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Title: EEG Oscillations during Prehypnosis and Hypnosis in Subjects with High and Low Dissociative Experiences

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Abstract

Aims: Hypnosis is a multifaceted phenomenon and refers to suggestions that are used to create desirable changes in behavior, experience and physiology. Most EEG research in hypnosis have allocated people into two groups of high and low hypnotizables. Hence, the empirical data are somewhat controversial, and there is no general agreement about the neurophysiology of hypnosis. On the other hand, dissociation theory of hypnosis posits that people candidates for hypnosis are typically prone to dissociation and individuals divide into two groups with high dissociative (HD) and low dissociative (LD). If this assumption is true, we can expect such a state should be visible as a distinct pattern of changes in absolute power and functional connectivity between brain districts after a hypnotic induction in high but not low dissociative suggestible.

Methods: The final sample consisted of 20 participants who scored six or higher on the SHSS: C. then we completed DES on them. To assess the electrical activity of the brain during hypnosis, nineteen channel EEG was recorded from 10 HD and 10 LD participants with their eyes closed before (baseline) and after the induction of hypnosis. We use EEG to measure absolute power and functional connectivity using coherence (COH). We expected that the two groups would have dissimilar pattern of EEG signals in spite of equivalent hypnotizability.

Findings: We found that in in bands of delta, theta, alpha, beta, and gamma, both groups were different from the baseline to hypnosis. In addition, both groups showed different connectivity in hypnosis in four bands (delta, theta, alpha, and beta).

Conclusion: These findings indicate that although the two LD low and HD groups had equal hypnotizability, the episodic prospection tasks did not involve the same neural networks in the two groups.

Key Words: EEG; Hypnotizability; Dissociative experiences; Hypnosis; Gamma oscillations

1. INTRODUCTION

Hypnotizability is described as a multifaceted ability (Dasse et al., 2015) whose most essential associates are imagery (Bowers, 1982; Glisky et al., 1995); Fantasy proneness (Green & Lynn, 2008; Lynn & Rhue, 1988); and absorption (Crawford, 1982). Several studies (Cardeña et al., 2013; Dasse et al., 2015; Glisky & Kihlstrom, 1993; Heap, 1999; Kumar & Pekala, 1988; Sadler & Woody, 2021) have attempted to explain the multifaceted nature of hypnosis.

Most EEG studies in hypnosis have allocated people into two groups with high and low hypnotizability. Hence, the empirical data are rather controversial, and there is no general agreement about the neurophysiology of hypnosis (see Gruzelier, 1998; and Jensen et al., 2015). This inconsistency may be due to the heterogeneity of highly hypnotizable individuals.

One of the controversial predispositions to hypnotizability is "dissociation." This construct was based on early clinical work and theories (Kopell, 1968; Woody & Sadler, 2008). According to these early views, people candidates for hypnotherapy are typically prone to dissociation (Breuer & Freud, 1895). The most influential theories of hypnotizability are Hilgard's theory of *neodissociation* (Hilgard, 1977) and the *dissociated control theory* (Bowers, 1992; Woody & Sadler, 2008). Some studies (Dale et al., 2009; Putnam et al., 1995) have confirmed the existence of high hypnotizability in people with a range of dissociative disorders (for a review, see Dell, 2017). Such support has led some to equate hypnotizability with dissociation, while other studies found no association between hypnotizability and dissociation or observed little association in non-clinical populations (Dienes et al., 2009; Frischholz et al., 1992; Segal & Lynn, 1993). However, some researchers (King & Council, 1998; Terhune et al., 2011b, 2011c) have been able to clarify the heterogeneity of the highly hypnotizable group by discovering subgroups such as *high dissociative highly suggestible* (HDHS) and *low dissociative highly suggestible* (LDHS). Their

studies showed that despite the equal hypnotizability - but different dissociative experiences - both groups were different in working memory, executive functions and focused attention (Terhune et al., 2011b, 2011c) and EEG oscillations (Terhune et al., 2011a).

According to the studies - in which there is no difference between high and moderate hypnotic individuals in response to treatment (Frankel et al., 1979) and cognitive functions (Labelle et al., 1990) - we selected our sample from moderate and highly hypnotizable individuals, and we divided them into two groups: *high dissociative* (HD) and *low dissociative* (LD). We expect two groups to have different EEG patterns despite the equivalent hypnotizability.

2. METHODS

2.1. PARTICIPANTS

First, 100 right-handed participants aged between 18 and 37 of both sexes (6 men and 14 women) among college undergraduate and graduate students voluntarily filled Symptom Checklist-90-Revised questionnaire, used for the measurement of psychopathology. A clinical psychologist in a clinical interview with the participants identified 10 people with psychiatric and neurological history, who were excluded from the study (see Figure 1). We also excluded individuals with a GSI score of more than one. Then we administrated the Stanford Hypnotic Susceptibility Scale Form C (SHSS:C; Weitzenhoffer & Hilgard, 1962) on 62 participants and selected them according to their hypnotizability. Finally, 20 participants were selected for recording an electroencephalogram (EEG) and analysis.

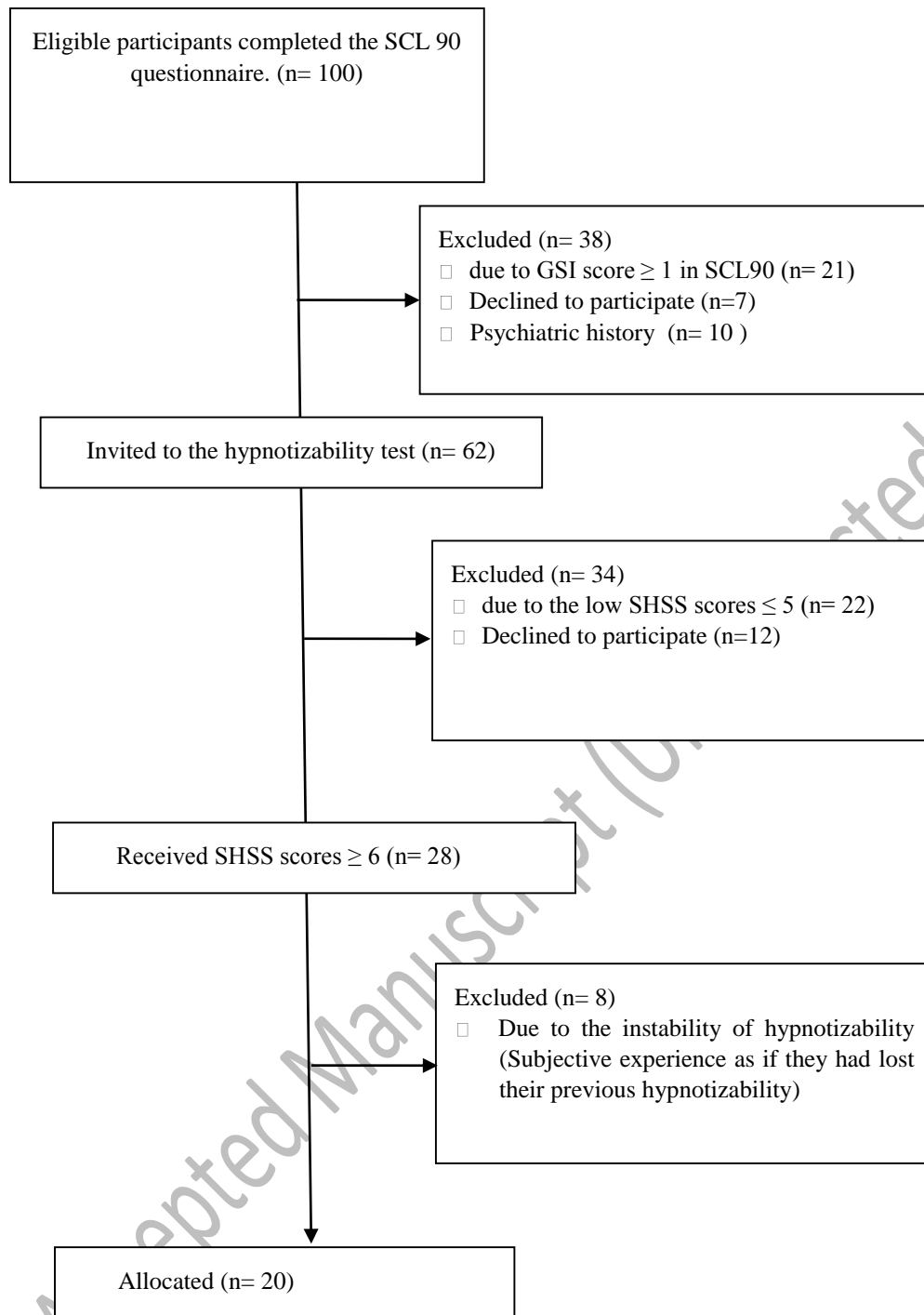


Figure 1

CONSORT Flowchart of Participants

2.2. MATERIALS AND EQUIPMENT

2.2.1. Dissociative Experiences Scales (DES)

Bernstein and Putnam (1986) presented The DES via data from interviews with persons who had dissociative disorders according to DSM-III. The scale contains 28 questions. The items contain experiences such as altered identity, impaired memory, reduced awareness, impaired cognition, and feelings of depersonalization or related phenomena such as déjà vu that Bernstein and Putnam (1986) supposed them as associated to dissociative experiences. They employed an innovational method to evaluate the dissociative experiences through a spectrum between zero and 100%. *Absorption, depersonalization-derealization, and amnesia* are three sub-scales of DES. Dubester & Braun (1995) reported the test-retest reliability 0.93 for the total score and 0.89, 0.95 and 0.82 for the depersonalization-derealization, amnesia, and absorption subscales, respectively. Other studies (Goldberg, 1999; Holtgraves & Stockdale, 1997) have confirmed the high reliability of this scale.

2.2.2. ELECTROENCEPHALOGRAPHY RECORDING

We employed Amplifier of Mitsar 21 Channel EEG. The sampling rate and montage was 250 Hz and *average* respectively. Since very slow oscillations are included artifacts owing to movement, sweating, metal-salt polarization, and electrode drift, we used the 40 Hz filter to prevent artificial low-frequency bands. The electrode impedance was ≥ 5 k Ω . We performed Artifacts by the *Neuroguide system* (Thatcher & Petersburg, 2008), and we removed all segments of the eye, head, and muscle movements' artifact from the signal. We selected no artifacts signals for *power spectrum* and *coherence analysis*. We used *Fast Fourier transform* (FFT) by Neuroguide software (Thatcher & Petersburg, 2008) to analyze the power spectrum. We calculated the *absolute power*

of EEG (μV) and *coherence* using FFT in the bands of delta, theta, alpha, beta, and gamma. We asked each participant to take part in recording EEG with an Electro-Caps which was attached to 19 electrodes according to the international 10–20 system (see figure 2). Each letter is defined by the area in which the electrode is placed on a lobe and represents a channel: prefrontal lobe (FP: Fp 1, Fp 2), frontal lobe (F: F3, F4, F7 , F8), central lobe (C: C3 , C4), parietal lobe (P: P3, P4), temporal lobe (T: T3 , T4 , T5 , T6) and occipital lobe (O: O1 , O2). In addition, there is no distinct lobe belonging to the central, they only are sites that reveal EEG activity of more conventional frontal, some parietal–occipital, and temporal. There are also electrodes that are labeled with (Z: Fz, Cz, Pz, and Oz) for zero located on the middle of the skull. Overall, we used 21 electrodes system containing standardized locations of electrodes (Nineteen electrodes on the scalp and two as reference).

2.3. PROCEDURE

We compared hypnosis to a resting (pre-hypnosis) baseline to determine hypnosis-specific oscillations.

2.3.1. First phase

At this phase , we selected the participants based on the level of hypnotizability, and finally 28 people were qualified . We used the script of the procedure of the eye closure and progressive relaxation in SHSS: C to induce hypnosis. Individuals who received a score of six or greater in the SHSS: C, were induced to "anchor" trance experiences. "Anchoring," describes the process through which an internal response is related to some environmental or internal stimulus. In this way, the hypnotized person may have rapid access to hypnotic experience. There is a similarity between anchoring and "classic conditioning". The "anchor" process can use to condition for

reliving and re-experiencing the hypnosis in the next sessions. We used the script following: *The changes in body and mind have been your experience today in hypnosis. Now become aware of the feelings on your hands, feet, sounds, and images. Make it possible for your memory to record all the hypnosis experiences. At another time, if you and I want to practice hypnosis again, I ask you to gaze at my pointer finger, and then I ask you to close your eyes. Therefore, you will experience again your mental feelings and body sensations, And you will find that you are in a deep state of trance again.*

2.3.2. Second phase

The second stage was performed about two weeks later the first phase. We asked the participants to close their eyes and let their thoughts be free. EEG recordings were performed with the participants' eyes closed for 5 minutes for the normal consciousness. EEG recordings were performed with the participants' eyes closed for 5 minutes for normal consciousness. We asked participants to avoid clenching their teeth and constricting their muscles to reduce the artifact.

2.3.3. Third phase

Hypnosis induction was induced soon after the second phase by anchoring. Participants were asked to inform us by raising their pointer finger while experiencing the trance state. We excluded eight subjects who could not experience hypnosis again after two weeks and could not ratify the trance. By using a simple countdown and progressing it from 20 to one, the trance state was deepened. When the depth of the trance was such as in the prior session, then *mental travel* was induced as follows: *Imagine that you are going on a nature walk. Maybe you want to have people you love and enjoy spending happy and relaxing moments with them. Whenever you reach a favorite natural place, raise your right hand's pointer finger.*

Immediately when the participants moved their pointer finger, EEG was recorded for five minutes with no verbal interaction or disturbance of trance state. When the recording was accomplished, the induction of awakening was performed and the participants opened their eyes. Then we asked them the subsequent questions concerning the quality of imaginings: *Where did you journey? Were you alone or was someone with you? Have you ever been there? Was it a dream place experience? When were you there? How long did you stay there?* The participants' answers to the mentioned questions showed the richness of their visual experience. Based on the median DES score, participants were divided into subjects into two groups: high dissociative (HD) and low dissociative (LD).

2.4. STATISTICAL ANALYSIS

In the Neuroguide system (Thatcher & Petersburg, 2008), statistical analysis of EEG files is possible using NeuroBatch and NeuroStat programs (Thatcher, 2012). We provided the *ngg* and *nga* files via NeuroBatch and then compared the baseline condition with hypnosis using the NeuroStat option via Paired t-Test. The result is shown in the form of color topographic maps. We presented the results of the analysis in two parts. In the first part - shown by the topographic map - the absolute power of the bands 1 to 40 Hz in the hypnosis condition was subtracted from the baseline condition through the paired t-test. We demonstrated the coherence of the delta, theta, alpha, and beta bands through the topographic maps in the second part of the statistical analysis.

3. RESULTS

3.1. Part one: Absolute power differences

3.1.1. Delta

As shown in Figure 3, delta amplitude change in hypnosis was observed only in the HD in the four areas, increasing in amplitude in the left medial prefrontal (Fp1) and a significant decrease in the other three areas.

3.1.2. Theta

As Figure 3 shows, the LD subjects did not have a significant difference in the theta band amplitude in the hypnotic condition compared to the baseline condition. However, in HD, except for four areas, there was a significant diminution in theta amplitude in the hypnosis condition. The decrease is more significant in the anterior areas of the right hemisphere and the posterior areas of the left.

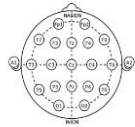


Figure 2B The 10-20 International system of EEG electrode placement

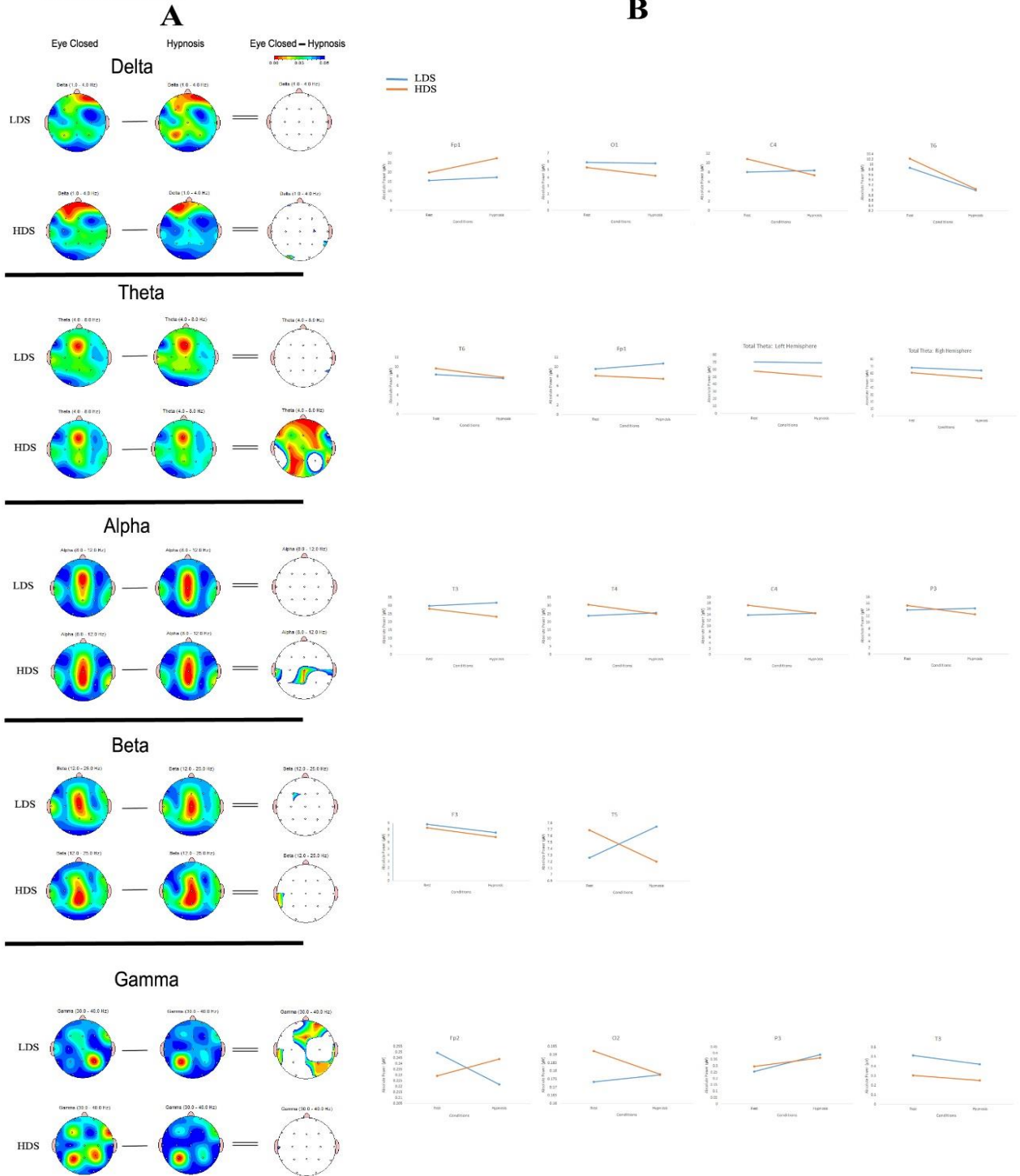


Figure 3. FFT group mean of absolute power in eye-closed, hypnosis and within subject difference. (A) The first column is the mean absolute power of the groups in the eye-closed (pre-hypnosis) condition, the second column is the mean absolute power of the groups in the hypnosis condition, and the third column is the difference between the hypnosis and the eye-closed conditions through paired t test. The color spectrum shows the least significance with blue and the highest with red. (B) Shows the absolute power of the groups in eye-closed and hypnosis conditions, as well as which group benefits the difference.

3.1.4. Alpha

As shown in Figure 3, HD in the baseline condition had more alpha than LD in the following areas: in the right hemisphere in the temporal (T4) and central right (C4), in the left hemisphere in the parietal (P3), and temporal (T3), and in the midline areas in the central (Cz) and parietal (Pz) areas. However, we observed the opposite pattern in the hypnosis condition. In other words, alpha decreased significantly in the HD group but increased insignificantly in the LD group. The opposite pattern is more marked in the left parietal area (P3) (see figure 3B).

3.1.5. Beta

Beta amplitude (12-25 Hz) showed a significant decrease in the frontal of the left hemisphere (F3) during hypnosis in the LD group (Figure 3a). However, we observed an opposite pattern in the temporal area; Beta decreased in HD and increased in LD (see Figure 3b).

3.1.6. Gamma

As figure 3 shows, gamma (30-40 Hz) amplitude decreased significantly in the hypnosis condition only in the left temporal area (T3) of the HD group, which was similar to the LD group. The LD group showed a significant change in 12 areas, increasing in the right occipital (O2) and the left parietal (P3) areas and decreasing in other areas. It is noteworthy that the two groups showed an opposite pattern in the medial prefrontal (Fp2) and occipital (O2) areas of the right hemisphere. The increase in gamma in the HD group was in the right midfrontal area (Fp2), and the decrease was in the right occipital area (O2), which was the opposite pattern in the LD group (see figure 3B).

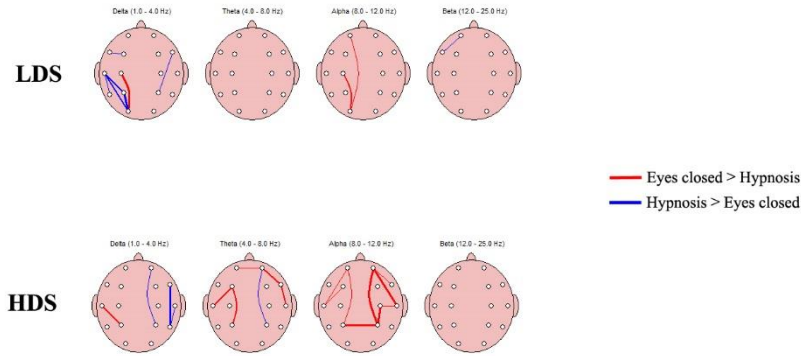


Figure 4 Group FFT coherence subtraction of hypnosis condition from eyes closed. The blue and red lines show a significant difference in the connections.

3.2. Part 2: Coherence Analysis

3.2.1. Delta

As Figure 4 shows, Delta connectivity increased in the LD in both hemispheres and the HD group only in the right hemisphere. In the LD, increased Delta connectivity in the left hemisphere were between the dorsolateral and medial prefrontal, temporal and parietal areas, the temporal and occipital; and in the right hemisphere were between the medial prefrontal and parietal. In the HD, increased Delta connectivity in the right hemisphere were between the medial prefrontal and parietal, and between the medial prefrontal and temporal.

3.2.2. Theta

As Figure 4 shows, there was a significant change in theta connectivity from the baseline to hypnosis in HD in both hemispheres, but not in LD. There was a decrease in theta connectivity between the frontal and temporal, as well as between the frontal and parietal in the left hemisphere. We recorded a decreased connectivity between the frontal and temporal, and an increased connectivity between the prefrontal and parietal areas in the right hemisphere (Figure 4).

3.2.3. Alpha

As Figure 4 shows, we observed a decrease of alpha connectivity in the left hemisphere in the LD during hypnosis that were fronto-occipital (Fp1-O1) and central- occipital (C3-O1). In contrast, in the HD group, there were decreased alpha connectivity in broad areas of both hemispheres that were frontoparietal and frontotemporal of both hemispheres. Decreased alpha connectivity in the right hemisphere was central-parietal. In addition, there was a decreased interhemispheric connectivity between the right (P4) and left parietal (P3).

3.2.4. Beta

As Figure 4 shows, during hypnosis, the anterior prefrontal (Fp1) had functional connectivity with the inferior frontal gyrus (F7) via the increased beta in the left hemisphere in the LD group.

4. DISCUSSION

We found delta amplitude change in hypnosis only in the HD in the four areas, increasing in the left medial prefrontal and a significant decrease in the other three areas. Delta connectivity decreased in both groups only in the left hemisphere. Some studies (Fingelkurts et al., 2007; Panda et al., 2019) have also reported a decrease in Delta connectivity during hypnosis in highly hypnotizable individuals. It was between central and occipital in the LD, and temporal and parietal in the HD. Delta connectivity increased in the LD in both hemispheres and the HD group only in the right hemisphere. In the LD, in the left hemisphere between the dorsolateral and medial prefrontal, temporal and parietal areas, the temporal and occipital; and in the right hemisphere between the medial prefrontal and parietal. Delta connectivity increased in the HD group only in the right hemisphere: between the medial prefrontal and parietal, and the medial prefrontal and temporal. We have learned from the neurophysiology of the delta band that every thalamocortical

neuron can become a delta band in the cortex if hyperpolarized (Buzsaki, 2006; Lu et al., 2007). Harmony et al. (1996) found that increased delta amplitude, especially in the frontal lobe, was associated with attention to internal processing. In a review, harmony (2013) explained his and others' findings that delta activity inhibit interferences that might disturb the cognitive functions, maybe by modifying the function of networks that must be inactive to complete the task. There were differences between the two groups in increasing the delta connectivity. In the LD group, the connection between the posterior areas and the temporal lobe increased in the left hemisphere. Whereas in the HD group, the frontal connection with other areas increased in the right hemisphere.

We observed a significant change in theta connectivity from the baseline to hypnosis in HD in both hemispheres, but not low dissociative. There was a diminution in theta connection between the frontal and temporal, as well as between the frontal and parietal in the left hemisphere. We recorded a decreased theta connectivity between the frontal and temporal, and an increased connectivity between the prefrontal and parietal areas in the right hemisphere. Jamieson & Burgess (2014) found an increase in theta connectivity from the baseline to hypnosis in highly susceptible in central-parietal but not lows (Jamieson & Burgess, 2014).

We found that the LD and HD groups, despite having equal hypnotizability, showed different patterns in alpha changes in the baseline and hypnosis conditions. We observed that HD has more alpha in both hemispheres under baseline than LD. Nevertheless, during hypnosis, the alpha decreased in the HD group and increased in the LD group. Several studies (Kumar & Pekala, 1988; Sadler & Woody, 2021; Stevens et al., 2004; Williams & Gruzelier, 2001) have reported more significant alpha activity among highly susceptible relative to low susceptible in pre-hypnosis, as well as increasing alpha during hypnosis. Our findings on alpha oscillation suggest that in pre-

hypnosis, HD individuals are similar to highly susceptible individuals, while in hypnosis, LD individuals are similar to highly susceptible. Some writers (Cardeña et al., 2013; Glisky & Kihlstrom, 1993; Heap, 1999; Sabourin et al., 1990) have challenged the alpha and hypnotizability relationship. We also observed that in the left hemisphere of LD, the alpha band showed less coherence during hypnosis. While in HD individuals, it was seen in both hemispheres and between the hemispheres. Terhune et al. (2011a) found highly suggestible participants showed lower frontal-parietal synchrony in the alpha during hypnosis than low suggestible. Our HD group also showed lower frontal-parietal synchrony in the alpha during hypnosis. In a review, Klimesch (2012) distinguishes between conditions that lead to alpha event-related desynchronization (ERD) and alpha event-related synchronization (ERS). Klimesch (2012) demonstrated, based on shreds of empirical findings, that the alpha ERD reflects cortical activation and the alpha ERS reflects cortical inhibition; We and Terhune et al. (2011a) found ERD in frontal connection with posterior cortices. These findings indicate that functional connectivity of the frontal-parietal network during hypnosis.

Beta decreased in the frontal of the left hemisphere during hypnosis in both groups. However, in the temporal area, an opposite pattern was observed. That is, beta decreased in HD and increased in low dissociative. We found that beta connectivity increased between left medial frontal and prefrontal areas in LD, but no change in HD. Jamieson & Burgess (2014) found that in the hypnotic condition, beta connectivity decreased in both the high and low susceptible groups, with a more significant decrease in the high susceptible group. However, White et al. (2009) found that beta connectivity decreased in the high susceptible group and increased in the low susceptible group. Increased beta connectivity in our LD group is consistent with White's finding of the low susceptible group, though we did not observe any change in beta connectivity in the HD group.

We observed that during hypnosis, in the LD group, the anterior prefrontal had functional connectivity with the inferior frontal gyrus via the increased beta in the left hemisphere. Increased connectivity in areas of the prefrontal indicates increased working memory activity, which we observed only in LD. This finding is consistent with Terhune et al. (2011c) finding of working memory impairment in the *high dissociative highly suggestible* (HDHS). Some neuroimaging (Benoit et al., 2011; D'Argembeau et al., 2010; De Brigard et al., 2015; Szpunar et al., 2007) and lesion studies (Andelman et al., 2010; Kurczek et al., 2015; Verfaellie et al., 2019) found some interesting points about this cortical network. Lesion studies have shown that patients with medial prefrontal cortex (mPFC) lesions who are unable to recall past events are also incapable of imagining hypothetical and future scenarios vividly (Benoit & Schacter, 2015; Buckner & Carroll, 2007; D'Argembeau, 2013) (For theoretical views, refer to Benoit & Schacter, 2015; Buckner & Carroll, 2007; D'Argembeau, 2013; and Suddendorf & Corballis, 2007). Anticipating future events occurs by a cognitive process so-called *episodic prospection* or *mental time travel* (imagine future events or generate hypothetical scenarios).

Comparing of the two groups in gamma oscillation in hypnosis condition revealed an opposite pattern in the prefrontal and occipital area of the right hemisphere. In other words, in the HD group, gamma increased in the right medial prefrontal (Fp2), and conversely decreased in the right occipital (O2); In contrast, the LD group showed the opposite pattern. In our study, the gamma band (30-40 Hz) had a larger amplitude in the waking state (baseline) in the right parietal and the hypnotic state in the left parietal. This finding is, in some ways, comparable to the findings of the study of De Pascalis et al. (1989). They asked participants to recall emotions during hypnosis. The result indicated an increase in gamma in both hemispheres while experiencing positive emotions and an increase in gamma in the left hemisphere while experiencing negative emotions (De

Pascalis et al., 1989). Our EEG recording process was different from De Pascalis et al. (1989). Their recording areas were three corresponding channels in the left and right hemisphere, whereas we recorded 19 electrodes based on the international standard 10-20 system. We compared each individual electrode in the left hemisphere with its corresponding electrode in the right hemisphere. While they used the sum obtained from the amplitudes of three channels to compare the asymmetry between the two hemispheres. In Babiloni et al.'s (2004) study, which examined the hemispheric asymmetry in encoding and retrieval of episodic memory, they found that the encoding phase was related to increased gamma band (28-40 Hz) over the left parietal cortex, and the retrieval phase was related to increased gamma mainly over the right parietal cortex (Babiloni et al., 2004). The brain needs to increase gamma fluctuations during the integration of neural activities, such as the integration of visual information (Gray, 1999; Singer & Gray, 1995). We can see the nature of the imaginal task used in our research. We found that subjects had to combine their creative visualization with stored information after visualizing the site of their choice, which is well explained by the brain's binding activity associated with increased gamma (for a good review, refer to Klimesch et al. (2010). De Pascalis et al. (De Pascalis, 1999, 2007; De Pascalis et al., 1989; De Pascalis et al., 1987) proposed the assumption for a link of gamma oscillations with hypnotizability. De Pascalis (1999, 2007) based his hypothesis on two sources: the nature of gamma synchronization as an operative that binds dispersed activity in the central nervous system to the cohesive functional states, and the high ability of individuals with high hypnotizability to inhibition of irrelevant stimuli and attention to relevant stimuli during hypnosis. He argued that we could expect to see an increase in gamma activity in people with high hypnotizability in response to hypnotic inductions.

5. Conclusion

Our prediction about the difference between HD and LD in EEG oscillations was confirmed. The results of our study show that in each of the in bands of delta, theta, alpha, beta, and gamma, both groups were different from baseline to hypnosis. In addition, both groups showed different connectivity in hypnosis in four bands (delta, theta, alpha, and beta). Although the HD and the LD groups were equivalent in hypnosis, the findings of several studies in highly hypnotizable individuals were consistent with the HD. Thus, these findings enhance our understanding of the heterogeneity of the highly hypnotizable individuals. The results of our study contribute to the current literature to suggest that dissociation may not be sufficient to explain the hypnotizability of all individuals.

6. Limitations of the current study

We considered several significant limitations. First, we did not include neutral hypnosis in the study. It would be interesting to compare the effects of neutral hypnosis with the scripts and pre-hypnosis. Second, we combined moderate and highly hypnotic people. A further study could assign individuals with moderate hypnotizability as a separate group from the highly hypnotizable group.

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