Research Paper

Electroencephalography Oscillations During Prehypnosis and Hypnosis in Subjects With High and Low Dissociative Experiences

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ABSTRACT

Introduction: Hypnosis is a multifaceted phenomenon that refers to suggestions for creating desirable behavior, experience, and physiological changes. Most electroencephalographic (EEG) research in hypnosis has 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, the dissociation theory of hypnosis posits that people candidates for hypnosis are typically prone to dissociation, and individuals divide into two groups: High dissociative (HD) and low dissociative (LD). If this assumption is true, 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 in LD suggestible.

Methods: The final sample consisted of 20 participants who scored 6 or higher on the Stanford hypnotic susceptibility scale form C (SHSS: C). Then, we completed dissociative experiences scales (DES) on them. To assess the brain's electrical activity during hypnosis, a 19-channel EEG was recorded from 10 HD and 10 LD participants with their eyes closed before (baseline) and after the induction of hypnosis. We used EEG to measure absolute power and functional connectivity using coherence. We expected the two groups to have dissimilar EEG signal patterns despite equivalent hypnotizability.

Results: We found that in the delta, theta, alpha, beta, and gamma bands, 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 LD and HD groups had equal hypnotizability, the episodic prospection tasks did not involve the same neural networks in the two groups.

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Highlights

• The power of delta, theta, alpha, beta, and gamma bands was different between HD and LD groups before and after hypnosis.

• The HD and LD groups had different functional connectivity in delta, theta, alpha, and beta bands before and after hypnosis.

• Dissociation may not be sufficient to explain the hypnotizability of all individuals.

Plain Language Summary

Most electroencephalogram (EEG) studies in hypnosis have allocated people into two groups: High and low hypnotizability. People who are candidates for hypnosis are typically prone to dissociation. In this regard, they are often divided into two groups: High dissociative (HD) and low dissociative (LD). In this study, changes in absolute power and functional connectivity between HD and LD groups were compared after a hypnotic induction. The results showed that the power of delta, theta, alpha, beta, and gamma bands was different between the two groups before and after hypnosis. Regarding functional connectivity, the difference was significant between the two groups in delta, theta, alpha, and beta bands. Therefore, it can be said that although the LD and HD groups have equal hypnotizability, the episodic prospection tasks do not involve the same neural networks in the two groups.

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 electroencephalogram (EEG) studies in hypnosis have allocated people into two groups: High and low hypnotizability. Hence, the empirical data are somewhat controversial, and there is no general agreement about the neurophysiology of hypnosis (Gruzelier, 1998; 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 experimental clinical work and theories (Kopell, 1968; Woody & Sadler, 2008). According to these experimental views, people who are candidates for hypnotherapy are typically prone to dissociation (Breuer & Freud, 1895). The most influential hypnotizability theories are Hilgard's neo-dissociation theory (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 (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; Terhune et al., 2011c) have clarified the heterogeneity of the highly hypnotizable group by discovering subgroups such as high dissociative (HD) highly suggestible and low dissociative (LD) highly suggestible. 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; Terhune et al., 2011c), as well as 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. We divided them into HD and LD groups. Despite the equivalent hypnotizability, we expect the two groups to have different EEG patterns.

2. Materials and Methods

Study 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 out the symptom checklist-90-revised questionnaire, which was used to measure psychopathology. In a clinical interview with the participants, a clinical psychologist identified 10 people with psychiatric and neurological history who were excluded from the study (Figure 1). We also excluded individuals with a GSI score of more than one. Then, we administered the Stanford hypnotic susceptibility scale form C (SHSS: C) (Weitzenhoffer & Hilgard, 1962) to 62 participants and selected them according to their hypnotizability. Finally, 20 participants were chosen for recording an EEG and analysis.

Materials and equipment

Dissociative experiences scales (DES)

Bernstein and Putnam (1986) presented the DES via data from interviews with persons who had dissociative disorders according to diagnostic and statistical manual of mental disorders 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 to be associated with dissociative experiences. They employed an innovational method to evaluate the dissociative experiences through a spectrum between 0% and 100%. Absorption, depersonalization-derealization, and amnesia are three subscales of DES. Dubester and Braun (1995) reported a test re-test reliability of 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.

EEG recording

We employed an amplifier of Mitsar 21 Channel EEG. The sampling rate and montage were 250 Hz and average, respectively. Since very slow oscillations include artifacts from 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 kΩ. We performed artifacting using the Neuroguide System (Thatcher & Petersburg, 2008) and removed all segments of the eye, head, and muscle movements' artifacts from the signal. We selected no artifact signals for power spectrum and coherence analysis. We used the fast Fourier transform (FFT) by Neuroguide Software (Thatcher & Petersburg, 2008) to analyze the power spectrum. We calculated the absolute power of EEG (uV2) and coherence using FFT in the delta, theta, alpha, beta, and gamma bands. We asked each participant to take part in recording EEG with electro-caps, which were attached to 19 electrodes according to the international 10–20 system. 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, no distinct lobe belongs to the central region; they are only sites that reveal EEG activity of more conventional frontal, some parietal–occipital, and temporal. Some electrodes are labeled with (Z: Fz, Cz, Pz, and Oz) for 0 in the middle of the skull. Overall, we used 21 electrodes system containing standardized locations of electrodes (19 electrodes on the scalp and two as reference).

Procedure

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

First phase

In 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 eye closure and progressive relaxation in SHSS: C to induce hypnosis. Individuals who received a score of 6 or greater in the SHSS: C were induced to "anchor" trance experiences. "Anchoring" describes how an internal response relates to some environmental or internal stimulus. This way, the hypnotized person may have rapid access to a hypnotic experience. There is a similarity between anchoring and "classic conditioning." The anchoring process can be used to condition for reliving and re-experiencing the hypnosis in the following sessions. We used the following script: "The changes in body and mind have been your experience today in hypnosis. Now, recognize 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 your mental feelings and body sensations again and find that you are in a deep state of trance again."

Second phase

The second stage was performed about two weeks after 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 normal consciousness. EEG recordings were performed with the participants' eyes closed for 5 minutes to ensure normal consciousness. We asked participants to avoid clenching their teeth and constricting their muscles to reduce the artifact.

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 8 subjects who could not experience hypnosis again after two weeks and could not ratify the trance. The trance state was deepened by using a simple countdown and progressing it from 20 to 1. When the depth of the trance was such as in the prior session, "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. Raise your right hand's pointer finger whenever you reach a favorite natural place.

Immediately when the participants moved their pointer finger, EEG was recorded for 5 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: HD and LD.

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 a 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, demonstrated by the topographic map, the absolute power of 1 to 40 Hz bands in the hypnosis condition was subtracted from the baseline 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

Part one: Absolute power differences

Delta

As shown in Figure 2, delta amplitude change in hypnosis was observed only in the HD group in the four areas, with increasing amplitude in the left medial prefrontal (Fp1) and a significant decrease in the other three regions.

Theta

As Figure 2 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 the HD group, 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 hemisphere.

Alpha

As shown in Figure 2, 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) (Figure 2B).

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 2a). However, we observed an opposite pattern in the temporal area: Beta decreased in HD and increased in LD (Figure 2b).

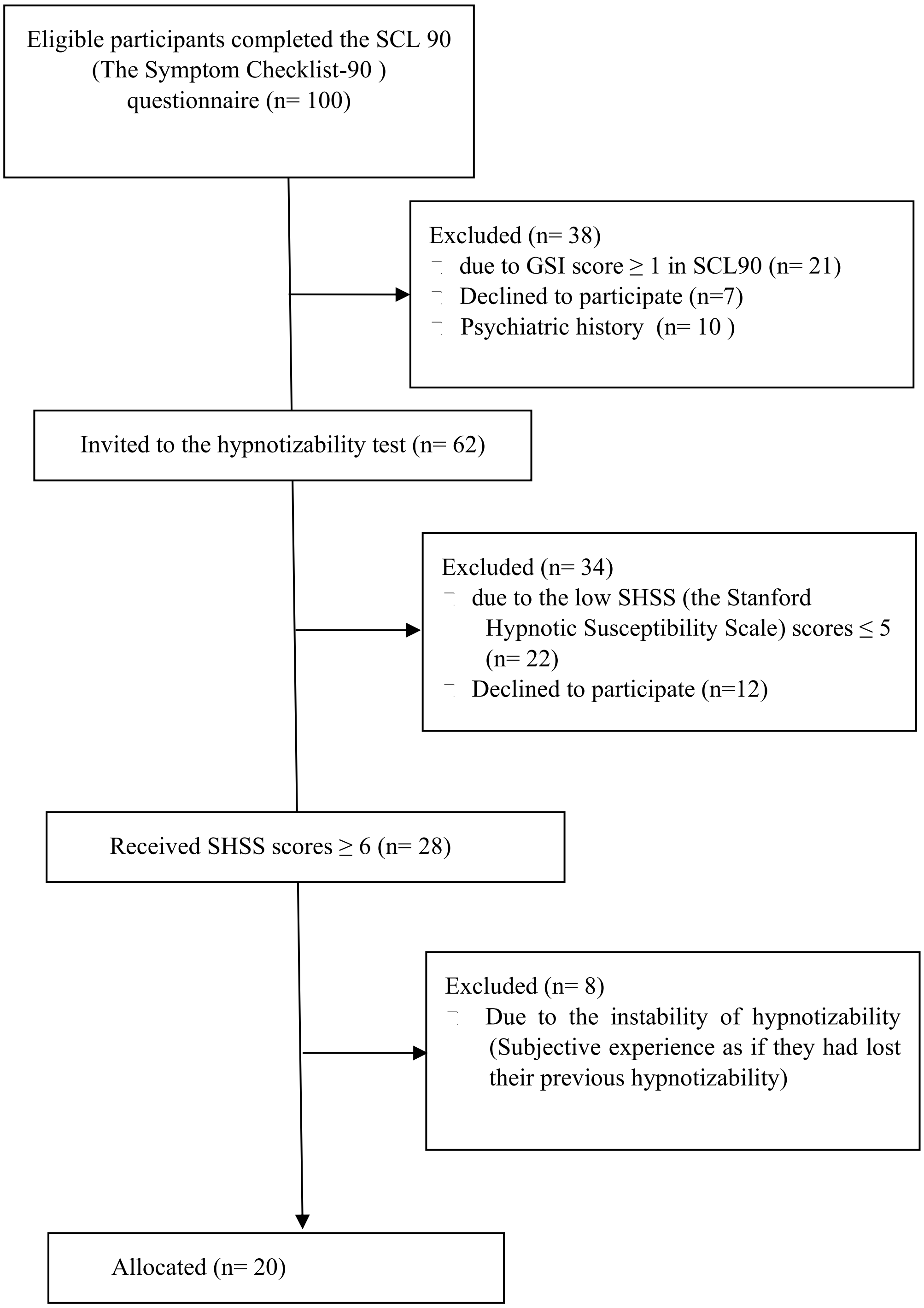

Figure 1. CONSORT flowchart of participants

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Gamma

Figure 2 shows that gamma (30-40 Hz) amplitude decreased significantly in the hypnosis condition only in the HD group's left temporal area (T3), 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. Notably, the two groups showed an opposite pattern in the right hemisphere's medial prefrontal (Fp2) and occipital (O2) areas. The increase in gamma in the HD group was in the right mid-frontal area (Fp2), and the decrease was in the right occipital area (O2), which was the opposite pattern in the LD group (Figure 2b).

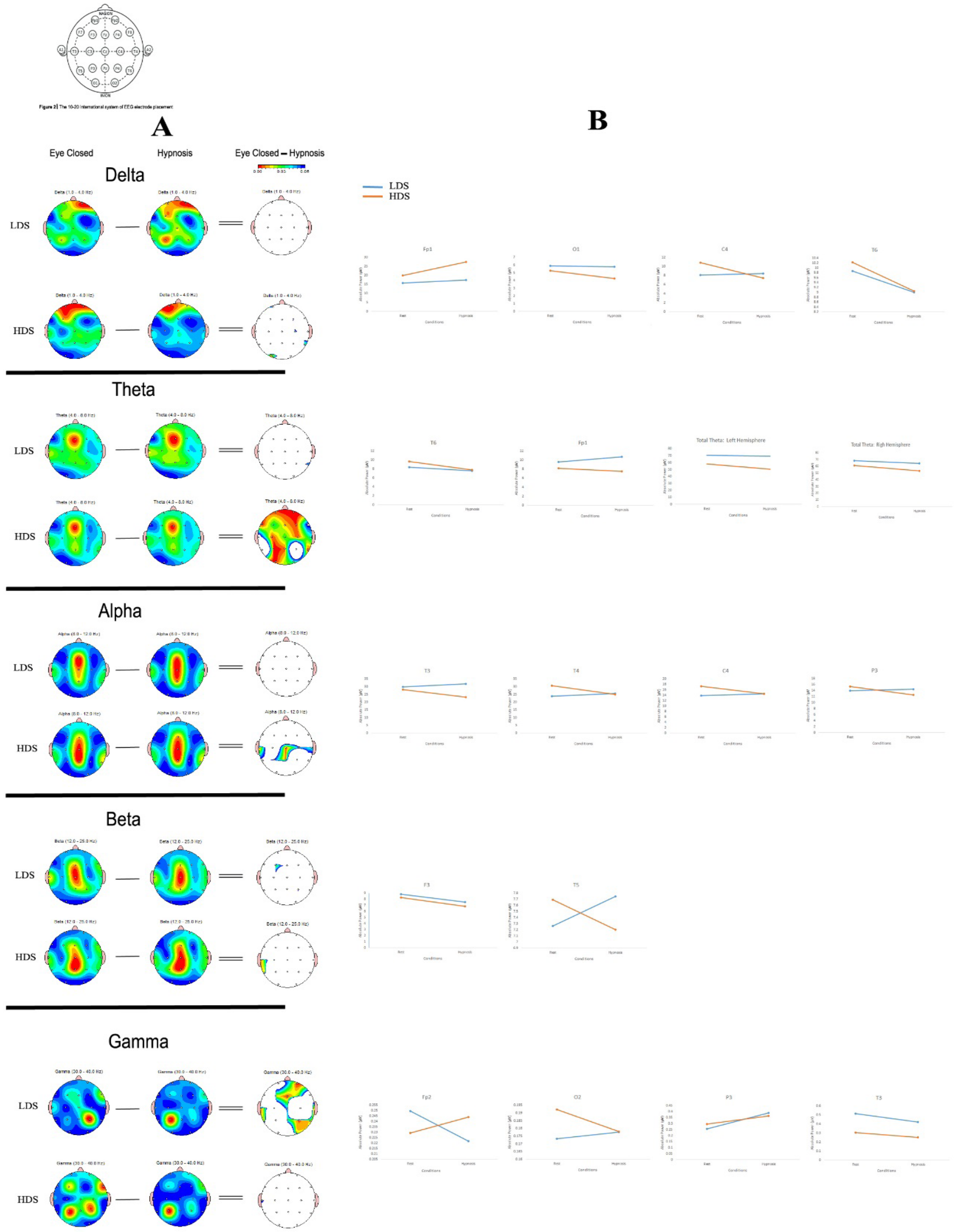

Figure 2. The mean absolute power of EGG bands for two groups and their within-subject differences NEUROSCIENCE

A) Brain maps showing the mean absolute power in the eye-closed (baseline) condition in the first column, hypnosis condition in the second column, and the difference between the two conditions assessed by a paired test in the third column. The least significance is shown with blue color and the highest significance with rot color. B) plotting the difference in the absolute power of the two groups in eye-closed and hypnosis conditions.

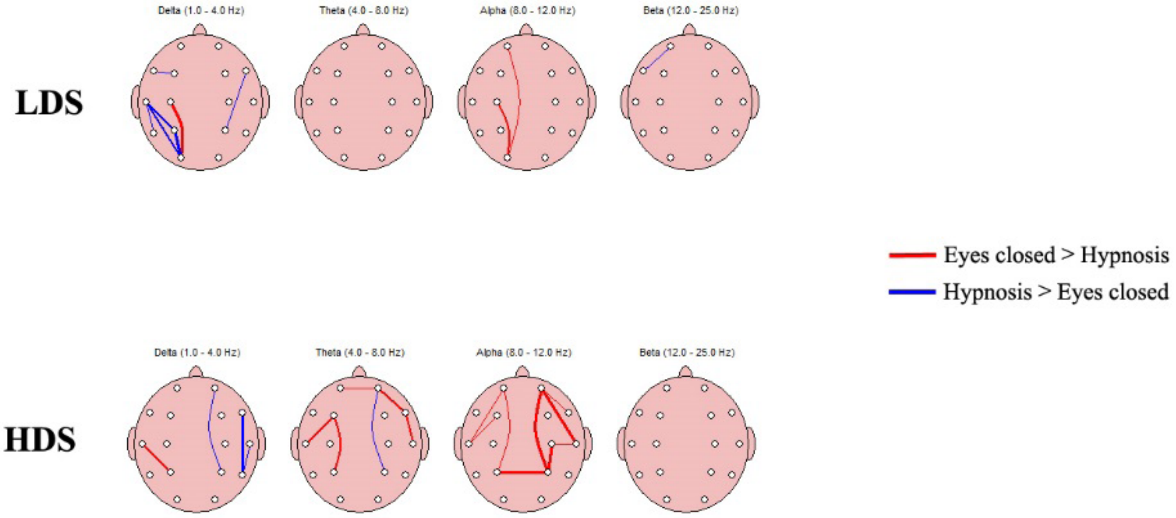

Figure 3. Functional connectivity map in different EEG bands in eyes closed and hypnosis conditions

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Notes: The blue and red lines show a significant difference in the connections.

Part 2: Coherence analysis

Delta

Figure 3 shows that delta connectivity increased in the LD in both hemispheres, but it only increased in the right hemisphere in the HD group. In the LD, increased delta connectivity in the left hemisphere was between the dorsolateral and medial prefrontal, temporal, and parietal areas, the temporal and occipital, and the right hemisphere was between the medial prefrontal and parietal. In the HD group, increased delta connectivity in the right hemisphere was between the medial prefrontal and parietal and between the medial prefrontal and temporal.

Theta

As Figure 3 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 and 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 3).

Alpha

As Figure 3 shows, we observed a decrease of alpha connectivity in the left hemisphere in the LD during hypnosis that was front-occipital (Fp1-O1) and central-occipital (C3-O1). In contrast, the HD group shows decreased alpha connectivity in broad areas of both hemispheres, ie, the frontoparietal and frontotemporal of both hemispheres. Decreased alpha connectivity in the right hemisphere was central-parietal. In addition, interhemispheric connectivity decreased between the right (P4) and left parietal (P3).

Beta

As Figure 3 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 significantly decreasing in the other three regions. 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 the 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, and it rose only in the right hemisphere. In the LD group, the left hemisphere is between the dorsolateral and medial prefrontal, temporal, and parietal areas, the temporal and occipital, and the right hemisphere is 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 inhibits interferences that might disturb 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 terms of increasing the delta connectivity. In the LD group, the connection between the posterior areas and the temporal lobe increased in the left hemisphere. Meanwhile, the frontal connection with other regions increased in the right hemisphere in the HD group.

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 and 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 and Burgess (2014) found an increase in theta connectivity from the baseline to hypnosis in highly susceptible central-parietal but not in lowly susceptible.

Despite having equal hypnotizability, we found that the LD and HD groups 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 lowly susceptible in pre-hypnosis, as well as increasing alpha activity during hypnosis. Our findings on alpha oscillation suggest that in prehypnosis, HD individuals are similar to highly susceptible individuals, while in hypnosis, LD individuals are identical to highly susceptible. Some writers (Cardeña et al., 2013; Glisky & Kihlstrom, 1993; Heap, 1999; Sabourin et al., 1990) have challenged the alpha band and hypnotizability relationship. We also observed that the alpha band in the left hemisphere of LD 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). Based on shreds of empirical findings, Andelman () demonstrated 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 the functional connectivity of the frontal-parietal network during hypnosis.

Beta oscillation 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 the LD group. We found that beta connectivity increased between the left medial frontal and prefrontal areas in LD, but no change was seen in HD. Jamieson and 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 HD 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. However, 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 prefrontal areas 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 HD highly suggestible people. 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 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) (Benoit & Schacter, 2015; Buckner & Carroll, 2007; D'Argembeau, 2013). Anticipating future events occurs through a cognitive process called episodic prospection or mental time travel (imagining future events or generating hypothetical scenarios).

Comparing 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. Our EEG recording process was different from that of De Pascalis et al. (1989). Their recording areas were three corresponding channels in the left and right hemispheres, whereas we recorded 19 electrodes based on the international standard 10-20 system. We compared each electrode in the left hemisphere with its corresponding electrode in the right hemisphere. They used the sum obtained from the amplitudes of three channels to compare the asymmetry between the two hemispheres. Babiloni et al.(2004) examined the hemispheric asymmetry in the encoding and retrieval of episodic memory. They found that the encoding phase was related to an increased gamma band (28-40 Hz) over the left parietal cortex. The retrieval phase was related to increased gamma, mainly over the right parietal cortex (Babiloni et al., 2004). The brain needs to increase gamma oscillation 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 (Klimesch et al., 2010). De Pascalis (1999, 2007, 1989, 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 inhibit irrelevant stimuli and attention to relevant stimuli during hypnosis. He argued that we could expect increased 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 delta, theta, alpha, beta, and gamma bands, 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 comparable in hypnosis, the findings of several studies in highly hypnotizable individuals are consistent with the HD. Thus, these findings enhance our understanding of the heterogeneity of 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.

Study limitations

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 prehypnosis. 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.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles are considered in this article. The participants were informed of the purpose of the research and its implementation stages. They were also assured about the confidentiality of their information and were free to leave the study whenever they wished, and if desired, the research results would be available to them. A written consent has been obtained from the subjects. Principles of the Helsinki Convention was also observed.

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Authors' contributions

All authors contributed equally to the conception and design of the study, data collection and analysis, interception of the results and drafting of the manuscript. Each author approved the final version of the manuscript for submission.

Conflict of interest

The authors declared no conflict of interest.

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