Session 2				Session 1		Session 2		
C	H	C	C	H	C	C	H	C	C	H	C	
Delta												
LS	0.13	0.11	0.12	0.12	0.11	0.12	0.06	0.06	0.06	0.07	0.06	0.07
	(0.05) ^a	(0.03)^b	(0.04) ^{a,b}	(0.04) ^a	(0.03)^b	(0.03) ^{a,b}	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
HS	0.12	0.07	0.11	0.13	0.07	0.12	0.07	0.05	0.06	0.07	0.05	0.06
	(0.04) ^a	(0.02)^b	(0.04) ^a	(0.04) ^a	(0.02)^b	(0.03) ^a	(0.02) ^a	(0.01)^b	(0.01) ^a	(0.01) ^a	(0.01)^b	(0.01) ^a
Theta1												
LS	0.22	0.21	0.20	0.23	0.21	0.22	0.22	0.20	0.19	0.22	0.20	0.20
	(0.03) ^a	(0.03)^b	(0.04) ^b	(0.04) ^a	(0.03)^b	(0.03) ^b	(0.04) ^a	(0.03)^b	(0.04) ^b	(0.04) ^a	(0.04)^b	(0.04) ^b
HS	0.23	0.17	0.21	0.24	0.17	0.22	0.23	0.16	0.21	0.23	0.16	0.22
	(0.03) ^a	(0.03)^b	(0.03) ^c	(0.02) ^a	(0.03)^b	(0.02) ^c	(0.04) ^a	(0.02)^b	(0.05) ^c	(0.04) ^a	(0.03)^b	(0.04) ^c
Theta2												
LS	0.25	0.24	0.24	0.26	0.25	0.26	0.19	0.18	0.17	0.19	0.18	0.18
	(0.04) ^a	(0.04)^b	0.05) ^{a,b}	(0.04) ^a	(0.04)^b	0.04) ^{a,b}	(0.05) ^a	(0.04)^b	(0.04) ^{a,b}	(0.05) ^a	(0.04)^b	(0.04) ^{a,b}
HS	0.26	0.20	0.24	0.27	0.20	0.25	0.21	0.14	0.19	0.21	0.15	0.20
	(0.04) ^a	(0.04)^b	(0.04) ^c	(0.04) ^a	(0.05)^b	(0.03) ^c	(0.05) ^a	(0.03)^b	(0.05) ^c	(0.05) ^a	(0.03)^b	(0.05) ^c
Alpha1												
LS	0.36	0.33	0.35	0.36	0.33	0.36	0.20	0.21	0.19	0.20	0.20	0.19
	(0.08) ^a	(0.07) ^b	(0.10) ^{a,b}	(0.07) ^a	(0.06) ^b	(0.08) ^{a,b}	(0.04)	(0.04)	(0.05)	(0.03)	(0.03)	(0.04)
HS	0.34	0.28	0.33	0.34	0.29	0.34	0.22	0.18	0.20	0.21	0.17	0.20
	(0.06) ^a	(0.07) ^b	(0.07) ^a	(0.07) ^a	(0.08) ^b	(0.06) ^a	(0.04) ^a	(0.03)^b	(0.04) ^c	(0.04) ^a	(0.03)^b	(0.04) ^c
Alpha2												
LS	0.30	0.29	0.29	0.30	0.29	0.29	0.20	0.22	0.19	0.21	0.21	0.20
	(0.05) ^a	(0.04)^b	(0.04) ^b	(0.05) ^a	(0.05)^b	(0.04) ^b	(0.03) ^a	(0.04)^{a,b}	(0.03) ^b	(0.03) ^a	(0.03)^{a,b}	(0.03) ^b
HS	0.30	0.24	0.29	0.31	0.25	0.30	0.22	0.18	0.21	0.22	0.18	0.21
	(0.04) ^a	(0.04)^b	(0.05) ^c	(0.04) ^a	(0.05)^b	(0.04) ^c	(0.03) ^a	(0.03)^b	(0.03) ^c	(0.04) ^a	(0.02)^b	(0.04) ^c
Beta												
LS	0.17	0.14	0.16	0.17	0.15	0.16	0.08	0.08	0.08	0.09	0.09	0.09
	(0.05) ^a	(0.04)^b	(0.05) ^{a,b}	(0.05) ^a	(0.05)^b	(0.05) ^{a,b}	(0.01) ^a	(0.01)^b	(0.02) ^{a,b}	(0.02) ^a	(0.02)^b	(0.02) ^{a,b}
HS	0.16	0.10	0.15	0.17	0.11	0.16	0.09	0.06	0.08	0.09	0.06	0.09
	(0.06) ^a	(0.04)^b	(0.04) ^c	(0.05) ^a	(0.04)^b	(0.04) ^c	(0.02) ^a	(0.01)^b	(0.01) ^c	(0.02) ^a	(0.02)^b	(0.01) ^c
Gamma												
LS	0.18	0.16	0.16	0.18	0.17	0.16	0.18	0.16	0.15	0.20	0.16	0.17
	(0.05) ^a	(0.04)^b	(0.05) ^b	(0.06) ^a	(0.05)^b	(0.04) ^b	(0.06) ^a	(0.03)^b	(0.04) ^b	(0.07) ^a	(0.04)^b	(0.04) ^b
HS	0.17	0.10	0.15	0.19	0.10	0.17	0.19	0.10	0.16	0.21	0.11	0.18
	(0.05) ^a	(0.04)^b	(0.04) ^c	(0.05) ^a	(0.03)^b	(0.04) ^c	(0.07) ^a	(0.03)^b	(0.06) ^c	(0.07) ^a	(0.05)^b	(0.04) ^c

Note. Values in bold are significantly different across groups, $p < .05$; different super-scripted letters among two conditions in a session indicate different cell means, $p < .05$; LS = low suggestible; HS = highly suggestible

Table 4
Inferential statistics (F and η^2) for synchronization likelihood

Frequency Session	Main effects and interactions				
	Region (1, 43)	Condition (2, 86)	Region \times Condition (2, 86)	Condition \times Group (2, 86)	Region \times Condition \times Group (2, 86)
Delta					
1	108.83***, .72	29.91***, .41	27.40***, .39	12.29***, .22	6.56**, .13
2	159.88***, .79	52.43***, .55	22.34***, .35	17.62***, .29	8.38**, .16
Theta1					
1		38.00***, .47		23.74***, .36	
2		61.59***, .59		30.94***, .42	
Theta2					
1	65.41***, .60	32.33***, .43		21.31***, .33	
2	68.08***, .61	45.35***, .51		27.39***, .39	
Alpha1					
1	141.61***, .77	16.99***, .28	13.71***, .24	12.00***, .22	
2	137.36***, .76	24.74***, .37	9.89***, .19	11.06**, .21	
Alpha2					
1	195.33***, .82	22.37***, .34	13.21***, .24	28.23***, .40	
2	172.90***, .80	33.41***, .44	4.90*, .10	26.75***, .38	
Beta					
1	136.38***, .76	34.35***, .44	25.48***, .37	11.56***, .21	
2	116.28***, .73	46.40***, .52	17.49***, .29	17.41***, .29	
Gamma					
1		23.34***, .35		8.53***, .17	
2		49.99***, .54		18.59***, .30	

Note. Degrees of freedom are reported in brackets for each analysis; AP = anterior/posterior.

* $p < .05$, ** $p < .01$, *** $p < .001$

Figure 1.

Geodesic sensor net layout. Electrode sites numbered along with the standard positions of the International 10/20 system. Black electrode clusters are regions that were included in the analyses.

Figure 2.

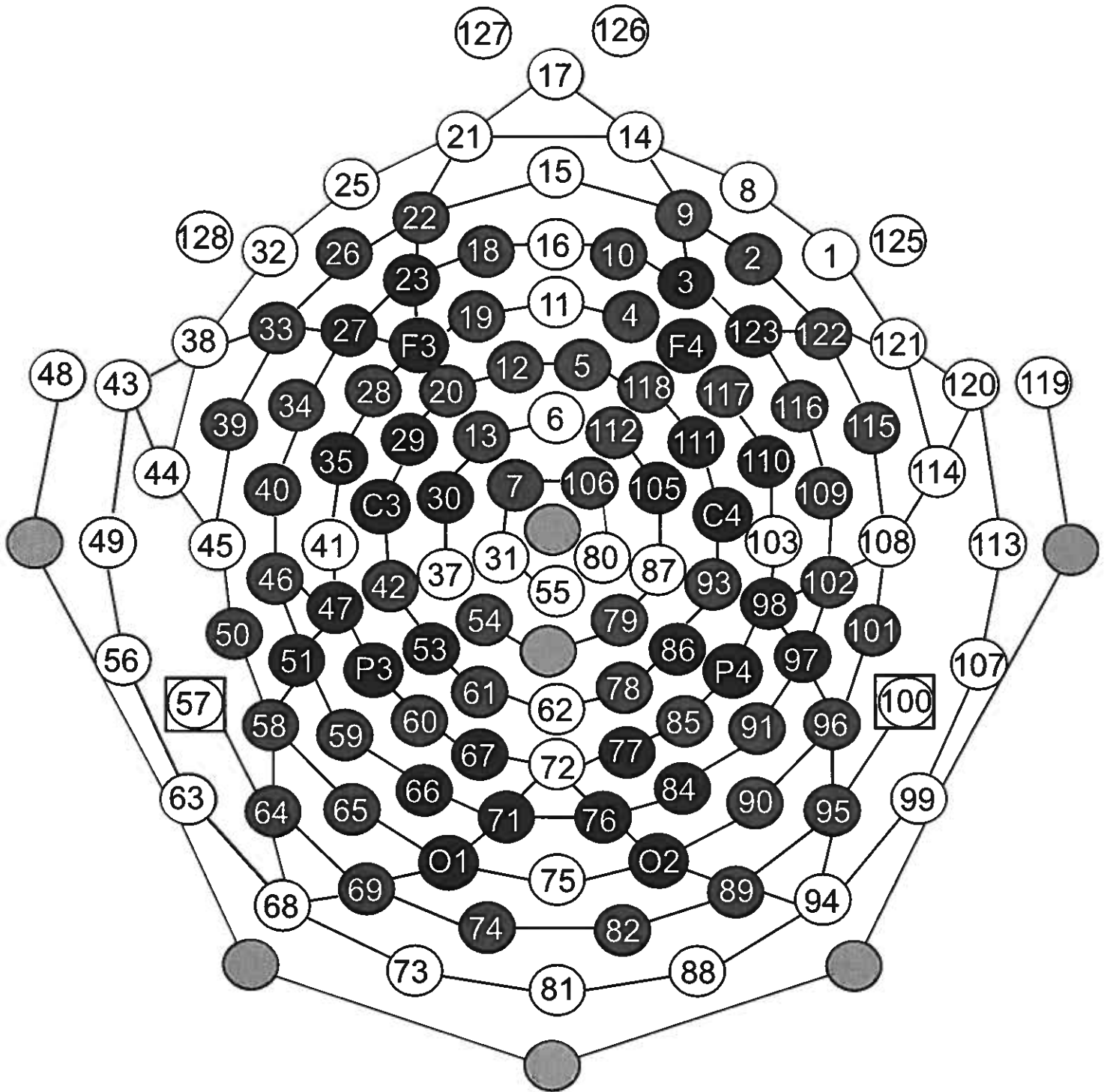
State dissociation (PDEQ) scores as a function of condition and group in sessions 1 and 2. LS = low suggestible; HS = highly suggestible; C = control; H = hypnosis. Error bars represent 1 S.E.M.

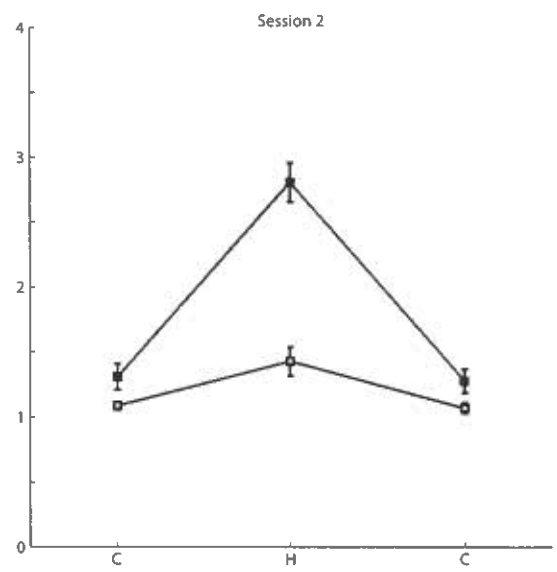
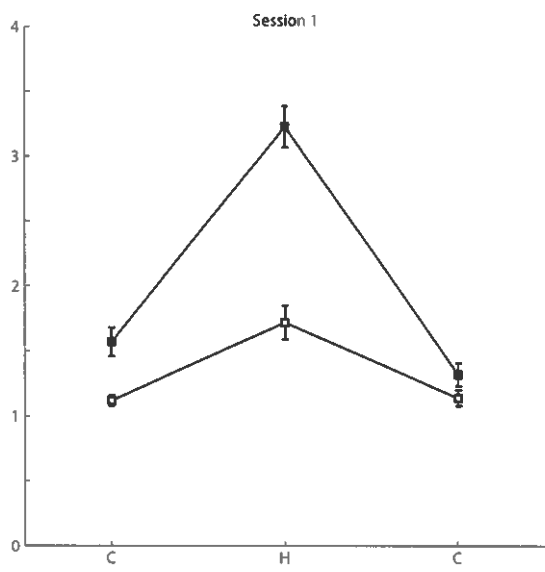
Figure 3.

Omega complexity averaged across sessions as a function of condition, group, region, and frequency. LS = low suggestible; HS = highly suggestible; C = control; H = hypnosis. Error bars represent 1 S.E.M.

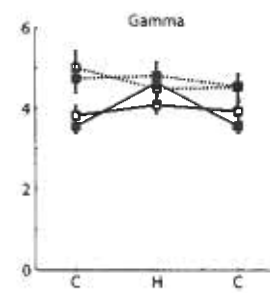
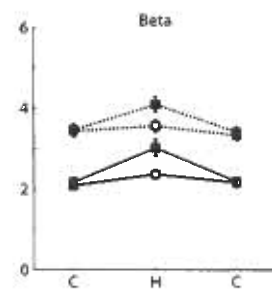
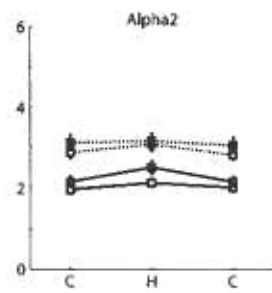
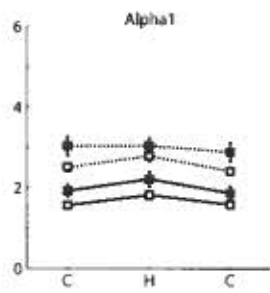
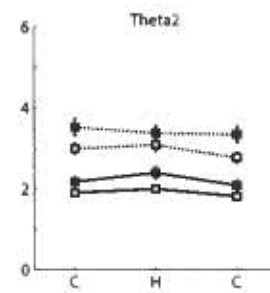
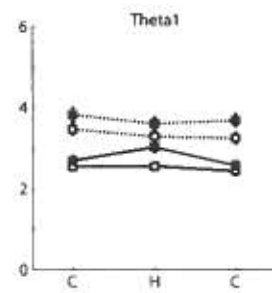
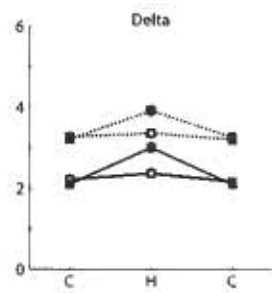
Figure 4.

Synchronization likelihood averaged across sessions as a function of condition, group, region, and frequency. LS = low suggestible; HS = highly suggestible; C = control; H = hypnosis. Error bars represent 1 S.E.M.





Anterior Posterior
 LS ○ □
 HS ■ ▣



Anterior Posterior
 LS \square \square
 HS \blacksquare \blacksquare

