EEG Functional Connectivity and Phenomenology of Induced Dissociative States

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Abstract

Dissociative phenomena are highly subjective states, disorders of consciousness with no clear organic cause and in many cases, few behavioural signs. This study aimed to identify an EEG signature for dissociative states, and for 4 sub-factors related to dissociative and altered consciousness type experiences. Resting alpha frequency-matched photic stimulation was used to successfully induce a temporary dissociative state in 23 healthy volunteers. Phenomenological reports were taken using a range of scales and results were clustered into 4 groups of phenomena (detachment, somatosensory changes, mystical/religious experience, visual hallucination). Differences in functional connectivity and network efficiency were identified for each of these groups. Participants reported higher levels of dissociation and anomalous experience under alpha-matched photic stimulation. There were significant differences in both connectivity and power in the induced dissociative state. There were also notable differences in regional connectivity within clusters of sub-phenomena related to detachment and mystical experience.

The term dissociation covers a broad set of psychological experiences which involve the disruption of the "usually integrated functions of consciousness, memory, identity or perceptions of the environment" (DSM-5, American Psychiatric Association, 2013). Dissociative disorders are seen in around 7% of the general (United States) population, they are disorders of consciousness, highly subjective and refer to a marked change in the individual's experience such that their "normal" waking reality comes to feel altered, or dreamlike (Spiegel & Cardena, 1991). Dissociative states can be seen in both a mild, transient forms through to more enduring, pathological states. Milder dissociative states can be experienced as a side effect of many normal activities: playing sports, sustained focus on an activity, engaging in meditative or mindfulness-type practices (Lehmann et al., 2001) certain religious activities (Ross, Joshi & Currie, 1990), or the use of psychedelic drugs (Good, 1989). Other types of mild dissociation could include confusion, or absorption after engaging in a cognitively demanding task for an extended period of time (Glisky et al,. 1991). More permanent and invasive dissociative states are considered pathological, these are often the product of trauma, drug abuse, or as an after effect or side effect of psychiatric illness. There is evidence to show that childhood trauma can increase the likelihood to dissociate in adult life and reports from psychiatric inpatients who describe dissociative states, often indicate high levels of anxiety or trauma preceding the experience (Spiegel & Cardena, 1991).

Dissociative Phenomena

Given the diversity of experiences which could be considered dissociative, alongside the inconsistencies in classification between the DSM and ICD schemas, a clear definition of dissociation is difficult to conceptualise. Modern psychiatry has described a continuum model of dissociation, with everyday mild dissociations at one end and pathological symptoms at the other (Bernstein & Putnam 1986). However in more recent years a study by Holmes et al (2005) has rejected this single axis description and described two independent sub-factors of pathological dissociation: detachment and compartmentalisation. Detachment is defined as "an altered state of consciousness characterised by a sense of separation … from aspects of everyday experience" (Holmes *et al.,* 2005, p12). Detachment is a highly subjective state, it is primarily a feeling - a sensation that one's reality has changed in quality. Compartmentalization refers to the splitting off of processes which would normally be under conscious control (Lawton, Baker & Brown, 2008). Compartmentalization is considered a cognitive mechanism employed during or after extreme anxiety, trauma or dissonance, and encompasses the 'conversion disorders'. In these disorders pseudo-neurological symptoms, such as unexplained paralysis, gait disturbances are seen with no obvious anatomical disruption (Medford, 2014).

These descriptions appear to indicate that dissociative disorders are both broad in terms of symptoms and experience and also highly subjective. This is a problem both for clinical diagnosis and for further understanding of the neural correlates of dissociation. Given the breadth of symptoms, firstly the identification of sub-factors may help in developing an accurate picture of dissociative disorders. By clustering dissociative phenomenology into distinct themes a more individual image of dissociative phenomena could be described. These themes could help to relate dissociative states to other pathological and non-pathological psychological states. Dissociation has been described as a key component of meditative states (Tei et al., 2009), the near-death experience (Greyson, 2000), psychosis (Moskowitz et.al, 2011, p355) and spiritual experience (Krippner, 1997). While these states all differ both in terms of phenomena and pathology, it is clear that there are similarities in that they share an significant altering of consciousness over and above normal experience.

The identification of sub-themes may aid in clarifying the specifics of these disorders. Sub-factors should include both detachment and somatoform-related changes while acknowledging other pathological and non-pathological states of consciousness which could be related to dissociative experiences. Dissociative disorder patients often report both auditory and visual hallucinations. Strong hallucinations (specific scenes, or distinct images, voices from outside the head) and weak hallucinations (shapes, geometric patterns, swirling colours, voices inside the head) have both been reported (Putnam, 1991) and there is some overlap here between dissociation and psychosis - although notably psychosis is dominated by strong hallucinations which cannot often be distinguished from reality (Bentall, 1990). Furthermore, clinicians have noted an association between subjective phenomena reported in the dissociative disorders and those reported in temporal lobe epilepsy (including complex partial seizures and psychogenic non-epileptic seizures) (Medford, 2014). These phenomena include hypnotic states, alongside mystical and religious phenomena such as strong emotion, dreamlike awareness and visions with religious-themed content . Clearer categorisation of dissociative phenomena may help in understanding the specifics of pathological conditions presented, which in turn is likely to aid in the prescription of better, more specific, therapeutic tools.

The Cambridge Depersonalisation Scale (CDS, Sierra & Berrios, 2000) uses statements such as "What I see looks flat or lifeless, as if I were looking at a picture" and "Parts of my body feel like they don't belong to me" in order to identify depersonalisation in normal populations. These statements appear to indicate that during the dissociative experience meta-cognition is fully present i.e. the subject is aware of what reality is usually like, and also what reality is like in the present moment and can make a comparison between the two states - however some aspect of the normal sensory stream has failed to be 'bound' together with the rest of the sensory data. In this way dissociation may be considered a 'functional neuropathology' (as has been described for other neuropathologies such as depression - Austin, Mitchell & Goodwin, 2001). While this statement cannot be fully evidenced due to the lack of research into dissociative neuroanatomy, the efficacy of CBT in reducing detachment related symptoms, the breadth of mild dissociative states in the normal population and the transience of non-pathological dissociative states may indicate that overt neuroanatomical differences are not the source of these disorders. Instead, alterations in the functional connections between regions may be the cause of dissociative states.

The 'binding problem' describes an important fundamental concept in the study of consciousness (Cleeremans, 2003). Namely that while the neural regions which code for various object attributes have been identified, no single "seat of consciousness" has been detected in the brain where these attributes are unified and perceived as a continuous experience. It has been proposed that conscious integration is directly equivalent to a co-occurence or synchronisation of signals from across discrete neural zones over a given time period (Tononi & Edelman, 2000, Varela et. al, 2001). Dissociation may indicate either a change or breakdown in this synchronisation and a separation of the usual binding of sensory streams. This disintegration is common to descriptions of dissociative experience.

A Multidimensional Approach to Measuring Dissociation

EEG can be used to measure neural activity in real time due to its high temporal resolution. However it is important to note that states of consciousness do not map directly to activity in anatomical regions of the brain. Modern neuroimaging has allowed the identification of a range of measures each which captures different dimensions of neural activity. These dimensions are more accurately able to describe the quality and tone of consciousness than the anatomically descriptive methods of historic psychology (Vaitl et al., 2013). Clearly this is not to say that discrete neuronal ensembles do not have separate function. However, there is an accumulating body of research which suggests consciousness arises from transient neuronal synchrony, and so instead, descriptions of spatial activity must be combined with other measures such as connectivity, power, and network topology (Seth et al., 2008). Furthermore, phenomenological or behavioural measures should be compared to these dimensions to correlate subjective states with the multidimensional space.

If dissociative states are functional pathologies it would be expected to see reduced integration (i.e. less functional connectivity) between discrete zones during dissociative states. An efficient measure of connectivity is the Phase Lag Index (Stam, Nolte, Daffertshofer 2007) which measures similarities in the timing of oscillatory processes[1]. This index allows for the detection of common temporal features from which functional connectivity can be inferred. Functional connectivity in a dynamical system, such as a neural network, can be further modelled using graph theoretical techniques which model the global network topology. Graph theoretical techniques can be applied to networks of any kind and are useful when applied to neurobiological networks to determine areas of activation, and the relationships between these areas (Smit et al, 2008). Global network parameters can be calculated to measure both the integration of the network and differentiation of activity in total across the brain[2].

Inducing Dissociation in the Laboratory

Previous studies have attempted to induce temporary dissociative states in non-pathological samples (Lickel et al., 2008; Leonard, 1999). These non-pharmacological interventions include: staring at a dot for an extended amount of time, staring at one's own reflection for an extended amount of time and repeating one's own name, amongst other techniques. These treatments elicit depersonalisation and derealization and are generally designed as part of therapeutic interventions, more often as techniques to assist in the treatment of panic disorder (Lickel et al., 2008) although some have used this method to study dissociation itself. Using healthy controls in research is useful as it avoids many of the methodological and ethical difficulties involved in the use of clinical populations. Furthermore, the

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1. The Phase Lag Index, is particularly useful in analysis of EEG data due to it's sensitivity to volume conduction. Volume conduction refers to the spreading of electrical activity from a primary source (the cortex) through biological tissue, such as the skull and meninges, before reaching the detection point (electrode), this can cause neighbouring electrodes to display equal values at certain time points, which does not accurately represent the true neural origin of the underlying signal.

2. These network parameters were first described by Watts and Strogatz (1998) and can be used in order to describe graphs derived from biological networks. The first is a measure of local interconnectedness between nodes. This "clustering coefficient" C is calculated for any node A, representing the amount of connection between A and all other nodes in the network. Then an average is taken of all C (from all nodes) in the network to derive a value for node clustering across the network. The second parameter, measures path length - this is average distance from each node to any other node while counting how many other nodes must be visited before the path is complete. This value L has a limited physiological interpretation when applied to scalp EEG, as many of the true neural pathways are not measurable (i.e. any non-cortical part of the brain, cannot be directly assessed with EEG), however this value can be used as a broad measure of global cortical communication.

brain is highly individual in anatomy and function. Thus the use of within-subjects designs in neuroimaging studies offers greater precision in measuring transient conscious states.

Of all induction techniques used, photic stimulation over short periods appears most effective in inducing a dissociative state. Siever (2007) showed that the rate of stimulation is most effective when in the 8-12hz range - a set of frequencies within the neural alpha frequency range. Other studies have taken this further, specifically matching the stimulation frequency to the subject's resting alpha rate (Grey Walter, 1963; Shevelev et al, 2000), subjective reports have indicated that this technique can elicit strong visual phenomena as well as alterations in bodily perception and emotion. It should be noted that the changes in conscious state reported after resting-alpha-matched photic stimulation, may be related to the Steady State Visual Evoked Potential (SSVEP). An SSVEP is a natural neural response to visual stimulation at specific frequencies. When the retina is repeatedly stimulated at certain frequencies (13.5hz - 75hz) these frequencies are mirrored in the brain, first in the occipital lobe, and then spreading further in a caudal-rostral direction across the cortex (Vialette et.al, 2010). It is possible that this wave phenomena is directly related to the subjective changes reported by subjects.

This study sought to first identify if alpha-matched photic stimulation can elicit a dissociative state in healthy participants. Secondly, we aimed to identify differences in power, functional connectivity and network architecture during the induced dissociative state and also within specific sub-phenomena of the broad dissociative state.

Method

Participants

Twenty-three participants (9 female, 14 male) were recruited from the general population. Age ranged from 18 - 64 (M = 28.83, SD = 8.18). 87% were postgraduate students in psychology or a related discipline. 48 hours prior to attendance participants were administered screening questionnaires (see Appendix D) in order to assess existing medical or psychological issues to asses suitability for participation. Exclusion criteria included: any kind of epilepsy, and past history of seizures, any adverse reaction to flashing lights, any history of panic attacks, any other long term psychological or medical complaint. Participants were also assessed for high levels of anxiety and depression with high levels of either resulting in exclusion. Participants were kept as naive as possible as to the nature of the experiment however in order to comply with ethical requirements participants were informed that the study would use ‘flickering light’, which may induce altered states of consciousness. Informed consent was obtained in writing. The study received approval from the Science and Technology Cross Schools Research and Ethics Committee (University of Sussex).

Preliminary Scales

Participants were administered four scales before participation in the study. These were administered online 48 hrs in advance of a participant’s lab appointment using Qualtrics (Qualtrics, 2013). These scales screened for existing psychological conditions, as well as recording pre-existing dissociative traits.

Pre-existing anxiety was measured using the State-Trait Anxiety Index, Trait Version (Spielberger, Gorsuch & Lushene, 1970), a 20-item measure using four point Likert scales (one, almost never; four, almost always) to assess trait anxiety. The STAI yields a total score between 20 and 80, with values above 50 indicating moderate anxiety. Participants reporting above 60 were excluded from participating in the study. Levels of depression were also assessed, using the Beck Depression Inventory II (BDI-II) (Beck, Steer & Brown, 1996), a 21-item measure covering factors such as sadness, pessimism, worthlessness and guilt. The BDI yields a score between 0 and 84. A score of 19 or more indicates moderate depression. Participants scoring over 21 were excluded from participation (this figure is based on data from Sprinkle et al (2002) who applied the BDI-II to student populations).

The Cambridge Depersonalisation Scale, Trait Version (CDS-T) (Sierra & Berrios, 2000) alongside the Dissociative Experiences Scale II (DES-II) (Berstein & Putnam, 1986) were both used to assess dissociative experience in day-to-day life. The CDS-T is a measure of the extent to which a person experiences depersonalisation during regular activities (Sierra, Baker, Medford & David, 2005). The CDS-T is a 29-item measure in which participants rate sentences (e.g., “What I see looks ‘flat’ or ‘lifeless’, as if I were looking at a picture.”) as to how often they experience the statement and the duration of the experience. The CDS is scored from 0 - 290 with a pathological cut-off at 70.

The DES-II is a 28-item measure in which participant rate statements (e.g., “ Some people sometimes feel as if they are looking at the world through a fog, so that people and objects appear far away or unclear. ") as to the likelihood of the event happening to them. Both the DES and CDST are considered reliable and valid, and are widely used in clinical practice to assess dissociative disorders.

Design

This study used a within-subjects design across two conditions. Participants sat eyes closed, in a comfortable high backed chair, in a low light, sound attenuated, electromagnetically shielded room facing a stroboscopic light for 5 minutes while EEG was recorded. The light was delivered using *Lucia No. 3* (Light Attendance GMBH, Austria)[3], a lamp-system comprised of an array of high-intensity LED's with a variable luminance and flash frequency. *Lucia No.3* has a flash frequency range of Xhz - Xhz and has a brightness range of X -X lumens. The two conditions were comprised of a low stimulation session, *LS* and a high stimulation session, *HS.* The flash frequency in both conditions was set to match the participants dominant resting alpha frequency. in the HS condition the lamp luminance was set to XX lumens while in the control condition the lamp luminance was set to X lumens.

The LS session was designed to be the control condition. This aimed to replicate almost all aspects of the experimental condition, including photic stimulation matched to the subject's dominant resting alpha-band frequency - this was considered important in order to control for effects related to SSVEPs. It was considered important to design a condition which would induce an SSVEP in the brain, while at the same time minimising the induction of altered states. LS and HS conditions were counterbalanced with 12 participants being administered the control condition first, while 11 participants were administered the experimental condition first. Participants were naive as to which condition they were experiencing at any time.

EEG Acquisition and Processing

EEG was recorded from all electrodes (including HEOG and VEOG) using a 64 channel ANT wave guard cap positioned according to the 10/20 montage. Impedances were kept below 10KΩ. EEG signals were sampled at 2048 Hz and online re-referenced to a linked mastoid reference. The EEG was

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3. Lucia No. 3 is a stroboscopic light array developed by a team of psychologists and neurologists for therapeutic and commercial purposes. It has been shown to induce vibrant colourful visual displays as well as changes in emotion, attitude and proprioception. See Appendix E for a photo

Table 1
Participant Responses during Post Experimental Interview

Cluster	*Comments*
Hallucination	"… a grid pattern… smooth flowing lines…" "it was like a rattlesnake at first, then more like a bike chain…" "kaleidoscopic shapes that were quite high intensity" "…there was a [strange] visualisation of familiar objects … a cylinder or on occasions a leaf was sitting there just falling through, or a hand grasping something… very strong, very clear"
Bodily Changes	"I had the sensation that I had some [feelings of] touching on my face" "Then [I felt like], not my body but like just me … …was moving through this tunnel" "Particularly in my upper half, and particularly in my hands, just like a tingling sensation" "felt like my hands were bigger… and I was generally lighter"
Detachment	"[I] feel like I have exhausted all my mental energy" "The last session I was quite spaced out" "I'm not in this world that I'm normally am" "I lost track of time and that particular experience felt like a minute, but [the researcher said] it was five minutes…" "my thoughts were disorganised but at the same time I didn't seem to mind… like I had no emotions"
Mystical Experience	"…I felt like there was someone in the room, and I realised it was me, and I was next to myself watching myself…" "…I was deeply connected to that 'other' that exists beyond this place" "…blissful…" "[at] the same [time] I did feel awe, and a little bit of wonder at what I was seeing" "I was seeing Buddhas and Ganeshas…"

recorded by use of the EEProbe Software (A.N.T. A/S, Enschede, The Netherlands). EEG files were preprocessed using the EEGlab toolbox (Delorme & Makeig, 2004) with ERPlab plugin (Lopez-Calderon & Luck, 2014) and ADJUST plugin (Mognon et al, 2011) for Matlab (MATLAB R2014a, The MathWorks, Inc, MA, USA). Parameters which measure power spectral distribution, functional connectivity and network topology were extracted from the processed data (preprocessing and parameter extraction methods are described in further detail in Appendix B).

Resting Alpha Calculation

In order to identify a dominant alpha frequency to be used throughout the conditions, EEG was recorded at rest for 5 minutes, at the start of the experiment. Participants were instructed to close their eyes, relax and stay awake while minimising body and eye movement. The dominant frequency from electrode Oz in the 8hz - 12hz range was identified (to 2 d.p.) using the *spectopo* function, part of the

Table 2
Means, Standard Deviations, Effect Size, Significance Value for Anomalous Experience Questions, ordered by p

Question	*Control*		*Experimental*		*d*	*p*
	M	*SD*	*M*	*SD*		
I saw lights, shapes or colours that weren't really there	46.15	27.81	69.43	26.19	0.84	< 0.01
I saw geometric patterns	41.67	27.51	67.67	24.59	0.94	< 0.01
My sense of space was distorted	20.36	20.05	36.38	27.33	0.80	< 0.01
I felt 'spaced-out'	30.01	22.33	43.50	25.69	0.60	< 0.01
My imagination became more vivid	21.64	23.72	30.82	28.86	0.39	< 0.01
I felt a sense of awe	5.55	13.50	15.93	20.36	0.77	0.01
Some of my senses felt heightened	10.47	11.41	21.06	24.23	0.93	0.01
I heard unexplained sounds or noises	3.41	13.12	6.96	17.93	0.27	0.02
I felt like I was dreaming	19.68	18.76	29.57	22.74	0.53	0.02
I felt flooded with sensations so that I had difficult distinguishing one of my senses from another	4.16	6.54	9.46	13.43	0.81	0.03
The experience had a religious, spiritual or mystical quality	3.54	10.98	10.81	18.08	0.66	0.04
I was sleepy	30.53	23.32	22.37	24.92	-0.35	0.07
I heard my own thoughts repeated or echoed	1.70	5.01	4.93	11.62	0.64	0.07
The experience had a supernatural quality	6.43	11.38	12.43	22.25	0.53	0.08
In addition to the researcher, I felt the presence of another being in the room	2.94	8.40	7.41	16.21	0.53	0.12
My sense of time was distorted	22.31	21.61	27.89	23.84	0.26	0.14
I felt unusual feelings in my body	11.74	12.43	15.10	16.37	0.27	0.20
I felt nauseated, dizzy or faint	9.55	16.27	12.96	19.78	0.21	0.34
I felt suspicious and paranoid	2.70	5.18	2.20	4.35	-0.10	0.53
I heard an unexplained voice or voices	2.65	9.88	3.01	9.72	0.04	0.66
I felt like there was someone touching me	0.83	3.15	1.04	4.86	0.07	0.86

EEGLab plugin for Matlab. Electrode Oz was selected since alpha activity is expressed most clearly at occipital electrodes.

Procedure

Participants were equally distributed across 3 lab sessions, starting at 9.00am, 11.45am and 2.30pm. During their appointed session participants were asked to sit through 3 trials each of 5 minutes, of both the LS and HS condition (see Appendix A). After each 5 minute session, participants were given a set of rating scales to fill in, which aimed to characterise their experience during the

Table 3
Pairwise Differences in Average PLI within Delta and Gamma Bands

Region	*Mean Difference (10*	*SD (10*	*p*
Delta Band			
Frontal	0.68	6.93	.644
Central	1.23	4.61	.214
Parietal-Occipital	0.77	6.49	.576
Temporal	0	4.19	.997
Gamma Band			
Frontal	2.53	1.56	.118
Central	3.83	1.97	.065
Parietal-Occipital	6.16	3.18	.066
Temporal	2.91	2.02	.164

previous 5 minutes. Participants were also asked to include any changes in experience which they may still be feeling while filling in the scales as a result of the stroboscopic stimulation.

During each condition participants were asked to sit comfortably, relaxed upright, with eyes closed. Participants were given no information as to what they may experience however they were asked to take note of the experience so that they could report it after the session was complete. The lamp was adjusted so the bulb faced the participant - at eye level and 100cm from participants eyes (Figure 1). For the duration of the stimulation sessions, participants were alone in the EEG booth with external sources of light eliminated, and wore earplugs (to attenuate background noise) throughout. After the session the booth was opened and relit while participants filled in the questionnaires. Participants had access to a emergency call button, if for at any point they became uncomfortable this could call the researcher and end the stimulation. At all times the participant was observable via a live camera feed to the workstation outside the booth. After all 6 sessions were complete, participants were debriefed and a short interview took place during which the researcher asked about their experience of the experiment. Subjects were also asked about their current psychological state to ensure they felt well and stable before leaving the lab.

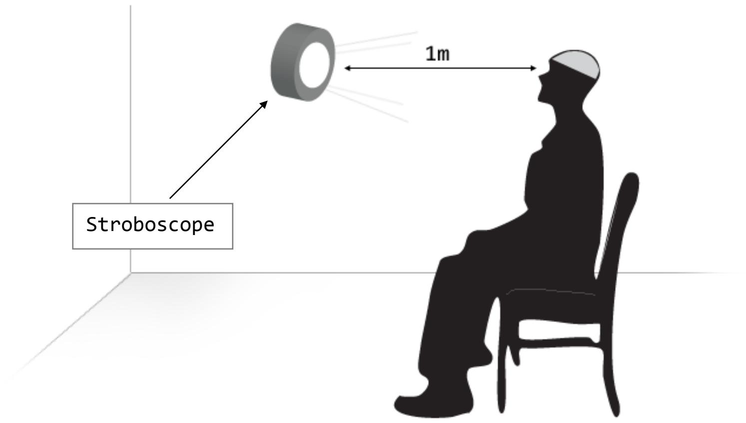


Figure 1: Illustration of laboratory setup. Participants were seated 1 metre away from the light source which was aligned at eye level and centrally fixated. Participants were seated in a comfortable high backed chair during all EEG recording sessions.

Post-Stimuli Scales

After each trial participants were administered 3 questionnaires. Firstly, the Cambridge Depersonalisation Scale, State Version (CDS-S) (Sierra and Berrios, 2000) was selected as a measure of detachment induced during a session. Following this a set of questions was administered which were designed to identify other phenomena within the dissociative state (these Anomalous Experience Questions (AEQ) are taken from Newson & Medford, 2013). Questions in this group tested for the presence of hallucinations, mystical experiences and strange sensations (e.g. "I felt flooded with sensations so that I had difficult distinguishing one of my senses from another.") alongside colloquial descriptions of dissociation ("I felt 'spaced-out'")[4]. Participants were also given the State-Trait Anxiety Index, State Version (STAI-S) (Spielberger, Gorsuch & Lushene, 1970), to assess levels of anxiety induced by each stimulation session. Finally, participants were asked, in a single question rated from 0 - 100, as to how pleasant they found the previous session. In total, these questionnaires took approximately 10 minutes to complete after each session.

4. The Anomalous Experience Questions were adapted from the Cardiff Anomalous Perceptions Scale (Bell, Halligan and Ellis, 2006), and from a questionnaire by Carhart-Harris *et al*. (2012) used to assess the subjective effect of psychedelics on healthy volunteers.

Data Analysis

One trial did not contain 300s of artifact-free data and this was removed from the analysis. Another three trials existed where participants did not complete the full set of post stimuli scales, these were also removed.

First it was important to identify if the experimental condition had successfully induced a dissociative state. Following this we aimed to characterise the network during the induced dissociative state by initially looking at differences in power (to identify activity within frequency bands) during dissociative states. Following this we used the Phase Lag Index (PLI) as a measure of functional connectivity to identify differences in synchronisation between the experimental condition and the control condition. These analyses involved paired samples tests across the whole participant group. We also clustered electrodes into 4 regions of interest (Frontal, Central, Parietal-Occipital and Temporal, following Molen & Molen, 2013) to observe connectivity within these sub-regions (see Appendix C for ROI details).

After identifying within-subjects differences across conditions we aimed to characterise sub-components of the broad 'dissociative state'. Drawing from previous research (Newson & Medford, 2013; Moskowitz et.al, 2011; Tei et al., 2009; Greyson, 2000; Krippner, 1997) and clinical experience, items in both the CDS-S and AEQ were assigned to one of four clusters: 'Hallucinatory Experience', 'Bodily Changes', 'Mystical Experience', 'Detachment'.[5] For each of these clusters a participant was given a score between 1 and 0 based on a mean standardised value from their total scores on those individual scale items. Values of 1 indicated a score of 100 (the maximum value) on all questions within that cluster. Values of 0 indicated a score of 0 (the lowest score) for all questions within that cluster (see Appendix D for questionnaires and question grouping).

In order to identify EEG characteristics of these components a between-subjects comparison was used. Here we compared experimental-condition trials for those participants reporting strong phenomena, against those reporting weak phenomena. For each cluster, scores were ranked and the top and bottom 15% of participant trials (n = 10) were compared. This was considered a better method of amplifying true neural differences in subtle and transient conscious states, than a within subjects

5. These clusters appear to map the many subjective effects seen in dissociation. They were selected by factoring individual questions in both the CDS-S and AEQ into relevant themes, alongside clinical experience of working with pathological dissociation, and reports in the literature.

comparison. For these clusters we first identified differences in relative power, and following this regional differences in functional connectivity were compared. Subsequently graph theoretical parameters were used to characterise the whole network. For all analyses, parameters were calculated separately for the following frequency bands: delta (0.5 - 4hz), theta (4-8hz), alpha (8-13hz), beta (13-25hz) and gamma (25-60hz).

Questionnaire data was analysed using SPSS Version 22 (IBM Corp, USA). EEG data was processed and averaged per participant-trial-frequency-band using Matlab (The MathWorks Inc, USA), following this statistical analyses were carried out in SPSS. Although many sets of both paired samples and independent samples tests were conducted, it was not considered appropriate to use a Bonferroni correction. As Perneger (1998) states (also Rothman, 1990), the use of adjustments to the type I error rate can lead to important differences being deemed non-significant. This is especially relevant to clinical research - given that the observation of subtle and transient physiological states are likely to be difficult to detect, especially in small samples. In relation to this we have also reported probability statistics which approach significance ($0.05 < p \leq 0.07$) throughout this report.

Results

Phenomenology

Participant comments from post-experimental interviews were recorded and these appear to support the choice of phenomenological clusters (a selection is shown in Table 1). Furthermore, pairwise analyses were conducted on responses to the AEQ in between control and experimental conditions. Largest effects were seen in items which relate to visual and sensory phenomena, with mystical phenomena producing moderately smaller - but nevertheless substantial - effect sizes (Table 2). Items related to physical changes (e.g. "I felt unusual feelings in my body", "I felt like there was someone touching me") appeared to show small effects (Table 2).

Preliminary Analyses

Responses to most scales displayed a normal distribution. Scales displaying a significantly non-normal distribution in the preliminary scales included the DES ($D(23) = 0.191$, $p = 0.20$), and the STAI-T ($D(23)$

= 0.191, p = 0.03). While in the post-stimuli measures only the Pleasant measure in the experimental condition was significantly non-normal ($D(23) = 0.186$, p=0.04). EEG parameters (relative power, PLI, C, L, σ) were normally distributed with some examples of strong negative skew in values of PLI which were reduced after thresholding. Due to the high proportion of variables which displayed a normal distribution it was not considered appropriate to transform the data. Furthermore due to the small sample size (n=23) it may be difficult to detect a normal distribution in this data.

Initial Findings

Paired samples t-tests were used to identify differences between the two conditions. Participants reported higher levels of depersonalisation (CDST) in the experimental (high-luminance) condition ($M = 7.57$, $SE = 0.83$) over the control (low-luminance) condition ($M = 5.16$, $SE = 0.67$). This was a significant difference $t(22) = -4.95$, $p < .001$, $d = 0.75$. This represents a large effect (as per Cohen, 1992). Participants reported significantly more anomalous experiences in the experimental condition ($M = 4.52$, $SE = 0.47$) over the control condition ($M = 2.97$, $SE = 0.38$), as reported via the AEQ: $t(22) = -5.56$, $p < .001$, $d = 0.84$. Interestingly, participants did not report significant differences in anxiety across the two conditions. t(22) = 1.156, p = .260. Participants rated more pleasant feelings in the experimental condition (M = 62.81, SE = 4.55) compared to the control condition ($M = 54.62$, $SE = 3.50$), $t(22) = -2.415$, $p < .025$, $d = 0.49$.

These findings seem to suggest that the high luminance condition did induce a dissociative state in participants. This was explored further, using participants CDS-T scores. When entered into a linear regression, a participants preliminary scores on the CDS significantly predicted their CDS response in the control condition $\beta = .09$, $t(22) = 3.67$, $p < .001$. and also in the experimental condition $\beta = .09$, $t(22) = 2.75$, $p = .012$. This would indicate that an individuals susceptibility to depersonalisation from photic stimulation, is in part predicted by their levels of depersonalisation in day-to-day life. The strength of the effect in the control condition would appear to indicate that the level of stimulation in this condition managed to induce dissociative states in participants - even though this was significantly weaker than in the experimental condition overall.

Induced State vs Control State: Power Spectra, Functional Connectivity and Network Character

During the induced state participants showed reduced mean relative power in the theta band $t(22) = 3.26$, $p = .004$, reduced mean relative power in the alpha band $t(22) = 5.96$, $p < .001$ and reduced mean relative power in the beta band $t(22) = 2.31$, $p = .031$

It was predicted that there might be an increase in power in the experimental condition due to the stronger luminance. Previous research has shown SSVEP amplitudes generally increase with higher contrast of the driving stimulus (Andersen et. al, 2012). However, the application of the SSVEP filter appeared to further accentuate the difference (for example: mean relative power in filtered beta band: $t(22) = 2.696$, $p = .013$). This would appear to indicate that the reported subjective phenomena of the dissociative state is unrelated to the SSVEP, i.e. the subjective effects are related to power differences outside of the SSVEP range.

At the same time, during the induced state, participants showed increased connectivity in the delta band $t(22) = -2.50$, $p = .020$, and also increased connectivity in the gamma band $t(22) = -2.19$, $p = .039$.

Further analyses were conducted on discrete regions of interest within the delta and gamma band to identify which regions may contribute towards the significant difference, however significant differences were not detected in any of the 4 zones within these two frequency bands. This may reflect either the fact that the significant differences reported above are equally spread across all regions, or alternatively that the electrodes which produce the differences are distributed somewhat evenly between the regions.

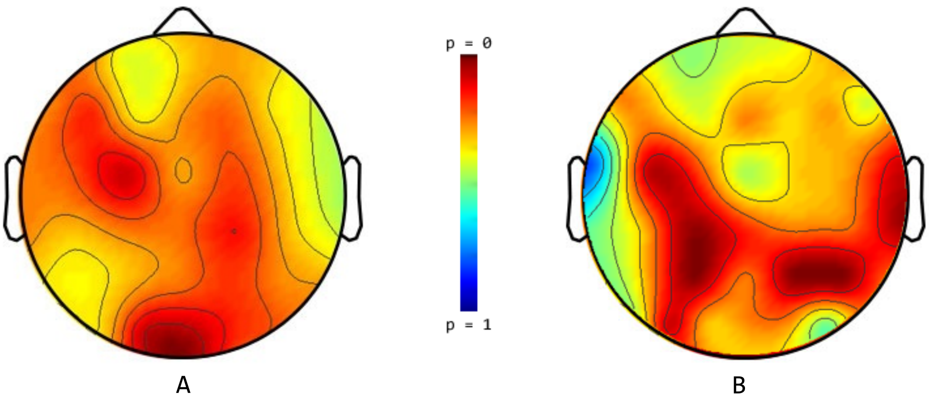


Figure 2: A) Differences in functional connectivity (Experimental - Control) in gamma band, more significant differences, indicating stronger connectivity indicated in dark red. n=23. B) Differences in functional connectivity (Experimental - Control) in delta band, more significant differences, indicating stronger connectivity indicated in dark red. n=23

This can be confirmed by looking at the topographic plot of connectivity differences in the gamma band (Figure 2A). This shows the difference as being fairly distributed, although there appears to be some strong difference in the lower parietal-occipital zone. This is reflected in the fact that for this zone, differences are approaching significance (p = .066, in Table 3).

Analyses of network parameters indicated that there were significant differences in C in the delta band $t(22) = -3.218$, $p = 0.004$. Indicating higher local segregation within neuronal populations which oscillate at delta frequencies. Furthermore, the value of C in the gamma band approached significance $t(22) = -1.944$, $p = .065$. There were no significant differences in L across any frequency bands. The small-world parameter σ was significantly different between control and experimental groups in the gamma band, $t(22) = -2.145$, $p = .043$. σ is an indicator of network efficiency (see Appendix B for calculation of σ), thus a more efficient network is seen in the gamma frequency band in the experimental condition.

Phenomenological Clusters: Power Spectra, Functional Connectivity and Network Character

Within phenomenological clusters, we identified relative power differences in all clusters except the *hallucination* cluster, which showed no significant differences in any frequency bands. The *bodily changes* cluster showed higher relative power in the gamma band: $t(18) = -3.17$, $p = .005$. Similarly, the *detachment* cluster showed higher relative power in both the delta band: $t(18) = 2.184$, $p = .042$ and theta

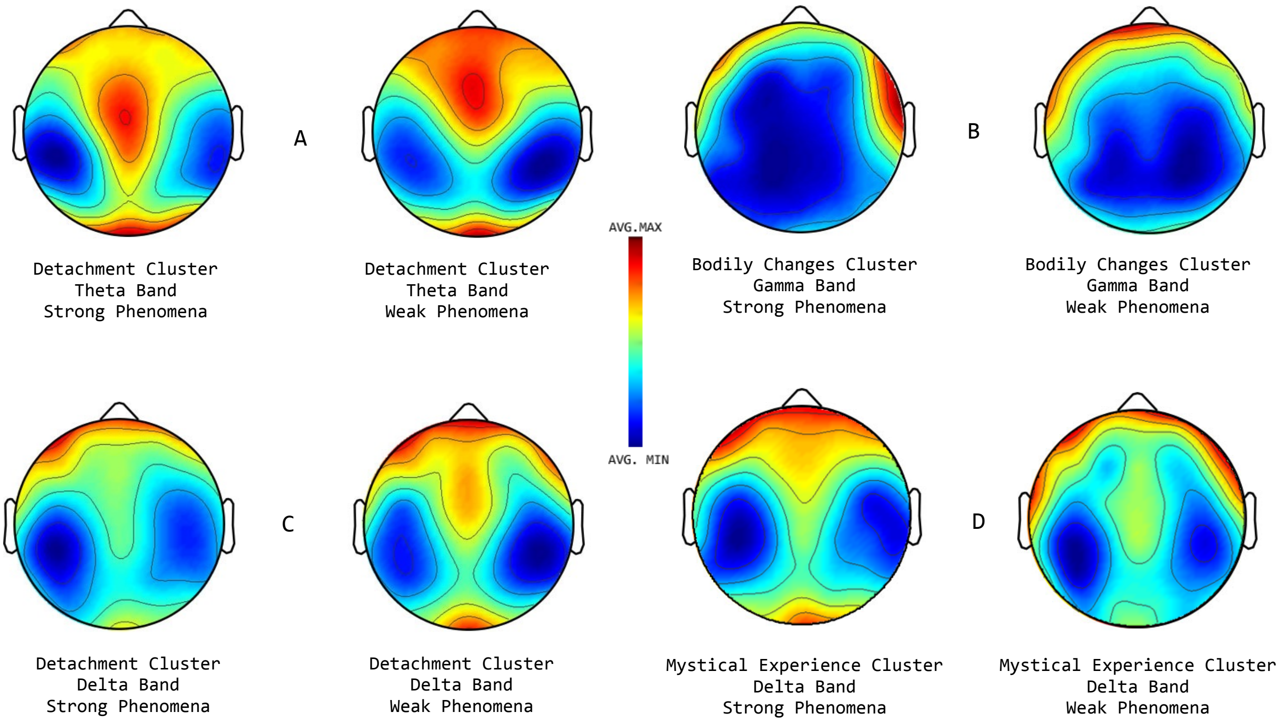


Figure 3: Topographic plots show relative power distribution per cluster/frequency-band/phenomena-type. A) Detachment Cluster, Theta Band B) Bodily Changes Cluster, Gamma Band C) Detachment Cluster, Delta Band, D) Mystical Experience Cluster, Delta Band. n = 10 for all plots

band: $t(18) = 2.732$, $p = .014$. *Mystical experience* showed lower relative power in the delta band: $t(18) = -2.209$, $p = 0.04$.

Topographic plots of power distributions in strong phenomena and weak phenomena groups, in the above bands can be seen in Figure 3. Functional connectivity was assessed between regions, and for each frequency band. Graph parameters were also identified between frequency bands for the whole network. This data is described in Table 4.

Table 4
Phenomenological Clusters, Strong Phenomena vs Weak Phenomena

Hallucination	*d*	*Detachment*	*d*
+ C Alpha		+ σ Delta*	
- L Gamma		- C Gamma	
+ Frontal Theta		- Frontal Alpha	
		- Frontal Beta	
		- Central Alpha	
		- Central Beta	
		- Parietal-Occipital Theta	
		- Parietal-Occipital Alpha	
		- Parietal-Occipital Beta	
		- Temporal Alpha	
		- Temporal Beta	
		+ Temporal Gamma	
Bodily Changes	*d*	*Mystical Experience*	*d*
+ L Beta		- L Alpha	
		+ σ Alpha	
+ Frontal Gamma*			
		+ Frontal Alpha	
		+ Central Alpha	
		+ Parietal-Occipital Alpha	

1. Note, in the table above regions and parameters are prefixed with +/- . This indicates the direction of the effect. + indicates that the synchronisation/clustering/path-length was stronger/more integrated/longer in those participants showing strong phenomena. - indicates that the synchronisation/clustering/path-length was weaker/less integrated/shorter in those participants showing strong phenomena.

2. C = Clustering Coefficient, L = Average Shortest Path Length, σ = Small-World Parameter (Relative Efficiency). All other regional/ bands are measured using Phase Lag Index (a measure of synchronisation within the zone)

3. All network parameters and regional synchronisation described below are $p < .05$, except where * indicates approached significance ($p < .07$). Each cluster represents differences as shown by independent samples t-tests. For each sample n = 10

Functional connectivity analyses showed few significant differences in the *Hallucination* cluster and *Bodily Changes* cluster. Items within the AEQ which related to hallucinatory experiences showed some of the strongest effects across all participants. It logically followed that the Weak Phenomena group within the *Hallucination* cluster had the largest subjective effects compared to the other clusters ($WP_{Hallucination}$ M = -0.36, WP_{Bodily} M = -1.12, $WP_{Detachment}$ M = -0.90, $WP_{Mystical}$ M = -1.20).

It seems likely that the difference in the effect was not strong enough to distinguish between these two groups, as both participants in the strong phenomena and weak phenomena groups both exhibited relatively strong hallucinatory effects. The *Bodily Changes* cluster exhibited the reported the smallest subjective effects of all the clusters (SP_{Bodily} M = 0.68, $WP_{Mystical}$ M = 1.22 , $WP_{Detachment}$ M = 1.44, $WP_{Hallucination}$ M = 2.50). Thus, it may be that the strength of the effect within the strong phenomena group was not enough to detect any clear differences between the two groups.

Several significant changes were seen in the *Detachment* cluster. This exhibited a clear picture of reduced synchronisation in all regions (frontal, central, parietal-occipital and temporal) in both the Alpha (see Figure 4) and Beta band. There was also reduced synchronisation in Theta frequencies within the Parietal-Occipital region. Notably, significantly increased connectivity in gamma frequencies within the temporal region was detected for this cluster. (see Table 4).

The *Mystical Experience* cluster showed significant increases in connectivity in the alpha band. This was specifically within Frontal, Central and Parietal-Occipital regions. σ was also significantly larger in the alpha band, indicating that neuronal networks which oscillate at alpha frequencies demonstrate a more efficient network during mystical states.

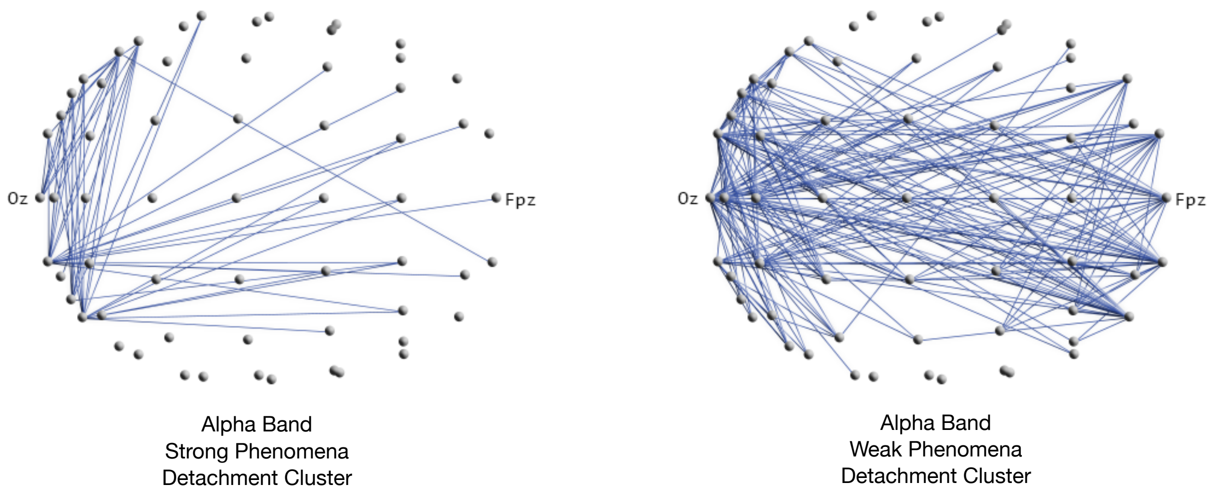


Figure 4: Functional Connectivity in Detachment Cluster, Alpha Band, Strong and Weak Phenomena. All connections > 0.18 PLI. n = 10

This was further supported by the fact that the average path length *L* was also shorter in the alpha band for this cluster. This would indicate that global information transfer within the network may be augmented during experiences of this sort (see Table 4).

Discussion

In both academic and popular literature the use of flickering light has been reported to induce novel states of consciousness. It is likely these states could be attributed to the combined sensory deprivation and sensory overload of the stimulation session, methods which have been shown to reliably generate altered states of consciousness (for a comprehensive review see Vaitl et al., 2013). In this study we attempted to characterise the state induced as being subjectively similar to a dissociative state. It was shown that participants did report higher levels of depersonalisation during the experimental condition. Furthermore the strong endorsement of many of the items on the AEQ (especially items related to visual hallucination, or supernatural, spiritual or mystical phenomena) alongside reports from interviews, indicates that other aspects of dissociative experience were felt keenly by participants. Items related to auditory hallucination and physiological issues had low levels of endorsement suggesting these effects were not widely seen in either condition.

The experimental condition was characterised by attenuated power in alpha, beta and theta bands. This finding is correlated with Kuhlo and Lehmann's (1964) study which showed that the hypnogogic state (the period between drowsiness and sleep onset) is characterised by reduced power in alpha and theta bands and have described these states as "reality-remote" and "dream-type" experiences. These descriptions appear close to subjective reports of detachment. Both alpha and theta oscillations are known to be highly associated with attentional processes (Klimesch, 1999; Gomarus et al., 2006, Basar-Eroglu et al., 1992), claims which are supported by the demonstrated modulation of both theta and alpha activity as a result of meditation practice (Lagopoulos et al., 2009; Baijal & Srinivasan, 2010; Aftanas & Golocheikine, 2001). These associations seem to make sense as meditation is known to be an activity which enhances attentional ability and scope.

Our results indicate that during induced dissociative states participants demonstrated a modulation in attention-related behaviour. Perona-Garcelán (2008) et al showed that patients exhibiting dissociation and psychosis had higher levels of self-focused attention, defined as ". . . an awareness of self-referent, internally generated information that stands in contrast to an awareness of externally generated information derived through sensory receptors" (Ingram, 1990). Thus, dissociative states may be related to an attentional bias driven by the salience of internally generated information over externally generated information. In this model, depersonalisation-like phenomena could be attributed to a functional neuropathology in which an ability to filter internal information in diminished, limiting the capacity of attentional resources available for processing real world sensory streams, leading to an unreal, dream-like state which is remote and lacking in vividness. This model does not support theories that dissociative states are akin to a failure to bind sensory streams in consciousness. Our data confirms this is not the case by the fact that gamma frequencies, known to be associated with binding (Engel & Singer, 2001), show a higher value for σ, alongside higher overall connectivity. This indicates that in actuality we saw a highly efficient 'binding-related' network across the cortex as a whole, during the induced state.

This conclusion may be further supported by results from the clustered phenomena. The detachment cluster demonstrated higher relative power in theta and delta bands. Given prior suggestions regarding theta decreases, it is initially unclear how the increase seen here can be reconciled with the above model. It is important to note that while overall theta band power was increased, topographic plots of theta band power in the *detachment* cluster (Figure 3A) show reduced relative power in the frontal zones, in those participants demonstrating strong phenomena. This is particularly notable given the wealth of literature which correlates higher frontal theta activity with reduced self-referential processing (Baijal, S., & Srinivasan, 2010; Aftanas & Golocheikine 2001, 2002). It is highly likely the reduction of theta activity in frontal zones, is related to a pervasive self-referential attentional bias, leading to detached and 'unreal' states.

Functional connectivity analyses within the *detachment* cluster described an overall reduction in phase synchronisation in alpha (see Figure 4) and beta bands. These phase connectivity analyses measure the amount of information which is shared between two topographic points for each point in time. Thus, a reduction in connectivity is equivalent to a reduction in the amount of integrated information (Tononi & Edelman, 2000) in a network. In recent years, neuroscientific theories of integrated information have described these highly integrated and unified neural states, as being a direct correlate of conscious states, positing that consciousness is an emergent property of integrated information (Tononi, 2011).

Alpha frequency band oscillations have long been associated with task-irrelevant functional processing. However, more recent studies have related alpha phase dynamics to mechanisms of attention and consciousness. Palva & Palva (2007) have proposed that simultaneous alpha and beta oscillations are required for 'unified cognitive operations' and propose that cross-frequency phase synchrony between the alpha and beta band coordinates neuronal object representations in attention, perception and consciousness. Within the *detachment* cluster there is widespread reduction across a range of distributed spatial regions, a result which correlates well with studies that show alpha frequency band oscillations both form functional large-scale and efficient attentional processes are considered to depend on phase locking attentional processes can be considered the result of phase locking between widely separated cortical regions (Palva, Palva & Kalia, 2005; Varela et al., 2001). Admittedly it is not clear from our results whether there is any interaction between the alpha and beta bands, however the clear reduction is phase synchrony would posit that there is a reduction in shared information, affecting attention and consciousness during detached states.

The reverse pattern was identified in those participants experiencing mystical states. Notably, we saw increased connectivity in alpha band phase synchrony (in frontal, central and parietal-occipital regions) alongside a shorter average path length and higher small-world parameter. Following our previous suggestions this would indicate a more integrated network, with faster information transfer and an overall higher efficiency between regions. Given earlier proposals that alpha synchrony is associated with attention and consciousness, this characterisation of these states appear logical. Mystical states tend to encompass feelings of becoming more in touch with reality, furthermore individuals often report changes in trait personality based on realisations and understandings during the state. These subjective descriptions would correlate well with a neural network characterised by increased communication of information in the domains of attention, perception and consciousness as is suggested by our results.

Another key characteristic of mystical experience is a shift from internal processing to a widening of one's awareness (and at extremes of the experience a state of all-encompassing 'oneness'). Within the mystical experience cluster we saw clear reductions in power in the delta band. These power reductions have been shown to correlate with reductions in internal attentional bias and could characterise an attentional state which favours external sensory streams over internal sensory streams. There is much descriptive overlap between mystical states (such as trance, awe or 'oneness') and pathological dissociation however mystical states tend to be overwhelmingly positive (common descriptions include timelessness, boundlessness, positive affect, peace, joy and love) for individuals. This discrepancy in affect alongside the distinctly different dimensional characteristics described in the mystical experience cluster may indicate that these two processes may fall at different ends of the same spectrum.

Summary

Here we investigated transient altered conscious states using a dissociation induction paradigm in order to identify key functional characteristics of dissociative states. Three measures of neural activity were compared alongside subjective scale reports. Firstly between experimental and control trials, and then between strong and weak experiencers of specific phenomena. Depersonalization and detachment appear to be highly correlated with reduced activity in functional systems related to self-referential attention, as well as a reduction in integrated information cortex wide in the alpha and beta bands. Furthermore, we have shown that mystical states are characterised by higher levels of cortical integration in systems which relate to conscious perception and a reduction in self-referential attention.

Design Limitations

Throughout this study there were two predominant limitations. Firstly, due to time limitations the sample size was smaller than was preferable. Increasing the sample size would in turn increase the number of participants which could be included in strong phenomena subgroups. Secondly, the control condition was found to elicit a slight, yet perceptible altered state. Due to the strength of the phenomena experienced during the control condition it was not considered proper to embark upon pairwise analyses. A more suitable control condition could be found by taking recordings at rest (as opposed to during photic stimulation) - as this study did not find that SSVEPs moderated effects, a baseline comparison could be considered suitable in the future.

Future Directions and Conclusions

It should be noted that there were many participants who noted little to no change in their conscious perception during the experimental condition. Future studies could try to identify what factors relate to an individuals susceptibility to experience altered states of consciousness using this induction paradigm. An analysis of baseline neural connectivity could aid with this task, and future studies could use baseline recording to predict the elicitation of certain types of phenomena in an individual. Finally, a more formal qualitative analysis could also be highly useful in identifying the specifics of phenomena to assist with the development of more detailed, cluster types.

Defining the the neural correlates of dissociation is critical in developing therapies to assist with these profound disorders of consciousness. Further multidimensional research into dissociative states will help to define dissociation in relation to other pathological and non pathological states, an important step in the emerging science of consciousness.

References

A.N.T. A/S, Enschede, The Netherlands

Achard, S., & Bullmore, E. (2007). Efficiency and cost of economical brain functional networks. PLoS computational biology, 3(2), e17.

Aftanas LI, Golocheikine SA (2001) Human anterior and frontal midline theta and lower alpha reflect emotionally positive state and internalized attention: high-resolution EEG investigation of meditation. Neurosci Lett 310:57–60.

Aftanas LI, Golocheikine SA (2002) Non-linear dynamic complexity of the human EEG during meditation. Neurosci Lett 330:143–146.

American Psychiatric Association. (2013). Diagnostic and Statistical manual of mental disorders (5th ed.). Arlington, VA: American Psychiatric Publishing.

Andersen, S. K., Müller, M. M., & Martinovic, J. (2012). Bottom-up biases in feature-selective attention. The Journal of Neuroscience, 32(47), 16953-16958.

Austin, M. P., Mitchell, P., & Goodwin, G. M. (2001). Cognitive deficits in depression Possible implications for functional neuropathology. The British Journal of Psychiatry,

Baijal, S., & Srinivasan, N. (2010). Theta activity and meditative states: spectral changes during concentrative meditation. Cognitive processing, 11(1), 31-38.

Basar-Eroglu C, Basar E, Demiralp T, Schurmann M (1992) P300-response: possible psychophysiological correlates in delta and theta frequency channels. A review. Int J Psychophysiology 13:161–179.

Bassett, D. S., & Bullmore, E. D. (2006). Small-world brain networks. The neuroscientist, 12(6), 512-523.

Beck, A.T., Steer, R.A., & Brown, G.K. (1996). Manual for the Beck Depression Inventory-II. San Antonio, TX: Psychological Corporation.

Bentall, R. P. (1990). The illusion of reality: a review and integration of psychological research on hallucinations. Psychological bulletin, 107(1), 82.

Bernstein, E. M., & Putnam, F. W. (1986). Development, reliability, and validity of a dissociation scale. The Journal of nervous and mental disease, 174(12), 727-735.

Briere, J., Scott, C., & Weathers, F. (2005). Peritraumatic and persistent dissociation in the presumed etiology of PTSD. American Journal of Psychiatry, 162(12), 2295-2301.

Cleeremans, A. E. (2003). The unity of consciousness: Binding, integration, and dissociation. Oxford University Press

Cohen MX (2014) Analyzing Neural Time Series Data: Theory and Practice Issues in Clinical and Cognitive Neuropsychology

Cohen, J. (1992). A power primer. Psychological bulletin, 112(1), 155.

David, A. (2012). Overcoming Depersonalization and Feelings of Unreality. Constable & Robinson.

Delorme, A & Makeig, S (2004) EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics (pdf, 0.7 MB) Journal of Neuroscience Methods 134:9-21

Engel, A. K., & Singer, W. (2001). Temporal binding and the neural correlates of sensory awareness. Trends in cognitive sciences, 5(1), 16-25.

Glisky, M. L., Tataryn, D. J., Tobias, B. A., Kihlstrom, J. F., & McConkey, K. M. (1991). Absorption, openness to experience, and hypnotizability. Journal of Personality and Social Psychology, 60(2), 263.

Gomarus HK, Althaus M, Wijers AA, Minderaa RB (2006) The effects of memory load and stimulus relevance on the EEG during a visual selective search task: an ERP and ERD/ERS study. Clin Neurophysiol 117:871–884

Good, M. I. (1989). Substance-induced dissociative disorders and psychiatric nosology. Journal of clinical psychopharmacology, 9(2), 77.

Grey Walter, W. (1963). The living brain.

Greyson, B. (2000). Dissociation in people who have near-death experiences: out of their bodies or out of their minds?. The Lancet, 355(9202), 460-463.

Harmony, T., Fernández, T., Silva, J., Bernal, J., Díaz-Comas, L., Reyes, A., ... & Rodríguez, M. (1996). EEG delta activity: an indicator of attention to internal processing during performance of mental tasks. International journal of psychophysiology, 24(1), 161-171.

Holmes, E. A., Brown, R. J., Mansell, W., Fearon, R., Hunter, E., Frasquilho, F., & Oakley, D. A. (2005). Are there two qualitatively distinct forms of dissociation? A review and some clinical implications. Clinical psychology review, 25(1), 1-23.

Horwitz, B. (2003). The elusive concept of brain connectivity. Neuroimage, 19(2), 466-470.

IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp.

Ingram, R. E. (1990). Self-focused attention in clinical disorders: review and a conceptual model. Psychological bulletin, 107(2), 156.

Johnson, J. G., Cohen, P., Kasen, S., & Brook, J. S. (2006). Dissociative disorders among adults in the community, impaired functioning, and axis I and II comorbidity. Journal of psychiatric research, 40(2), 131-140.

Klimesch W (1999) EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis. Brain Res Brain Res Rev 29:169–195.

Krippner, S. (1997). Dissociation in many times and places. Broken images, broken selves: Dissociative narratives in clinical practice

Kuhlo, W., & Lehmann, D. (1964). Das Einschlaferleben und seine neurophysiologische Korrelate [Experience during the onset of sleep and its neurophysiological correlates]. Archiv fur Psychiatrie und Zeitschrift fur die Gesamte Neurologie, 205, 687–716

Lagopoulos, J., Xu, J., Rasmussen, I., Vik, A., Malhi, G. S., Eliassen, C. F., ... & Ellingsen, Ø. (2009). Increased theta and alpha EEG activity during nondirective meditation. The Journal of Alternative and Complementary Medicine, 15(11), 1187-1192.

Lawton, G., Baker, G. A., & Brown, R. J. (2008). Comparison of two types of dissociation in epileptic and nonepileptic seizures. Epilepsy & Behavior, 13(2), 333-336.

Lehmann, D., Faber, P. L., Achermann, P., Jeanmonod, D., Gianotti, L. R., & Pizzagalli, D. (2001). Brain sources of EEG gamma frequency during volitionally meditation-induced, altered states of consciousness, and experience of the self. Psychiatry Research: Neuroimaging, 108(2), 111-121.

Leonard, K. N., Telch, M. J., & Harrington, P. J. (1999). Dissociation in the laboratory: A comparison of strategies. Behaviour research and therapy, 37(1), 49-61.

Lickel, J., Nelson, E., Lickel, A. H., & Deacon, B. (2008). Interoceptive exposure exercises for evoking depersonalization and derealization: A pilot study. Journal of Cognitive Psychotherapy, 22(4), 321-330.

Light Attendance GMBH, Austria

Lopez-Calderon, J., & Luck, S. J. (2014). ERPLAB: an open-source toolbox for the analysis of event-related potentials. Frontiers in human neuroscience, 8.

MATLAB R2014a , The MathWorks, Inc., Natick, Massachusetts, United States.

Medford, N. (2014). Dissociative symptoms and epilepsy. Epilepsy & Behavior, 30, 10-13.

Mognon, A., Jovicich, J., Bruzzone, L., Buiatti, M., ADJUST: An Automatic EEG artifact Detector based on the Joint Use of Spatial and Temporal features. Psychophysiology 48 (2), 229-240 (2011).

Moskowitz, A., Schafer, I., & Dorahy, M. J. (2011). Psychosis, trauma and dissociation: Emerging perspectives on severe psychopathology. John Wiley & Sons.

Newson, T. & Medford, N. (2013). One Kind of Dissociation or Two? Using Stroboscopic Induction to Investigate the Phenomenology of Dissociative Experience. Unpublished manuscript.

Palva, J. M., Palva, S., & Kaila, K. (2005). Phase synchrony among neuronal oscillations in the human cortex. The Journal of Neuroscience, 25(15), 3962-3972.

Palva, S., & Palva, J. M. (2007). New vistas for α-frequency band oscillations. Trends in neurosciences, 30(4), 150-158.

Perneger, T. V. (1998). What's wrong with Bonferroni adjustments. Bmj, 316(7139), 1236-1238.

Perona-Garcelán, S., Cuevas-Yust, C., García-Montes, J. M., Pérez-Álvarez, M., Ductor-Recuerda, M. J., Salas-Azcona, R., ... & Rodríguez-Martín, B. (2008). Relationship between self-focused attention and dissociation in patients with and without auditory hallucinations. The Journal of nervous and mental disease, 196(3), 190-197.

Qualtrics, Utah, United States, 2013

Ross, C. A., Joshi, S., & Currie, R. (1990). Dissociative experiences in the general population. American Journal of Psychiatry, 147(11), 1547-1552.

Rothman, K. J. (1990). No adjustments are needed for multiple comparisons. Epidemiology, 1(1), 43-46.

Rubinov, M., & Sporns, O. (2010). Complex network measures of brain connectivity: uses and interpretations. Neuroimage, 52(3), 1059-1069.

Seth, A. K., Dienes, Z., Cleeremans, A., Overgaard, M., & Pessoa, L. (2008). Measuring consciousness: relating behavioural and neurophysiological approaches. Trends in cognitive sciences, 12(8), 314-321.

Shevelev, I. A., Kamenkovich, V. M., Bark, E. D., Verkhlutov, V. M., Sharaev, G. A., & Mikhailova, E. S. (2000). Visual illusions and travelling alpha waves produced by flicker at alpha frequency. International Journal of Psychophysiology, 39(1), 9-20.

Sierra, M., & Berrios, G. E. (2000). The Cambridge Depersonalisation Scale: a new instrument for the measurement of depersonalisation. Psychiatry research, 93(2), 153-164.

Sierra, M., Baker, D., Medford, N., & David, A. S. (2005). Unpacking the depersonalization syndrome: an exploratory factor analysis on the Cambridge Depersonalization Scale. Psychological medicine, 35(10), 1523-1532.

Siever, D., & Evans, J. (2007). Audio-visual entrainment: History, physiology, and clinical studies. Handbook of neurofeedback: Dynamics and clinical applications, 155-183.

Smit, D. J., Stam, C. J., Posthuma, D., Boomsma, D. I., & De Geus, E. J. (2008). Heritability of "small–world" networks in the brain: A graph theoretical analysis of resting–state EEG functional connectivity. Human brain mapping, 29(12), 1368-1378.

Spiegel, D., & Cardena, E. (1991). Disintegrated experience: The dissociative disorders revisited. Journal of abnormal psychology, 100(3), 366.

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). Manual for the state-trait anxiety inventory.

Spitzer, C., Spelsberg, B., Grabe, H. J., Mundt, B., & Freyberger, H. J. (1999). Dissociative experiences and psychopathology in conversion disorders. Journal of psychosomatic research, 46(3), 291-294.

Sprinkle, S. D., Lurie, D., Insko, S. L., Atkinson, G., Jones, G. L., Logan, A. R., & Bissada, N. N. (2002). Criterion validity, severity cut scores, and test-retest reliability of the Beck Depression Inventory-II in a university counseling center sample. Journal of counseling psychology, 49(3), 381.

Stam, C. J., Nolte, G., & Daffertshofer, A. (2007). Phase lag index: assessment of functional connectivity from multi channel EEG and MEG with diminished bias from common sources. Human brain mapping, 28(11), 1178-1193.

Tei, S., Faber, P. L., Lehmann, D., Tsujiuchi, T., Kumano, H., Pascual-Marqui, R. D., ... & Kochi, K. (2009). Meditators and non-meditators: EEG source imaging during resting. Brain topography, 22(3), 158-165.

Tononi, G. (2011). Integrated information theory of consciousness: an updated account. Archives italiennes de biologie, 150(2-3), 56-90.

Tononi, G., & Edelman, G. M. (2000). Schizophrenia and the mechanisms of conscious integration. Brain Research Reviews, 31(2), 391-400.

Vaitl, D., Birbaumer, N., Gruzelier, J., Jamieson, G. A., Kotchoubey, B., Kübler, A., ... & Strauch, I. (2013). Psychobiology of altered states of consciousness. Psychology of Consciousness: Theory, Research, and Practice, 1, 2-47.

Van der Molen, M. J., & Van der Molen, M. W. (2013). Reduced alpha and exaggerated theta power during the resting-state EEG in fragile X syndrome. Biological psychology, 92(2), 216-219.

Varela, F., Lachaux, J. P., Rodriguez, E., & Martinerie, J. (2001). The brainweb: phase synchronization and large-scale integration. Nature reviews neuroscience, 2(4), 229-239.

Vialatte, F. B., Maurice, M., Dauwels, J., & Cichocki, A. (2010). Steady-state visually evoked potentials: focus on essential paradigms and future perspectives. Progress in neurobiology, 90(4), 418-438.

Watts, D. J., & Strogatz, S. H. (1998). Collective dynamics of 'small-world'networks. nature, 393(6684), 440-442.

World Health Organization. (1992). The ICD-10 classification of mental and behavioural disorders: clinical descriptions and diagnostic guidelines.

APPENDICES

Appendix A: *Experimental Procedure*

1. 48hrs prior to attendance participant completes preliminary measures, and screening questionnaires
2. Participant attends laboratory (sessions start at 9am, 11.45am, 2.30pm)
3. EEG Cap Fitted
4. Dominant resting frequency in Alpha band is measured (5 mins)
5. Participant is given short demonstration of lamp effects to accustom them to the experience (2 mins)
6. Participant is counterbalanced into a 'control-condition-first' or 'experimental-condition-first' group. *For this example the participant is in the 'experimental-condition-first' group*
7. Experimental Trial 1 is initiated (5 mins)
8. Participant is given post-stimuli measures (approximately 10 mins)
9. Control Trial 1 is initiated (5 mins)
10. Participant is given post-stimuli measures (approximately 10 mins)
11. Experimental Trial 2 is initiated (5 mins)
12. Participant is given post-stimuli measures (approximately 10 mins)
13. Control Trial 2 is initiated (5 mins)
14. Participant is given post-stimuli measures (approximately 10 mins)
15. Experimental Trial 3 is initiated (5 mins)
16. Participant is given post-stimuli measures (approximately 10 mins)
17. Control Trial 3 is initiated (5 mins)
18. Participant is given post-stimuli measures (approximately 10 mins)
19. EEG Cap Removed
20. Short Interview with Participant (5 mins)
21. Participant Leaves

Appendix B: *EEG Preprocessing and Analysis*

EEG Preprocessing

EEG data was bandpass filtered between 0.1 and 60Hz and downsampled to 256Hz. Channels were visually plotted and obvious artifactual segments were manually removed. For each dataset Independent Component Analysis was used to identify artifactual components. This technique automatically identifies irregularly occurring signals within the data which can then be removed manually on inspection. The ADJUST plugin (Mognon et al, 2011) for EEGLab was used to automatically identify the worst offenders of these components (the ADJUST plugin identifies components based on spatial and temporal features which are common to artifactual data (Mognon et al, 2011)). All components suggested by ADJUST were automatically removed from the data for all participants. During recording, channels exhibiting high levels of noise were noted (per session), and following ICA the noted channels within these sessions were interpolated.

Each trial began with 30 seconds of recording before the stroboscopic stimulation was initiated. During this first 30 seconds, the lamp array produced a constant steady bright light with subtle flicker in the background. This period allowed participants to 'settle in' to the condition. Once 30 seconds had passed a trigger code was manually added to EEG data to signal onset of the strobe, and the strobe light was engaged. All files were trimmed to 300s from strobe onset and a baseline subtraction of -3000ms to -2000ms was applied to the entire epoch.

Power Spectra

The power spectral distribution across the entire epoch was calculated using the EEGlab *spectopo* function. This function transforms the data from the temporal domain to the frequency domain using a Fast Fourier Transform (0 - 60hz) it estimates relative power across frequencies, and is not sensitive to time. Power values were averaged for each participant-trial within the following frequency bands: delta (0.5 - 4hz), theta
(4 - 8hz), alpha (8 - 13hz), beta (13 - 25hz) and gamma (25 - 60hz). Relative power was calculated in dB, and was chosen as preferable to absolute power as relative power is more representative of inter-individual differences than absolute power and can be more accurately interpreted across subjects.

SSVEP Filter

Given that SSVEP's are known to be produced when individuals are presented with flickering stimuli, it was predicted that the relative power values at the stimulation frequency *F* (and harmonics of *F*) would be increased (above baseline) and this increase would be augmented in the experimental condition - due to the increased strength (luminance) of the stimuli in this condition.

A filter was designed which sought to normalise power values at a values surrounding *F* and harmonics of *F* based on a linear interpolation of values directly preceding and following a window of fixed size (1hz) around *F* (see Figure 5). Should there be large differences detected in the size of SSVEPs between control and experimental groups, this technique is useful as these differences can bias results. Thus the application of the filter can be used to see if the SSVEP has any effect on significant differences in relative power between the two groups. This could help to relate subjective effects as being correlated directly with the size of the SSVEP seen in the power spectrum.

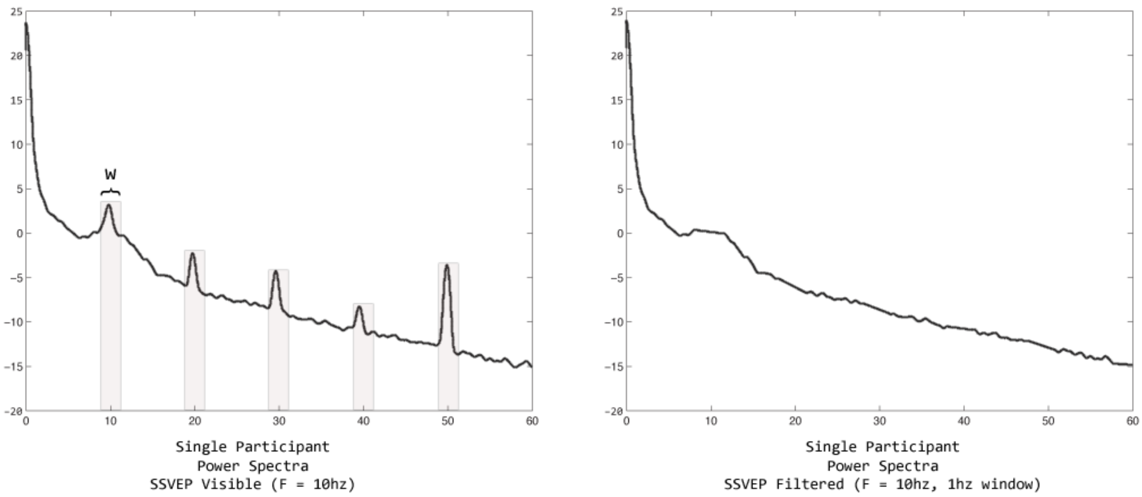


Figure 5: Example of SSVEP Filter Process. Single participant power spectra before (left) and after (right) the SSVEP filter is applied. Here the stimulation frequency (F) is 10hz and the filter window (w) is ±1hz.

Phase Lag Index

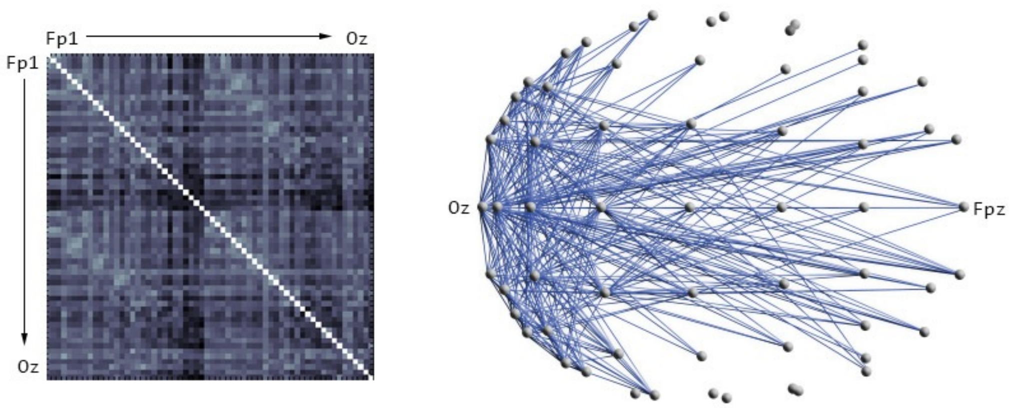
Functional connectivity between 61 electrode pairs (64 electrode montage, with M1, M2 and self-to-self connectivity values removed) was computed over time and calculated using the Phase Lag Index (PLI). PLI can be calculated for two electrodes x and y, using:

$$PLI_{xy} = \left| n^{-1} \sum_{t=1}^{n} sgn(imag(S_{xyt})) \right|$$

and was computed using Matlab code customised from Cohen (2014), (full instructions for computing PLI can be found in Stam et al., 2007 or Cohen, 2014). The Phase Lag Index is an accurate value of phase synchronisation between two zones, and it has been found to be robust to the influence of volume conduction between neighbouring sites (Stam et al, 2007). This is due to the fact that zero-lag synchronisation does not contribute to the final index. PLI ranges from 0 to 1, a PLI value of 1 indicates perfect phase synchronisation whereas 0 indicates no synchronisation. To compute the PLI, data was first epoched into 1000ms epochs and a value of PLI is computed for each electrode pair at 500ms intervals over the whole data set. Averages for Phase Lag were taken for each participant-trial-frequency band over all electrodes, and within 4 sub-groups of electrodes (Frontal, Central, Parietal-Occipital and Temporal) to identify regional differences in connectivity. (see Appendix 3).

Graph Theoretical Parameters

A subsequent step when analysing functional connectivity in a network, is to characterise the connectivity values as a graph, where electrodes represent nodes and the level of connectivity between nodes represent a functional path, or relationship. Graph theoretical parameters can be extracted from the network to describe the overall network architecture. The strength of the synchronisation between a pair - i.e. the closer the PLI value is to 1, the more it contributes to the network synchronisation overall. Thus, a sparse graph can be created by applying a threshold *t* to a the connectivity matrix, which effectively removes any weak connections (where PLI < *t)*. This is an effective way to only observe the strongest relationships in the network and make inferences about the network architecture. For this analysis, connectivity matrices were computed for each participant-trial-frequency band, and *t* was



Alpha Band
Experimental Condition
Weighted Adjacency Matrix

Alpha Band
Experimental Condition
Unweighted Graph

Figure 6: Example of network graph procedure. A connectivity matrix of Alpha Band PLI is shown on the left. This indicates strong connections in darker colours and weaker connections in lighter colors. A threshold *t* is applied to remove weak connections (here, *t* = mean) and the network diagram on the right can be drawn from it.

equal to the mean value of PLI across the entire matrix. Connectivity matrices were computed for each participant-trial-frequency band. This process can be seen in Figure 6.

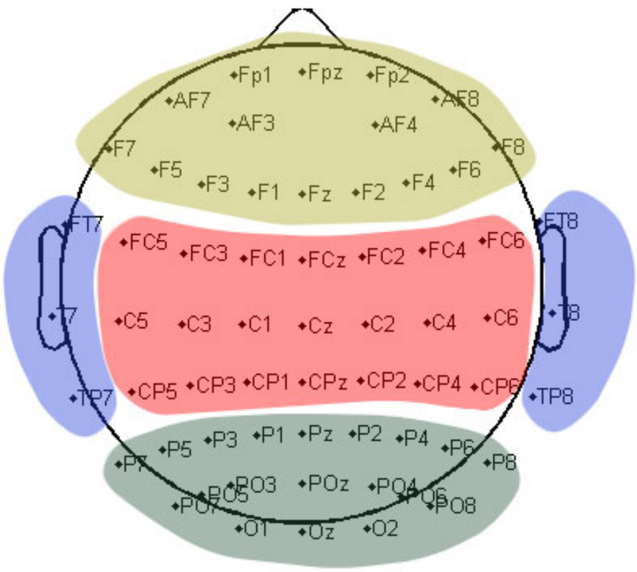
The next step is to extract parameters which describe the network. For this analysis we chose to look at values of the graph clustering coefficient *C*, average path length *L*, and σ the small-world parameter. *C* is a measure of clustering in the network. This is an indication of how differentiated the network is, i.e. how many independent pockets of synchronised activity exist. *L* is a measure of the average shortest path in the network. This is a value indicating the average number of steps to go from each vertex to each other vertex in the network. In a neural network this value could infer a measure of integration, or how much communication there is between disparate neural areas (Achard & Bullmore, 2007, Bassett & Bullmore, 2006). A low value of *L* would indicate high levels of information transfer between discrete neural regions. Finally σ is a measure of the overall efficiency of the network. It is derived from the relationship between values of *C* and *L* the graph in question, and values of *C* and *L* from a random, unordered graph. Higher values of σ describe a graph with short *L* and large *C*, which characterise a network as being highly integrated and highly differentiated - in essence, a more efficient network than would be expected by chance.

Values of *C* and *L* were calculated using functions from Brain Connectivity Toolbox for Matlab (Rubinov & Sporns, 2010), values of σ were calculated following the procedure from Smit et. al (2008). Detailed descriptions of the original methods used to calculate C, L and σ can be seen in Smit et.al (2008), or alternatively Molen et. al (2014).

Appendix C: *Electrode Regions*

Frontal		Central		Parietal-Occipital		Temporal	
1	Fp1	9	FC5′	22	P7′	13	T7
2	Fpz'	10	FC1'	23	P3'	17	T8'
3	Fp2'	11	FC2'	24	Pz'	57	FT7'
4	F7'	12	FC6'	25	P4'	58	FT8'
5	F3'	14	C3'	26	P8'	59	TP7'
6	Fz'	15	Cz'	27	POz'	60	TP8'
7	F4'	16	C4'	28	O1'		
8	F8'	18	CP5'	29	Oz'		
31	AF7'	19	CP1'	30	O2'		
32	AF3'	20	CP2'	49	P5'		
33	AF4'	21	CP6'	50	P1'		
34	AF8'	39	FC3'	51	P2'		
35	F5'	40	FCz'	52	P6'		
36	F1'	41	FC4'	53	PO5'		
37	F2'	42	C5'	54	PO3'		
38	F6'	43	C1'	55	PO4'		
		44	C2'	56	PO6'		
		45	C6'	61	PO7'		
		46	CP3'	62	PO8'		
		47	CPz'				
		48	CP4'				

Channel Montage



Appendix D: *Questionnaires and Question Grouping*

Questionnaires were administered via Qualtrics online questionnaire program. Thus, the pages overleaf are printouts from this software. As part of the study they would have been presented on screen in a more user friendly format.

Appendix E: *Photos of Lucia No. 3, taken from manufacturer website*

Appendix F: *Ethical Review Approval*

Submission History (ER/AW378/1) Help

Submission Date	Submitted To	Risk Rating (System)	Risk Rating (User)	Decision / Status	Reason(s) for Return
13-Jun-2014 14:41	Sciences & Technology C-REC (Richard de Visser)	High	High	Approved	
04-Jun-2014 20:33	Supervisor (Nick Medford)	High	High	Approved by supervisor	
02-Jun-2014 11:49	Supervisor (Nick Medford)	High	High	Returned for revision (by supervisor)	• Amendments required to the application
	Explanation of Return: Minor change in wording to information sheet required				
27-May-2014 08:48	Sciences & Technology C-REC (Richard de Visser)	High	High	Returned for Revision	• Amendments required to the application
	Explanation of Return: Your application has now been reviewed by CREC members. They identified some issues that would need to be addressed before approval could be given: 1] Please give greater attention to the (unlikely) possibility the strobing may induce a seizure, and consider the implication this may have for a participant's driving licence. These issues should be made more clear on the information sheet for participants so that they can make a fully informed decision. 2] In relation to the right of withdrawal and the alarm button, is there any chance the participant will be impaired to the point that they would be unable to press the button? (can CREC members assume that this is unlikely, as only likely in the event of loss of consciousness, which would not therefore go un-noticed) 3] Provide evidence that the researcher has a basic training in first aid (recovery position, etc.) 4] at item c15, specify that participants' eyes are to be closed during exposure to flicker stimuli (as in information sheet and recruitment email). 5] at item c19, it should be stated that the supervisor (who any upset people are free to see) has suitable qualifications. In this section, the wording "Any sensitive information participants mention in debriefing will not be recorded and treated confidentially." Should be changed to				

Appendix G : Consent Form, Information Sheet, Experimental Protocol