The not so resting mind:

Investigating Neural Activity associated with daydreaming using EEG

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Abstract

A recurring question since the times of classical psychology is concerned with how the human brain gives rise to a variety of experiences despite the lacking of sensory arousal (Antrobus, Singer & Greenberg, 1966). The current study sought to ascertain whether distinct brain activity could be observed across three different visual tasks (Visual, Day-dreaming & N-Back). Areas of interest included both a priori Brodmann areas (in light of previous literature) and post-hoc Brodmann areas – which primarily concern what this investigation found and how it fares with previous academic insight. Using source localization analysis via electroencephalography (EEG), distinct patterns of brain activity were observed across the three tasks. However, the major differences found were shown to be largely dependent on the cognitive-demand of the task – with the N-Back phase eliciting significantly more activity across the majority of Brodmann areas compared to the visual and day-dreaming tasks which, at points, demonstrated very similar patterns of brain activity. These results offer strength to some academic proposals as well as further questioning for others. Finally, these results are weighed in light of what contemporary academia currently proposes and may provide sound reasoning for more integrative measures to reliably assess instances of day-dreaming in a psychological setting.

Chapter 1

1.0 Opening

As members of society driven by efficacy, motivation and productivity, it may not be too difficult to appreciate why daydreaming is often met with a negative tone, although more recent findings appear to tell a different story (Mooneyham et al, 2013). Academic interest concerning such phenomena has overseen significant transitions over recent decades, each of which has arguably had an impact on the perceived importance and value of such research.

Academic interest in internally-produced thoughts has been effectively labeled as insignificant, since introspection as a concept was condemned by leading behaviorists (Singer et al, 1963), this statement alone encapsulated several decades of academic research, during which day-dreaming and internal mentation were viewed as minor, if not irrelevant altogether. Despite such conflictions however, daydreaming has been an exciting area for many who wish to attain a greater holistic understanding of human cognition. A fundamental time period for the initiation of day-dreaming research arguably took place during the emergence of psychophysics as a respective discipline. This period oversaw the first attempts to integrate mathematical and scientific principles to facets of human consciousness; and in doing so, allowed for the first objective and falsifiable insights into the science of human experience.

A major principle of psychophysical and sensory deprivation research highlighted how the working brain always seems to have some form of experience, whether these be images, fantasies or day-dreams (Antrobus et al, 1966). During the early period of psychophysics as an emerging discipline, William James outlined what he claimed to be the key characteristics of consciousness (James, 1892). James firstly acknowledges that all states are part of our personal consciousness. He goes on to argue that this is a permanent, yet forever changing process that is always interested in some particular feature or characteristic of an object to the exclusion of alternate potentials in the wider visual field. Concentrating on the empirical self, James argued that it is not simply a case of me or mine, but rather that the widest sense to understanding ‘the self’ entails acknowledging the necessary constituents, as well as the emotions they produce (self-feelings) and the actions to which they prompt (self-seeking and self-preservatory) (James, 2011). This proposal details the first attempt to explain consciousness as a stream of sensibly continuous thought (James, 2008) and helped demonstrate how the basis for obtaining knowledge can achieved directly through experience (Luding, 2010). This, we now know, is fundamental to human cognition, yet may well be equally important to lesser known areas of human cognition, such as day-dreaming.

1.1 Historical background to research on Day-dreaming

The nature of daydreaming as a phenomenon has been critically debated for several years, with many respective insights being suggested along the way. The understanding that such experiences are largely intuitive does not aid the establishment of a consensual definition (Klinger, 2009). Nonetheless, many agree daydreaming can be essentially defined as spontaneous brain activity often carried out in a unique stream of thought concerning past experiences, potential scenarios or prediction of future experience (Mueller, 1990).

In modern academia, much research has focused on how the mind wanders and the introspective elements of human cognition to see what this may tell us about daydreaming. Although there is ongoing deliberation as to how similar these states of mind are, most agree that daydreaming can be defined behaviorally, by failure to maintain a response to a given target; as it can subjectively, through self-reports following thought probes (Smallwood et al, 2008). These mental states therefore appear to share important qualities, as daydreaming processes generally follow lapses in attention, often detrimental to the task at hand. As a result, a greater understanding of how the mind wanders may be beneficial to future research on daydreaming.

The use of self-report probes has been particularly useful to early daydreaming research for a number a reasons. Primarily, due to a lack of alternative approaches being available to study daydreaming, self-report probes were particularly useful. Secondly, with little empirical information about how daydreaming occurs, having participants self-report their daydreaming experiences in real time provide many questions for further investigation. In more recent years advancements in technological methodologies have become the favored approach to study the daydreaming mind, although it has been argued that this is problematic also.

Smallwood and Schooler (2006) have rigorously discussed the issues of implementing empirical investigations into daydreaming. An important reason for the lack of systematic study in this field is the framing issue, in that the concept of daydreaming has been re-addressed through differing academic connotations and now refers to task unrelated thoughts, ideas and images, as well as stimulus independent thought and zoning out, which are arguably not reflective examples of daydreaming behavior. For example, if task unrelated thoughts occur as a result from decreasing correspondence between internal and external fields, there is reason to argue that daydreaming is a unique form of daydreaming as it is a structured process which holds a purpose, rather than a state which simply occurs during lapses of attention. This provides many further questions that science currently struggles to answer when attempting to distinguish these states of mind. As daydreaming is often so personal and private to the individual, explaining daydreaming in a scientific models has proved to be particularly difficult.

1.2 Potential onset of day-dreaming in childhood

Daydreaming is a fundamental element of human cognition, yet its origins in early life are still debated. Investigating children's steam of thought and what this may indicate about day-dreaming in childhood, Flavel, Flavel & Green (1993) sought to establish whether children steam of thought were at all reflective of an adults.After observing others, children aged 4 generally gave the view that an individual without any external engagement with their environment had an 'empty head', as they stated they also do in similar scenarios. This could point towards daydreaming not taking place in later childhood. On the other hand, it has been documented how the metarepresentation of the self usually occurs roughly at age 4 (Sabbagh & Callanan, 1998), which may help explain why children fail to understand the thoughts of others.

What is of interest however, is that the stream of conscious thought is often referred to as a unity of continuous experience (Dainton, 2006) yet in this unity there comes a time where this stream begins to amplify, and in doing so allows the individual to understand the introspective nature of their mind and other also. It is interesting to see that some children detailed their own individual experiences of doing nothing as if their mind were simply empty. Although logical reasoning would suggest this is not the case, it does call into scientific question, if not innate, where and when these respective criterions for internal consciousness develop? As evidence exists to propose those in early childhood lack the capacity for introspective awareness and metarepresentation of others.

More contemporary insight does not believe this to be the case however, suggesting the infant brain is able to daydream (Fransson et al, 2007). Although this is hard to demonstrate empirically, children often engage in fantasy-like play with imaginary companions (Gleason, 2002; Hoff, 2005; Root-Bernstein, 2014) which would suggest daydreaming is achievable during childhood. Research suggests children with imaginary friends are more likely to view themselves negatively (Hoff, 2005), as imaginary friends are objects of nurturance (Gleason, 2002), rather than conflict which can often be associated with human interaction. School teachers also agree that those who engage with imaginary figures are much less likely to be socially accepted and create these companions to compensate for poor social attachments (Gleason, 2004). Understanding that children engage in imaginary play to compensate for poor social interactions has led some to argue that this sort of creative engagement does not reflect the ability to daydream. Although these ideas are still contested, many agree that children do engage with daydreaming, as exemplified through fantasy play with imaginary friends.

1.3 Daydreaming, personal characteristics and experience

Some research has focused on whether day-dreaming may be related to general cognitive capacity or development. Henderson, Gold & McCord (1982) had four hundred and forty-nine children between ten and sixteen years separated into two groups based on their IQ (average IQ mean = 100.8; High IQ mean = 138.8) and complete an Imagine Processes Inventory, as well as Reactivity Curiosity Scale. Factor analysis showed that gifted individuals engaged in more constructive, positive-outcome daydreaming and showed higher curiosity factor scores. Average students were found to experience less constructive daydreaming in place of daydreams centered around guilty and fear. They also amounted lesser scores on the Curiosity Scale. Patterns were also established between grade level and the nature of daydreams experienced. Similar research from Henderson et al (1984) also found reason to believe IQ may be interrelated with daydreaming.

The impact of valance-specific stimuli and the experiences we have is another area which has been seen to have an impact on the nature of our daydreaming experiences. Supporting this, results following longitudinal research have demonstrated the relationship between frequency of exposure to violent/non-violent programs and the three categories of daydreaming in children. Valkenburg & Van Der Voort (1995) established positive-intense daydreaming to be largely encouraged through non-violent children programs. Similarly, aggressive-heroic daydreaming became more frequent after prolonged exposure violent programs, and was largely reduced after watching non-violent programs. This may suggest that daydreaming occurs as an internalized process reflective of an individual's view of their own position to the outside world. The idea that daydreaming can be manipulated by such factors is consistent with research which shows how daydreaming often revolves aroud current thoughts and concerns (Johannessen & Berntsen, 2010; Mar, Mason & Litvack, 2012).

In light of such findings, researchers examined the darker side of human impulse and behavior. Investigating death and daydreaming, eighty-three college students underwent the Beck Depression Inventory, Anger Rumination Scale and Beck Scale of Suicide Ideation. Data supported the two-way hypothesis proposed that increased levels of depression and violent daydreams accurately predict suicide risk (Selby et al, 2007). This may suggest that daydreaming content is, in some way at least, manipulated by what the individual is, or has previously been exposed to – suggesting individual experiences are a key variable in the content of day-dreams.

To further support this idea, L' Abate (1960), discovered among ninety-six pupils between nine and thirteen years (M:49, F:47), that proneness to anxiety impacts daydreaming.

In 2011, researchers found individuals were more likely to be found daydreaming when exposed to a stereotype threat. This was found in both sustained attention tasks and through a thought sampling approach (Mrazek et al 2011). In another experiment, students reporting greater levels of anxiety were caught daydreaming much more than calmer students. These students also reported greater levels of negative self-thought and were more likely to underestimate their task performance in post-task evaluations. These findings demonstrate the important role social factors can have on daydreaming. They also highlight how different feelings can alter the content and frequency of the daydreams we experience, which can be detrimental to task performance and emotional state.

L' Abate also argues sex to be another factor when investigating daydreams.

In a particularly unique study, Golding and Singer (1983) found psychological sex roles to have a greater impact on daydreaming than our biologically predisposed sex. These psychological sex roles had ominously contrasting meanings beyond males and females. This demonstrates that daydreaming can be influenced in ways which conflict with fundamental biological factors. Evidence showing sex-specific individuals experience daydreaming more resemblant to the opposite sex than their own highlights the potential significance of individual differences and wider lifestyle factors implicated in daydreaming. Such findings have led some to revise the potential of personality correlates and what they may offer daydreaming research; - this will be an interesting area of worthwhile research to future investigations of day-dreaming.

As daydreaming, in some cases, appears more motivated by social factors such as memories and experiences, rather than biological factors such as hormones and other neurobiological factors.

1.4 Day-dreaming and psychological well-being

It has been estimated up to half of human cognition has been found to arise in a stimulus independent manner (Baird et al, 2011), leading some to call daydreaming the occupation of the mind (Bagatell, 2008). Daydreaming has also been linked with lower levels of psychological well-being, with some arguing a wandering mind is an unhappy mind (Killingsworth & Gilbert, 2010), and somewhat resemblant of a thinking mind in depression (Smallwood et al, 2007). Using questionnaire methods, it has been suggested the connection between frequency of daydreaming and lower levels of psychological well-being can be wholly explained by individual differences centered on mindful awareness and encoding style (Stawarczyk et al, 2012). This may suggest that a wandering mind is not categorically an unhappy mind; in that frequency of task unrelated thoughts do not seem to have direct connections to unhappiness. Investigating the links between daydreaming and its negative impact on the individual, researchers have suggested that it is not necessarily the daydreaming process which bring psychological upset (Stawarczyk et al, 2012). Instead, they argue that the less aware and attentive minds are those most likely to catch themselves daydreaming negatively.

It is therefore being suggested that the more fleeting minds, less attentive to the present moment that have a greater tendency to fixate on internal mentation which, depending on context amongst other variables, can be detrimental to psychological well-being. Consistent with this claim, those found daydreaming more frequently were more likely to report being concerned about their worries (McVay et al, 2009). Daily life performance ratings were also impaired in those who daydream most. Similar research however tells a different story, participants were induced into either positive, negative or neutral moods before being given a sustained attention task. Daydreaming was characterized by rate of behavioral lapses and cases of retrospective subjective experience. Compared to the positive condition, negative participants displayed greater rates of daydreaming activity and a weaker ability to reengage with the task after lapses (Smallwood et al, 2009). These results comply with that has already been proposed, although may again call into question the direction of effects. That is, rather than the mind being unhappy because it is daydreaming, the mind may daydream more frequently because it is unhappy.

1.5 Research on Task-unrelated Thoughts and Attention.

Task unrelated thoughts refer to the action of thought being engaged in something independent of the current situation (Smallwood, Obonsawin & Heim 2003). Research on these thoughts may be relevant to understanding day-dreaming. It has been noted how daydreaming can often compromise task performance when our attention is not directly focused on the task at hand. Testing this, results show that daydreaming does compromise reaction times and increase error-rate (Smallwood et al, 2007). For example, vehicle users who daydream frequently were found more likely to be involved in traffic and road accidents (He et al, 2011). It has also been documented how tasks dependent on working memory appear to restrict the likelihood of daydreaming (reference). This has led researchers to consider how working memory may be implicated in daydreams, as it is much rarer to find ourselves daydreaming during a cognitively demanding situation. Some propose that daydreams are still likely to occur in these situations, but go unnoticed when not aided by working memory faculties. Levinson et al (2012) created an undemanding task and found participants daydreamed more frequently. They argue that propensity to daydream was largely increased as working memory was unnecessary for task completion, and was therefore facilitated increased rates of daydreaming instead. Understanding how cognitive demand is implicated may help explain why daydreaming takes place sporadically on a daily basis.

Smallwood et al (2004) investigated the issues of information encoding whilst maintaining internal thoughts or images over three experiments. The first two were concerned with mutually encoding words and non-words and the frequency of thoughts unrelated to the task; and the intensity of images retrieved from long-term memory and maintained whilst under dual task conditions. The third experiment assessed the physiological arousal via heart rate which accompanied daydreaming in semantic tasks. Data output indicated that internally-generated stimuli were largely disregarded, as a result of working memory processes appearing to override the capacity for internalised attention. Increased physiological activity was also establishing during higher rates of daydreaming.

This would therefore suggest that personal salience and the semantic faculties of working memory are two main factors which interfere with the formulation and maintenance of internal thought. It has also been shown that daydreaming during working memory tasks correlate with inability to retrieve information efficiently (Lowe & Obonsawin, 2003). This may suggest that rather than working memory faculties overriding simultaneous attempts of both internal and external engagement, the fact that one can only can be attended to at the expense of the others rejection may suggest a domain-specific network which undergoes shifts as a result of attentional focus.

Holistic theories of attention may too be of benefit to daydreaming research. Broadbent found that when participants were asked to recall the different numbers sounded in each ear respectively, that participants would always recall the number from a particular ear first – irrespective of whether this was the first ear to be presented with the number (Pizzamiglio et al 1974). These findings led to the idea of a filtering model being implicated in the processing of attention. Filtering models of attention may perhaps be useful to help understand why we daydream. The daydreaming experience often entails disengagement from the external world. Although the individual is still conscious of external on-goings, the filtering of this attention leads to a relocation of attentional focus, with the emphasis being placed on the contents of one's mind when not cognitive engagement is not externally required.

Generating insight into the basis of daydreaming and the relationship between endogenous and exogenous attention has been elementary for the progression of understanding the mechanisms implicated in daydreaming. Particularly an individual's ability to maintain executive control of own self-generated mentation through attention and working memory may be fundamental to understanding how day-dreaming occurs. Much evidence suggests attention to the outside world fluctuates considerably over time (Smallwood et al, 2008), which may demonstrate how day-dreaming is interlinked with attentional systems.

Further investigation highlighted the important interaction which exists between exogenous and endogenous attention during visual tasks and general vigilance (Berger et al, 2005); strengthening the notion that both exogenous and endogenous attention are intimately involved in day-dreaming processes. Exogenous attention has shown to increase perceptual sensitivity (Maclean et al, 2009) and be dominant in localising visual stimuli in binocular rivalry (Chong & Blake, 2006), with endogenous faculties being responsible for the prolonging and maintenance of binocular rivalry (Chong et al, 2005). Hopfinger and West (2006) have shown the initial stages of information processing to be largely exogenous-based, which may prove useful to understanding the onset of daydreams. These earlier stages appear to operate independently of endogenous involvement, which in later stages oversees high-order information processing. This may indicate that exogenous and endogenous components are discreet in how they allow the brain to process information. fMRI insight has highlighted how both endogenous (top-down) and exogenous (bottom-up) orientation brings about activity in key brain regions, namely the fronto-parietal network (Peelen et al 2004). Orienting of attention refers to the ability to allocate necessary cognitive resources at the correct moment, allowing for the optimization of behavior (Coull et al, 2000). This can be considered useful to daydreaming research as it appears failures in orienting attention affects the emergence of daydreams.

The general basis for attention and how it is implicated in day-dreaming has served as a reliable foundation for academic investigation and advancement within scientific approaches to day-dreaming - as we often experience daydreaming in situations whereby attentional faculties have no external engagement or requirement, just as the engagement of attention tasks consumes or suppresses much daydreaming activity.

Further investigation into the impact of working memory capacity on daydreaming has confirmed how working memory capacity moderates between daydreaming and cognitive demand. Daydreaming is at its lowest when working memory capacity and complexity of task are increased (Kane et al, 2007). Both laboratory and real life investigations have found higher rates of daydreaming to correspond with lower working memory capacity, as increased working memory generally accommodates lesser daydreaming - suggesting an individual’s ability to maintain executive control of self-generated mentation is fundamental to how daydreaming takes place. Concentrating on daydreaming more broadly, consistent results across several investigations proves particularly useful in establishing key factors such as working memory capacity, and how variance of such faculties brings about individual differences with regards to daydreaming experiences.

This research is particularly important to better our understanding of daydreaming and how respective elements of everyday cognition and attention are implicated in daydreaming. A greater understanding of how attentional systems impact daydreaming could be particularly useful to those with lower attention spans and working memory capacity in education (Smallwood et al, 2007).

1.6 Perceptually-decoupled thought

Perceptually-decoupled thought refers to the ability to disengage attention from perceptual information (Schooler et al, 2011). Rather than viewing daydreaming as a phenomenon concerning the acquisition of extended executive resources, McVay & Kane (2010) argue daydreaming results from failing cognitive control, in that a dualistic failure occurs when simultaneously exposed to both automatically occurring thoughts alongside environmental cues, which cannot be dealt with through cognitive control.

A situation in which we may experience perceptually decoupled thought is reading. Sometimes our eyes proceed to scan the sentence despite our attention being directed elsewhere. Smallwood (2011) states how in these situations ongoing perceptual information is often compromised in favor of internally generated thoughts. He argues how complex interactions take place when reading which results in perceptually-decoupled thought. Bottom-up processing concerns the words and sentences we read, as top-down processes produce a meaningful narrative to keep the reader engaged. It may therefore be argued that daydreaming in this context is the result of failure within endogenous attention. Analysis of eye movements show these movements vary considerably between reading and reading in a perceptually-decoupled state. Eye-movements proceeding self-caught daydreaming were particularly active and unpredictable (Reichle, 2010).

It may be of academic interest that physiological changes which accompany daydreaming states are observable. Particularly if it helps better understand how daydreaming takes place without our own inherent awareness. Increased skin conductance is another physiological marker which accompanies daydreaming (Smallwood et al, 2007). This is also consistent with idea of daydreaming often being focused on stress and negativity, as increased skin conductance regularly accompanies a stress response (Lin et al, 2013).

Meta-awareness findings show the mind only goes through time period intervals in which it is self-aware that daydreaming is taking place (Schooler et al, 2011). Investigating the importance of awareness to our own minds, researchers have shown that daydreaming in the lack of awareness corresponded with failure to efficiently supervise task performance. Participants were required to remember words and detect targets of either high or low probability. Low probability conditions found daydreaming to be coupled with absence of the influence of recollection at retrieval (Smallwood et al, 2007), suggesting daydreaming involves both decoupled attention and perception, and demonstrates the nature of meta-awareness when daydreaming. These results may highlight the role of endogenous attention during stimulus-independent thought. Although not all day-dreams necessarily seem to occur as an intentional process, awareness of the fact we are having such an experience would suggest endogenous attention is in some way involved. Investigating the neural basis of meta-awareness abilities, it has been proposed that meta-awareness accuracy is dissociable from performance of tasks, and varies between individuals (Fleming & Dolan, 2012). More specifically, reflecting on performance generally recruits rostral and dorsal activity within the lateral prefrontal cortex, with prospective judgments concerning the medial prefrontal cortex.

Evidence has also been found for default-mode network activity during perceptually decoupled thought. The default mode network corresponds to certain brain areas which display the greatest level of metabolic activity when at rest (Uddin et al 2009). Researchers found both prefrontal and posterior cingulate cortices demonstrated higher activity when; actions independent of perceptual input were faster and when actions based on perceptual input are slower. These findings may emphasize how intrinsic the default-mode network is to the daydreaming mind and human cognition; as the default network operates independent of sensory input or stimulation (Smallwood et al, 2013).

Baron et al (2011) used event-related potentials to investigate whether daydreaming originates from general distractions, issues concerning task-relevant processing or can be explained by the decoupling hypothesis. Increased rates of daydreaming were found with a reduction of cortical processing of task-relevant events and distractor stimuli. These findings are somewhat contrasting to the bulk of daydreaming research which often explains daydreaming in terms of executive attentional systems. This may indicate truth exists within perceptually-decoupled thought - as evidence has demonstrated that task unrelated thoughts restrict the efficacy with which sensory information can be attended to, and applied to the current task. Thus, perceptual decoupling research shows that mental events which spontaneously occur often interrupt one’s ability to encode sensory information.

Operating on the notion that internally produced thoughts arise from corresponding default-mode and fronto-parietal control networks, researchers discuss how the top-down control system is fundamental to conscious experience, hence why its activity is coupled with default-network activity (Smallwood et al, 2012). Conflict between internal and external thoughts arises due to the limited capacity of the top-down control system however, which gives reason as to why day-dreaming is associated with a state of perceptual decoupling. Additional evidence to support the idea of a limited capacity within both visual and top-down control systems (Desimone &

Duncan, 1995; Pessoa et al, 2003; Olivers & Humphreys, 2002) can be seen to demonstrate why day-dreaming may often occur in the perceptually-decoupled mind.

Moreover, pupil diameter analysis has also been shown to support the idea of decoupling during cognitive activity. Throughout offline periods (no external engagement), pupil diameter exhibits spontaneous activity decoupled for task events (Smallwood et al, 2011). Furthermore, intervals of external engagement were characterized by significant task-evoked variances in pupil diameter, with failures in information encoding following high spontaneous pupil diameter activity. In addition to this, higher spontaneous pupil diameter took place prior to only 20% of correct answers given, indicating that spontaneous pupil activity corresponds with distinct forms of cognitive function. These findings also seem to support the decoupling hypothesis; in that observation of pupil diameter serves as a physiological basis which takes place during cognitive difficulties concerning the attending of domain-specific information to the exclusion of the secondary domain.

Essentially it would seem daydreaming results from a fundamental breakdown in which theprocessing of external information is compromised by the attended of internal thoughts, which as a result, neglects the attendance of stimuli in the external environment (Smallwood, Frisahman & Scholer, 2007).

1.7 The neuroscience of day-dreaming

Over more recent years neuroscience has had an important job in aiding contemporary knowledge of daydreaming. A major contribution is widely accepted to be establishing the default mode network, a set of midline and cortical brain regions that serve as interacting systems fundamental to internal mentation and introspection (Andrews-Hanna, 2012), which are most active when the brain is at rest (Greicius et al 2009; Mars et al, 2012; Korgaonkar et al, 2014). The default-mode network is made up of several important brain areas which seem particularly important to daydreaming processes. The midline temporal lobe subsystem is more active when generating mental scenes from memory (Andrews-Hanna et al, 2010), whilst the medial prefrontal subsystem allows for flexible use of this information (Buckner et al, 2008). These two respective processes may be considered to be fundamental to day-dreaming, as they document how the brain retrieves mental imagery from previous experiences or memories, and implements these into uniquely flowing internalized thought processes.

Using judgment making tasks on positive vs negative stimuli, researchers have confirmed the dorsal and ventral medial prefrontal cortices operate independently during attention demanding and self-referential tasks (Gusnard et al, 2001). These brain regions could therefore be intimately linked with other brain areas which aid the facilitation of daydreaming. Processes concerning self-reference showed correspondence with increased dorsal medial prefrontal activity, whilst decreased ventral medial prefrontal activity supported the notion that these complex attention-orientated processes inhibit emotional processing.

The medial prefrontal cortex does appear to be multi-faceted however, with it also being largely involved in the processing of negative emotional stimuli (Etkin et al, 2011). The same has also been demonstrated with nonhumans, in that this regional activity is strongly linked to stressors (Amat et al, 2005) and can bring about regulation of hypothalamic-pituitary-adrenal response to such stimuli (Viau & Meaney, 1993). Evidence to suggest the medial prefrontal cortex is implicated in both day-dreaming and the processing of unpleasant emotional stimuli may offer insight into why the daydreaming mind is often regarded as an unhappy mind in academic research.

Assembling data from primate and human studies, researchers propose functional interactions between the posterior medial pre-frontal cortex and lateral pre-frontal cortex facilitate regulatory processes allowing for adjustments in performance, and are thus fundamental to cognitive control (Ridderinkhof et al, 2004). This evidence seems to propose that respective areas of the medial prefrontal cortices are imperative to cognitive control, despite the knowledge similar regions also display peaked activity during resting phases. This arguably exemplifies the complexity of the interconnected structures which make up the resting network, alongside how a lack of cognitive control is implicated in day-dreaming – as both mental processes appear to depend on the same brain mechanisms. Moreover, evidence from post-traumatic stress disorders highlights the inverse relationship that exists between the amygdala and ventral medial prefrontal cortex (Hampton et al, 2006). In that responsiveness of amygdala output neurons decrease as medial prefrontal activity increases (Quirk et al, 2003). What was more surprising to find was that like the amygdala, damage to the ventromedial prefrontal cortex also reduced risk of post-traumatic stress disorder onset (Koenigs & Grafman, 2009).This would therefore seem to support the notion that respective components comprising the medial prefrontal cortex are instrumental in aiding a sentient, cognitive continuum which allows for day-dreaming to occur.

Mitchell et al (2005) found activation in the dorsal medial prefrontal cortex to be far greater when thinking of others rather than objects, which may suggest that dorsal regions of the medial prefrontal cortex are particularly vital to the social and cognitive aspects of daydreaming. What's more, ventral regions of the medial prefrontal cortex were found to actively correlate in light of how similar the person being thought was to the individual (Mitchell et al, 2005). In other words, ventral medial prefrontal regions become more active when the individual in thought is considered to share more commonalities with the thinker. These results provide some indication of how self-reference is implicated in inferring mental states of others. This research may be particularly useful for future advancements concerning the brain activity involved in self-referential thoughts compared to others, and how such activity may contribute to issues such as stereotyping and discrimination in wider society and across cultures.

The role of the posterior cingulate cortex in the default network has received much attention. The major connections highlighted between the posterior cingulate cortex and default mode network have led to the assumption that the posterior cingulate cortex is an important brain region for daydreaming (Greicius et al, 2003). Leech et al (2011) used fMRI to show the posterior cingulate cortex undergoing minor deactivation during increasingly difficult tasks. Following this, Leech et al (2012) argue interactions between the dorsal posterior cingulate cortex and fronto-parietal networks demonstrate how the posterior cingulate cortex is fundamental to regulating the balance between internally and externally focused cognition. However, in light of findings to suggest the posterior cingulate cortex is heterogeneous and responsible for the maintenance of attentional focus (Mesulam et al, 2001), it has been suggested the dorsal posterior cingulate cortex attends to attentional focus through tuning whole-brain metastability (Leech & Sharp, 2014). This may therefore indicate that day-dreaming processes are facilitated by harmonious synchronization of multiple brain regions; despite trending regions that show significantly enhanced activity when day-dreaming takes place.

Dual-regression analysis of functional activity highlights distinctions between ventral and dorsal regions of the posterior cingulate cortex. The ventral posterior cingulate cortex demonstrated lessening interaction within the default mode network and smaller anti-correlation within the cognitive control network as task difficulty progressed, the dorsal posterior cingulate cortex on the other hand did the opposite. Evidence therefore points towards a strong connection between the dorsal posterior cingulate cortex and cognitive control networks, which is fundamental to the resourceful allocation of attention (Leech et al, 2011). It may therefore be proposed that the unsuccessful transmission of information between such areas is in some way responsible for diminished attention allocation, which in turn increases the propensity of day-dreaming.

Neuroscientific insight has played an important role in identifying what are now known to be key brain regions imperative to daydreaming. Moreover, scientific research has also allowed for a greater understanding of the respective roles of such brain regions. In doing so, researchers have ascertained a greater idea of how respective brain regions interact with each other to allow for meaningful yet spontaneous daydreaming processes.

1.8 Executive control and day-dreaming: key brain systems and regions

Although operating on somewhat contrasting wavelengths, the decoupling hypothesis may be considered somewhat similar to executive control theories of daydreaming. Despite differing epistemological stances, a fundamental similarity between the two concerns the notion that, in some form or another, the inability to efficiently attend to domain-specific information ultimately encourages the potential of finding oneself daydreaming.

Research into executive functioning may also provide a worthwhile insight into the brain states associated with day dreaming. Executive functioning involves the ability to postulate ideas and give consideration to responses, as opposed to responses through impulsiveness (Diamond & Lee, 2011). Although much research demonstrates how attentional lapses often precede daydreaming phases, descriptions of executive functioning, which are dependent on attentional focus, appear somewhat descriptive of the daydreaming experience.

Nevertheless Smallwood and Schooler (2006) propose how difficulties defining executive control are problematic for cognitive approaches to daydreaming. They argue how contemporary views of executive control view intent as a required characteristic of executive functioning. Reber and Reber (2001) however propose that executive functioning in itself, suggests self-initiated, goal-directed and self-aware processes. Thus, defining the executive systems involved in states of thought which, in their own nature, occur without any intent or even awareness, appears to create a particular anomaly in daydreaming research. Furthermore, executive functioning as a psychological term has been applied to various models such as working memory

(Baddeley, 1992; Gathercole & Baddeley, 2014), problem solving frameworks (Rose et al, 2011) and self-regulatory behaviors (Zhou et al, 2012; Hofman, Schmeichel & Baddeley 2012) to name a few. The use of this term across academic schools of thought does not aid the establishment of an agreed definition as to what constitutes executive functioning, especially within day-dreaming research.

Nevertheless, neuroimaging and neuroelectical investigation has achieved evidence to locate the brain areas that are active and just as importantly inactive during daydreaming experiences. Converging evidence now places particular emphasis on the multifaceted nature of day-dreams and how such processes are intrinsically linked with executive control systems when regulating internal thought (Andrews-Hanna et al, 2014).

Executive functioning can be considered useful to understanding daydreaming as executive functioning may be implicated in the development and decline of cognitive potential over the life-span. Developmental studies of executive functioning are therefore considered a reliable mode of research (Best & Miller, 2010). Developmental approaches to executive functioning can arguably be summarized by the cognitive complexity and control theory; the proposal that executive functioning can be best understood through age-related increases of maximum cognitive capacity (Zalazo et al, 2003). In particular, reflective awareness of our own understandings is important in using this information to give further guidance, which is facilitated through the developing brain (Zelazo & Frye, 1997).

The functional connectivity of the brain becomes much more integrated in these early years with the growth of dendrites and synaptic connections (Huttenlocher, 1990) which aid the advancement higher-level cognition and independent thought. With this in mind however, fMRI has given evidence to suggest the functional network in infants to be structured to support perception-action tasks (Fransonn et a0.l, 2011). The architectural differences between the adult and infant functional networks perhaps reflect the importance of the physical brain in executive functioning and internal thought. This could may also comply with previous research which found a lack of internalization to generally occur within children; in that they sometimes self-report a blank mind when not externally engaged.

Developmental models of executive functioning in childhood focus on four respective, yet inter-related executive dimensions; attentional control, cognitive flexibility, goal setting and information processing (Anderson, 2002). The key components of executive functioning are apparent from preschool age (Blair et al, 2005), with later developments of this preschool period resulting from developing attention, and integration of executive functioning components (Garon et al, 2008).

Research has focused on analyzing the behaviors relating to executive functioning and attention in children with poor working memory. Low working memory was found to correspond with increased cognitive difficulties and distractibility, as well as problems monitoring current progress were found to exacerbate tasks concerning problem solving and working around issues (Gathercole et al, 2008). It is understood that complications within working memory restrict the child’s ability to sustain attention, compromising the amount of information they are able to retain. Complications within working memory subsystems would appear to exacerbate the processes concerned with the acquisition of introspective knowledge. In turn, these deficiencies arguably polarise developmental progress which has further implication for the controlling of executive functioning in later life.

Research would seem to suggest issues within executive functioning may affect how the individual experiences day-dreams, perhaps more so when we consider the strong associations that exist between executive functions and day-dreaming processes (McVay & Kane, 2012). More recently however, adaptive training focusing on children with poor working memory has overseen significant improvement in the capacity and sustainability of working memory (Holmes et al., 2009). If failures in early working memory are in part responsible for later issues concerning wider executive functioning, such data will be empirical to the formulation of new approaches to combat lower levels of working memory in early childhood. In order to avert increased achievement gaps in later life (Diamond & Lee, 2011). These early years are particularly important for the development of inhibition and cognitive flexibility (Davidson et al., 2006).

It is said the execution of cognitive control serves to inhibit unwanted stimuli, whether these are emotions, memories or tasks (Aron, 2007). On this pretense, it could perhaps be argued that cognitive control could be placed on the opposing end of an attentional spectrum, with day-dreaming being placed on the other side – as cognitive control seems to serve as a means to reject the emergence on such spontaneous thoughts. Particularly if these thoughts are likely to consist of negative themes. However, day-dreaming has also been coupled with positive experiences too. So, if we stay true to the notion of cognitive control as previously mentioned, this would seem to suggest cognitive control encourages the emergence of positive spontaneous thoughts, with the rejection of the negative, yet the vast majority of insight concludes a daydreaming to be an unhappy mind. This may be seen to exemplify some of the issues faced with attributing solid, objective concepts to spontaneous processes which can even take place without individual awareness. Right hemisphere regions including the middle and inferior frontal gyri, frontal limbic area, anterior insula and inferior parietal lobe have been found to be particularly active during inhibitory control (Garavan et al, 1999).

Again however, the prefrontal cortices appear dominant in cognitive control (Miller, 2000). The medial frontal cortex is concerned with performance monitoring, relative to social and cognitive processes (Amodio & Frith, 2006), with lateral and orbitofrontal components of the prefrontal cortex tending to appropriate adjustments in the external environment (Ridderkhof et al., 2004). Neuroscientifically speaking, it is understood the medial frontal cortex is also implicated within the default-mode network during subjective self-reports and independent behavioral measures (Christoff et al., 2009). By this logic, it can be argued, as well as demonstrated, that the development and involvement of executive function is fundamental to daydreaming processes. Although some may be more hesitant to accept such a claim, evidence to show how several major brain regions are fundamental to both executive functioning and daydreaming gives good reason to accept such a claim in good faith. In addition, the notion of prefrontal cortices being responsible for such a range of fluctuating functions can arguably be made clear through the understanding that this cortex takes over twenty years to reach full maturity (Diamond, 2002). It is this developmental process which enables the attainment of increasingly complex abilities as we develop (Kolb et al, 2012). Uniquely, neurons are known to develop in the prefrontal cortex prior to birth (Mrzljak, Uylings, Kostovic & van Eden, 1988), which would appear to stress the importance of frontal network activity in early-life cognition, and for later development of executive functions. Evidence has also illustrated how the developing prefrontal cortex is susceptible to an array of both pre and postnatal factors (Kolb et al, 2012). This, coupled with the understanding that the prefrontal cortex is fundamental to day-dreaming, may give reason as to how individual differences within day-dreams can be so contrasting.

New scientific evidence to suggest the infant brain is structured to support perception-action tasks may help explain why children struggle with the ability of contemplating what is in another's mind – in that they often detail what they perceive. This is consistent with children's creative ability to conjure imaginary friends and fantasies – as these are primarily dependent on specific sensory inputs (visual), which neuroimaging insight has proposed is reflected in the architecture of the developing brain. A greater understanding of the physical structure of the brain, alongside factors such as working memory capacity, are important in determining how day-dreams take place. These factors also provide a reason as to why distinctions exist between how daydreaming may be experienced between children and adults.

Although we can objectively accept that both executive functioning and the default-mode network are implicated in daydreaming experiences – recent reexamination has proposed daydreaming to be an outcome resulting from the synchronisation of both executive functions and the default-mode network (Christoff et al, 2009). Establishing an objective insight to show that both these network systems are implicated with internalised mentation has also given further substance to contemporary explanations of daydreaming. Further examples of using both executive and default networks may be used to make sense of why daydreaming is primarily concerned with current issues, as well as the understanding that such processes are largely goal-orientated; or at least have some form of desired outcome. This would appear consistent with the notion that executive brain regions are also implicated in the default-mode network and resting brain states. Moreover, understanding how daydreaming often compromises task performance also demonstrates how executive functioning resources are likely to be recruited when daydreaming occurs.

Although key brain areas for daydreaming are reasonably clear in contemporary research, an important question concerns the aetiological source of such process. In other words, the debate as to whether daydreaming is the outcome of stimulus orientated or stimulus independent thought (Gilbert et al, 2005).

Research seems to suggest that day-dreaming experiences appear to occur in various ways which may demonstrate that more than one answer is required to offer a holistic explanation when explaining the aetiological basis of such processes. However, this may also reinforce the idea that daydreaming can take place in respective domain-specific networks, corresponding with attentional focus between environmental factors and internalized mentation.

Thus, in light of the fact that specific brain areas are now know to be responsible for daydreaming (Mason et al, 2007). A key debate still remains as to whether default-mode network activity follows stimulus orientated, rather than stimulus independent thought (Burgess et al, 2007). This debate has encapsulated what is known as the gateway theory: the hypothesis that the rostral prefrontal cortex aids a cognitive mechanism which, to some degree, allows for the attending of one field (environment v self-generated) to the exclusion of the other, and vice versa (Burgess et al, 2007). If true, evidence to support the idea a domain-specific network being responsible for both internal and external attentional projections may be seen to demonstrate the importance of researching both domains respectively in order to achieve a more enhanced, holistic perspective of the nature of day-dreaming (Gilbert et al, 2007).

Academic investigation has supported the view of the medial rostral prefrontal cortex being important for domain-specific thought (Burgess et al, 2007), supporting social and nonsocial functioning (Gilbert et al, 2007). Evidence has also been put forward for the role of the lateral rostral prefrontal cortex being activated by a switch, between stimulus-orientated and stimulus-independent thought (Gilbert et al, 2005). Activity in the rostral prefrontal cortex has also been well documented in the resting brain, as posterior cingulate and ventral anterior cingulate cortices display considerable inverse correlations in light of the cognitive demands of the current task (Greicius et al, 2003). Indicating activity in this network may be regulated by cognitive demand Moreover, combining diffusion tensor imaging with fMRI, rostral prefrontal regions have been found to be largely interconnected with key brain networks which are known to faciliate the brain when resting, such as the posterior cingulate cortex and retrosplenial cortex (Greicius et al, 2009).

Evidence would appear to lead to the assumption that the rostral prefrontal cortex is particularly important in the switch of attention between self-generated, and that in the greater visual field. Rostral prefrontal activity has also been attributed to fundamental cognitive capacities such as prospective memory (Burgess et al, 2007). Investigating this, Brodmann area 10 was observed during respective memory tasks in differing conditions. Both medial and lateral rostral regions showed lower regional cerebral blood flow during more engaging tasks than the more simple tasks. In addition to this, a lack of correlational data between reaction time and regional cerebral blood flow led to the rejection of rostral regions being responsible for functioning prospective memory. From this however, the researchers proposed respective medial and lateral roles. They hypothesize the medial region to be implicated with the disregarding of internally-generated thought and the lateral rostral areas to maintain to this engagement (Burgess et al, 2003).

Further research is consistent, suggesting an antagonistic relationship is apparent between activity in the lateral and medial regions of the anterior prefrontal cortex (Simons et al, 2006).

This is also consistent with the gateway hypothesis, as it promotes the idea of the anterior cingulate cortex biases between internal thought and environmental stimuli (Burgess et al 2007). This may suggest that although experienced to be independent of each other, in that we cannot allocate attention to respective domains simultaneously, a commonality concerning these domains exist in the neuronal basis of the lateral and medial anterior cingulate cortices as both appear to be facilitated through them same neuronal network.

Evidence also suggests medial and anterior cingulate cortices operate through multi-faceted means arguably provided greater area for investigating other potential functions that arise from these networks.

This may also give reason as to why medial prefrontal cortices are a common occurrence in day-dreaming research, as they appear responsible for the distribution of both organized and more spontaneous thoughts. Reynolds et al (2009) investigated whether prospective memory primarily concerns sustaining strategic monitoring or alternatively transient-based processes, such as memory retrieval and what this may tell us about daydreaming.

Prospective memory was found to be mainly associated with sustained responses in the anterior cingulate network (lateral Brodmann area 10). In addition, sustained responses were also distinguishable when working memory was required. Sustained attention in the anterior prefrontal cortex was found to correlate with response times.   This may suggest that day-dreaming is dependent on different types of memory faculties to allow for high-order cognition whereby nothing is unimaginable. This can also be supported through the knowledge that both anterior cingulate and anterior prefrontal cortices are important in day-dreaming (Schooler et al, 2011; Burgess et al, 2007).

It is generally argued that prefrontal networks offer bias signals to extended brain structures and pathways which involve mapping between inputs, internal states and outputs necessary to complete current tasks (Miller & Cohen, 2001). The scientific examination of working memory is majorly associated with lateral frontal cortex activity (Owen & Evans, 1996). This has been demonstrated to be case that in both spatial and non-spatial working memory processing (Owen et al, 1998). Similarly lateral parietal activity has also been found important to episodic memory retrieval (Wagner et al, 2005; Cabeza et al 2008). Further support for this claim can be found in brain injury cases whereby lateral parietal damage disrupts components of episodic memory (Davidson et al, 2003). Conversely, mentalising tasks appear to operate primarily in medial prefrontal regions (Frith & Frith, 2006). The understanding that mentalising tasks recruit medial prefrontal activity, as well as such regions being implicated in the bias signals which occur in the primary stages of cognition would confirm these regions being fundamental to spontaneous thought processes. Furthermore, evidence to suggest how lateral parietal damage interferes with episodic memory would also lead to this region being implicated with day-dreaming and the default-mode network (Hassabis et al, 2007).

Taking into account this seemingly distributive nature of the prefrontal cortex to other brain regions, researchers sought to explain the functional specialisation of the rostral prefrontal cortex that may have some bearing on daydreaming. Meta-analysis of one hundred and four neuroimaging studies found functional variation along the rostral-caudal axis. Studies concerning mentalising produced generally caudal activations, with multiple-task co-ordination yielding more rostral activation (Gilbert et al 2006). Investigating the role of the rostrolateral prefrontal cortex in delaying execution of intended behaviours, research shows rostrolateral activity during these periods (Gilbert, 2011). Moreover, the intended cue for action, as well as intended behavior could be established through distinct posterior brain activity, although no such information could be extracted from the rostrolateral prefrontal cortex. Intentional storage of information showed progressed activity between rostrolateral cortices and various other brain areas, depending on the type of information being maintained. This may suggest the rostrolateral prefrontal cortex may allow for awareness of delayed intentions through its interconnectivity with posterior brain regions, which allows for fundamental abilities such as working memory (Sarnthein et al, 1998) and memory retrieval (Ciaramelli et al, 2008). This again could be seen to emphasise rostrolateral activity in both the intentional maintenance of particular information, as well as aiding the emergence of thought processes which are not necessarily created through intentional means – suggesting this domain-specific network attends to both intentional and spontaneous thoughts respectively. This may also call into question the involvement of the rostrolateral areas when we find ourselves day-dreaming without initial realization. Evidence for the rostral-caudal axis being majorly implicated within the mentalising of such processes would also lead to the assumption of caudal activity being particularly important in day-dreams when they concern the self or others – which is often the case (Lombardo et al, 2010).

Investigating whether rostrolateral areas operate in a domain-specific manner or alternatively via a dorsal-ventral gradient; fMRI data was obtained to assess semantic and visualspatial variations during matching tasks, in an attempt to establish the fundamental nature of rostrolateral regions. The left rostrolateral prefrontal cortex showed a considerable overlap of activity between semantic and visuospatial tasks – supporting the idea of this area being active in both engaged and resting brain states. Moreover, unique activity was found between tasks engaging with the necessary areas based on the mental representation being formed. With this in mind, researchers proposed that respective rostrolateral neurons may have specific access to certain mental engagements, based on their anatomical contributions along the dorsal-ventral gradient, allowing for their involvement across a variety mental processes including day-dreaming. Further insight suggests the left rostrolateral prefrontal cortex is particularly vital in the integration of distinct mental operations which are fundamental to higher-level cognition in humans (Bunge et al, 2009) – it would be logical to assume day-dreaming falls in to such a category.

fMRI investigation was undertaken to assess whether participants can demonstrate improved regulation of fMRI signals in rostrolateral regions through shifting attention towards and away from internal thoughts. Before training, meta-cognitive awareness showed the acquisition of prefrontal sub-regions, involving rostrolateral and medial prefrontal cortices. After training, regulatory improvements were found only in the rostrolateral prefrontal cortex, with no other differences being observed in any frontal, midline or parietal cortical areas (McCaig et al, 2011). These results can be seen to demonstrate the control one can obtain over important prefrontal regions implicated in various thought processes, and the impact such control can have over these thoughts as experienced by the individual.

Thus in summary, key brain regions linked to executive functions that may be also involved in day-dreaming are the posterior cingulate and anterior cingulate cortices, medial frontal cortex and rostral prefrontal cortex as well as extended regions within the prefrontal lobes. Taking all of this into account arguably leaves insufficient room to contest the proposition that executive functioning and day-dreaming processes are dependent on the same cortical structures in order to take place.

1.9 Meditation and daydreaming

Objective evidence to assess the claim that activity in key brain regions underlies attentional and motivational faculties potentially relevant to day-dreaming may be aided by neuropsychological studies of meditation, as cognitive event-related potentials suggest practice in meditation manipulates attention allocation (Cahn & Polich, 2006). Meditation is largely conceptualised as complex emotional and attention regulatory training (Lutz, Slagter et al, 2008) constantly focusing on the present, as opposed to daydreaming which is not cemented to the present, despite often concerning current issues. If we accept that daydreaming is, to some degree at least, partially characterized by task unrelated thoughts and decreased attention allocation, perhaps academic insight into meditation can be of benefit to understanding the neuronal implications of day-dreaming. Especially when we consider attention and self-awareness to be the primary concern of such practices (Raffone & Srivasan, 2010). Mindfulness meditation, a branch of the meditative practice centered primarily on the promotion of internalized cognition has been associated with significant increases in signal projections among dorsolateral prefrontal and parietal cortices, temporal lobe, pregenual anterior cingulate cortex, hippocampus, parahippocampus and striatum (Lazar et al, 2000). This may suggest various brain regions being dependent on some form of improved coherent synchronization in order to achieve higher levels of introspective awareness. Correlational data also gives reason to suggest meditators with over ten years of practice can demonstrate more consistent and flexible use of dorsolateral prefrontal areas (Baron-Short et al, 2010), regions majorly implicated in cognitive control and self-monitoring - evidence to suggest a connective link exists between time spent engaging in thought-orientated practice and the ability to regulate specific brain activity at increased levels.

Short-term mindfulness has been met with decreased self-reported levels of stress, anxiety, fatigue and depression, whilst proving beneficial to attentional abilities (Tang et al, 2007). This evidence may prove consistent with the notion that a wandering mind is an unhappy mind, as evidence points towards lower levels of negativity in those with enhanced attentional faculties. In addition to this, understanding the attentional implications of these techniques may also be enhanced by investigating the respective roles of endogenous and exogenous attention in meditative practice. Exogenous attention appears to dictate vigilance when exposed to stimuli without expectance (Maclean et al, 2009). With this being the case, it would seem meditative practice is particularly useful in inhibiting such cues so as to avoid distraction. EEG methodologies have also observed alpha blocking in advanced meditators (Lo et al, 2003). This may suggest that ability to ignore exogenous cues could correlate with meditative practice. Such findings may also be seen to comply the neuroscientific proposal that both types of attention are facilitated by the same neuronal network. In that, voluntary, sustained attentional faculties (endogenous) can, in meditative contexts at least, dictate the spontaneous and unexpected attentional processes (exogenous) to the extent of their nonexistence. This would seem to imply that endogenous attention is particularly important to meditative practice and more so that both types of attention share cohesions despite apparent distinctions also.

To add further substance, the cortical thickness of twenty individuals with considerable knowledge and experience of meditation were investigated. Compared to controls, cortical thickness was most pronounced within areas of the brain such as the posterior cortex and right anterior insula (Lazar et al, 2005) which are known to be involved in attention, sensory perception and other aspects of social-cognitive processing (Amodio & Frith, 2006). Other brain areas implicated in cognitive control and self-monitoring, primarily the dorsolateral prefrontal cortex also show extensively stronger connectivity to other brain regions in advanced meditators (Brewer et al, 2011).

In all, research on brain activity during meditation is consistent with the conclusion that neuroplasticity can occur within the brain as a result of prolonged meditative practice (Davidson & Lurz, 2000; Treadway & Lazar, 2010; Widdett, 2014). Thus, if maintaining a fundamentally clear focus on internalized activity can lead to physical changes in brain structures involved with such abilities, does this suggest the enhanced attentional networks of the meditator experience task unrelated thoughts or general lapses of attentional focus less frequently? Although the more phenomenological aspects of daydreaming cannot be so objectively accounted for, research shows the default network of experienced meditators shows higher levels of synchronous activity than non-meditators, particularly in posterior cingulate and medial prefrontal cortices (Jang et al, 2011). Within meditative contexts these can be generally referred to as tuning out the distractions, neuroscience however shows much more than this - in that brain regions can be stimulated to the degree of physical neuroplasticity, resulting in lower potential for the mind to wander into day-dreams. In fact, neuroplasticity of the default-mode network is just one example of the physical changes observed in advanced meditators. Advanced meditators display greater gray matter density in lower brain stem regions (Vestergaard-Poulsen et al, 2009), increased gyrification (Luders et al, 2012) and increased myelin and axonal density (Hadlich & Sandberg, 2013). Multi-tasking is also found to be much more achievable in meditators, who show higher abilities of tackling simultaneous tasks, less distractibility and increased focus (University of Washington, 2012), ensuring less frequent shifts of attention. This may be perceived as an additional merit to the benefits of mindfulness-based techniques, although it may be more logical to argue that multi-tasking becomes easier for meditators. As increased gyrification, myelin and axonal density undoubtedly empower the efficacy of neuronal transmission.

Although this may not directly answer questions concerning the preceding attentional lapses of the default-mode network and following daydreaming in all individuals; it does demonstrate that practice in internalized attention and state of mind can, over time, manipulate the physical basis of the brains anatomy. These studies offer real world examples of endogenous attention, diminished daydreaming and altered neuroplasticity. More to the point, , if we observe meditative practice as a technique of controlling daydreaming, the benefits and potential of harnessing daydreaming has arguably, to a degree, been demonstrated by meditative studies. Thus, meditative insight may be somewhat useful, in that it characterizes a falsifiable insight into how experiences and intentionality can alter brain connectivity, which may be important in achieving a more holistic concept of how daydreaming tendencies can be controlled through the intentional allocation of internalized attention.

1.10 Neurotransmitters and day-dreaming

Great deals of research have helped identify the brain areas most active when daydreaming. Generating an insight into how neurotransmitters are implicated in such processes may prove a more difficult task. The ventral tegmental area projects dopamine to several brain areas including the cingulate cortex and frontal cortices via the mesocortical pathways (Lewis & O’Donnell, 2000), which are both responsible for executive functioning. Understanding how these areas are responsible for executive functioning may explain why they commonly appear in daydreaming research. The mesolimbic pathways are responsible for transferring dopamine from the ventral tegmental area to brain areas responsible for emotional processing such as the nucleus accumbens to the limbic system (Isaacson, 1982). Research showing significant dopaminergic pathway involvement in both emotional (Jones et al, 2010) and executive functioning brain regions (Miyake et al 2000) may indicate towards dopamine being intrinsic to daydreaming processes. Disorders resulting from abnormal activity in these pathways include schizophrenia (Laviolette, 2007; Howes & Kapur, 2009) and attention-deficit hyperactivity disorder (ADHD) (Vallone et al, 2000; Sonuga-Barke, 2005), both of which entail abnormal thoughts and perceptions that may result from an initial daydreaming phase.

The tuberoinfundibular pathway may be important to how we daydream and process internal thought. This dopaminergic pathway transmits dopamine to the pituitary gland through the hypothalamus (Pivonello et al, 2007). Neuroscientific insight has shown how the role of the tuberoinfundibular pathway involves mediating the volume of hormones released in the human system (Wagner et al, 1994). This pathway would therefore appear especially important to how we experience day-dreams, as the integration of additional hormones is dependent upon the level of dopamine registered when passing through this pathway. Abnormal tuberoinfundibular pathway activity is majorly linked with schizophrenic-based disorders (Risch, 1995), which arguably demonstrates its importance in aiding healthy cognitive cycles. We may therefore propose current dopamine levels could also impact the form and context in which day-dreaming processes take place – as dopamine is shown to be strongly implicated with motivational, emotional, attentional and cognitive faculties (Nieoullon, 2002; Nieoullon & Coquerel, 2003; Phillips et al, 2008; Gold et al, 2014). It would appear logical to argue evidence points towards strong dopaminergic involvement in day-dreaming processes. The role of dopamine has also been attributed to cognitive control of behavior (Cools, 2008). Research into the role of dopamine has ascertained insight, to some extent at least, to demonstrate how the majority of key psychological factors (motivation, emotion, attention and cognitive control) are in some way implicated with this particular neurotransmitter.

In a rare case study, Schupak and Rosenthal (2009) followed a patient with a long history of disproportionally frequent daydreams to the point of distress. No other psychological or clinical issues were reported with this patient, and numerous approaches had been taken to try disrupt the rate of daydreaming. The use of fluvoxamine therapy was found to be most helpful in allowing the patient to control their daydreams. Understanding fluvoxamine operates as a specific serotonin reuptake inhibitor (SSRI) (Grimsley & Jann, 1992) may therefore demonstrate the involvement of respective neurochemical systems in the brain. Fluvoxamine has most commonly been used to help treat and prevent recurrences in depression (Gatti et al 1996; Terra et al 1998). It is of particular interest that this therapy was found to be most successful. Particularly when considering the scope of research drawing resemblances between the negative mind and the daydreaming mind. This can also be seen to demonstrate the importance of specific neurotransmitters being regulated throughout the brain and wider central nervous system, as well as the impact they have on how directed and spontaneous thought processes take form. In sum, evidence indicates toward day-dreaming not only arising from coherent synchronization across brain regions, but also the neurotransmitters within the brain that too appear to be heavily involved.

1.11 Review of neuroscience methods for studying daydreaming issues

It is well understood that the breakthroughs and discoveries of daydreaming over recent decades are largely in the debt of neuroimaging methodologies for their unrivaled contributions. This does not mean however that such methodological approaches are appropriately best matched for researching daydreaming. Granted, this vast sum of academic knowledge has undoubtedly had some form of neuroimaging input, yet this does not mean limitations do not exist in neuroscientific approaches to research. For example, neuroimaging method such as PET and fMRI are usually concerned with secondary metabolic changes rather than primary outputs such as neuronal activity, which is the source for EEG research. fMRI does provide a strong advantage with precise spatial resolution, single trial-BOLD responses have been established efficiently at a 500 x 500 μm^2 in plane and 250ms temporal solution (Pfeuffer, van de Mortele et al, 2002). Then again, this is often compromised by neuroimaging dependence of BOLD response (D'Esposito et al, 2003). Unlike EEG which receives neuronal electrical activity over the space of milliseconds. In addition, researchers compared local field potentials to single and multi-unit spiking activity with highly spatio-temporally resolved blood-oxygen-level –dependent (BOLD) response. Analysis indicates that local field potentials provide a better estimate of BOLD than multi-unit response (Legothetis et al, 2001). When considering the limitations of neuroimaging methods in neuroscience, haemodynamic signals have also been scrutinized. Haemodynamic signals underlying brain imaging methodologies such as fMRI operate on the notion that metabolic demand as a result of neuronal activity corresponds with increases in haemodynamic signals, effectively suggested an isomorphic relationship exists between the two. However, dual-wavelength optical imaging methods have discovered two respective components of haemodynamic signal in the primary visual cortex of alert animals (Sirotin & Das, 2009).The first is the more predictable signal ascertained from the neuronal responses of visual output. The second however operates independently of both sensory inputs and neuronal predictors of haemodynamics. In addition, although neuronal activity, haemodynamics and fMRI signals are assumed to be related, how they are exactly still remains unclear (Heeger & Ress, 2002). More to the point however, haemodynamic signals are assessed to attain indirect activity of the brain via cerebral blood flow, not neuronal activity (Malonek et al, 1997). Thus, although neuroimaging has been fundamental to the evolving body of literature in contemporary academia, recent investigations have brought about questions that have probed the foundational assumptions upon which such methods are implemented. Taking this into consideration may lead to a revised account of the credibility of neuroimaging insight, as well as the usefulness of alternative neuroscientific methods.

Electroencephalography (EEG) is a methodological tool often used in in medical and clinical practice to observe the spontaneous electrical activity exhibiting from various cortical structures. EEG has previously been defined as the electrical activity recorded from the surface of the scalp via necessarily positioned electrodes (Teplan, 2002). EEG signals are largely the result of postsynaptic ionic currents from actively synchronized pyramidial cortical neurons (Babiloni et al, 2009). Electroencephalographic research has offered further clues to the nature of brain activity during daydreaming. EEG evidence suggests alpha-band (8-12 Hz) and beta-band (12-32 Hz) activity correspond with spontaneous mental processes, with gamma frequency activity (33-45 Hz) being present during both wakefulness and REM sleep (Tang et al, 2012). Like neuroimaging methods, EEG also operates in a non-invasive manner, mapping brain activity of cortical areas (Zhang et al, 2003). The basis of this method makes it particularly useful for objectively assessing disorders of consciousness (Boccagni et al, 2011), especially when the aetiological basis of the disorder is also unknown (Kaplan, 2004).EEG findings have also contributed to advancing knowledge in this field. EEG research has offered insight into a unique midline theta rhythm (Fmθ) located in the frontal midline region that becomes more engaged during mental tasks (Ryouhei et al, 1999). Leading to the hypothesis that emergence of Fmθ during successive psychological tasks reflects the shifts of activity between medial prefrontal and anterior cingulate cortices (Asada et al 1999). The high spatial resolution offered by EEG (Davidson et al, 2007), makes it a suitable methodological tool for the analysis of varying brain rhythms over visual tasks and would therefore seem particularly appropriate for the current investigation. Additionally, it seems electroencephalography is a particularly reliable method of recording neuronal firing rates using source localization. This will be particularly useful for investigating both a priori and newer regions of interest which appear to correspond to day-dreaming behaviors.

1.12 Summary of the evidence on day-dreaming

Convering evidence leads to the assumption that day-dreaming experiences are ultimately facilitated by the default-mode network in the brain, which exhibits peak activity when the mind is at rest. The involvement of brain regions which are also involved in executive functioning has been important in making sense of the nature of day-dreams, offering insight into why such seemingly spontaneous thought processes can often be concerned with issues currently significant to the individual. The understanding that day-dreaming processes are often extended from current issues has been beneficial in developing a greater understanding of the wider brain regions which may be in some way connected to the default-mode network. Moreover, converging research to demonstrate how stimulus-independent thought is often goal-orientated may be seen to provide a behavioral basis as to how brain regions implicated with executive functioning are also important to day-dreaming. Research into disorders within executive functioning can arguably be seen to demonstrate how fundamental key executive functions, such as working memory, also serve to aid and facilitate day-dreaming experiences too. Similarly, amounting research is also bringing to light the spectrum of idiographic factors and individual differences which too appear implicated within how day-dreams are experienced by the individual.

This too is vital to the progression of day-dreaming research, not only to ascertain a strong comprehension of the neuropsychological systems which facilitate daydreaming, but to attain a more holistic conception of how experiences, memories and psychological well-being are as imperative to how day-dreams are experienced as the brain structures are which give rise to them.

1.13 The key issues yet to explore

Numerous studies have focused on day-dreaming through thought-probe tasks whereby researchers wait to observe an individual drifting of before they get back their attention and ask them to detail what they thought (Lindquist et al, 2011). This has been beneficial in understanding what day-dreaming often entails but can arguably only offer so much. This investigation seeks to implement a contemporary approach to assess the pattern and frequency of brain activity corresponding to visual tasks which vary in terms of required cognitive engagement. One phase requires the observation of simply emerging and disappearing shapes, the second phase a fixed interval during which day-dreaming is expected to occur – and finally a working memory phase. This has been devised in an attempt to observe brain activity corresponding to three different mental states, which may allow for better comparisons and contrasts within future analysis.

With this being said, Brodmann areas (BA) 23 and 31 may be particularly insightful as they include brain areas such as the posterior cingulate and precuneus, regions heavily implicated in stimulus-independent thought (Mason et al, 2007; Vann, Aggleton & Maguire, 2009), with BA 23 being especially associated with the formation and retrieval of memories (Salimpoor et al, 2010). Similarly, ventral and dorsal regions of the medial prefrontal cortex correspond to BA's 6, 8 and 9 (Schupak et al, 2009) which have also heavily implicated in past day-dreaming research (Barron et al, 2011; Passingham et al, 2010). BA 10 corresponds to the rostral prefrontal cortex (Burgess et al, 2007; Gilbert et al, 2006), the brain region responsible for the gateway hypothesis (Burgess, 2006). This too will be a fundamental area of investigation to assess any evidence of day-dreaming behaviour. BA 17 corresponds to the primary visual cortex and has been shown to be consistent with primary visual processing (Amunts et al, 2000). This will therefore be a key area also, due this experiment focusing on the day-dreams experienced as a result of a visual task. BA 9 which covers the dorsolateral prefrontal cortices (Macdonald, Cohen, Stenger & Carter, 2000) has also been shown to be strongly implicated within attentional faculties (Macdonald et al, 2000; Bidet-Caulet et al, 2014), and may therefore be of academic importance during this investigation, in light of the vast research which has attributed daydreaming to compromised attentional systems (Smallwood et al, 2008; McVay et al, 2010). The experimental (H1) hypothesis for this investigation predicts that distinct brain activity will be observable across the three respective tasks which make up the procedure. The null (H0) hypothesis suggests that no observable differences will be found.

Chapter 2

Method

2.1 Sample

The participants for this study consisted of an opportunity sample of twelve students (2 left handed; 10 right handed with a mean age of 21) from the University of Gloucestershire, some of which had recently graduated. Each participant was asked if they had a pre-existing psychological or neurological issue and each confirmed that they did not. Participants were recruited through opportunity sampling.

2.2 Development and Pilot

As the mechanics of this study were centred on analysis of EEG data during differing levels of brain activity, it was necessary to consider the practical elements of each phase of the procedure.

In the early stages of developing the experiment, a key question was what would appear on the slides – first for the visual task and later for the N-Back task. As each participant would be asked to recall whether something which appeared during the visual task had reappeared during the N-Back phase, it was necessary to have something which was easily recognisable and would not require significant cognitive exertion. As some words and colours can be considered to have valance attached to them (Arnell et al, 2004), it was considered that shapes would be appropriate content for the slides and would provide the necessary engagement (or otherwise) during each phase.

A pilot was conducted using one participant who was unaware of the precise nature of the study. It was intended as a method by which to test the period of time the participant spent engaging with each of the three tasks, the material contained within each task and the EEG readings generated during each task. It was decided, for example, that in order to increase the likelihood of observing activity in relation to cognitive activity as opposed to visual processing, the samples received during the N-Back stage of the procedure were not extracted until 500ms after stimulus. Further, a small alteration to the pilot was considered necessary. During the pilot, the shapes displayed on the relevant slides were all two dimensional. It was decided upon reflection that, given the participant would be taking part in the study for a not inconsiderable amount of time (the pilot lasted 25 minutes in total) further variety was needed in order to both minimise the possibility of predictability on the slides and to maintain an appropriate level of cognitive functioning. As such, the experiment itself was altered to include three dimensional shapes.

2.3 Design

This study used a within-participants design. The independent variable within this study was the nature of the task participants were asked to do. This generated three conditions:

1) A ‘daydreaming’ condition in which participants looked at a screen (as shown in Figure 2) for 60 second intervals. This condition was interweaved with,
2) A ‘visual’ condition, where participants would passively look at blocks of six slides (like that in Figure 1). Each slide was presented for one second. The daydreaming and visual conditions were followed by,

3) An N-back condition. A sequence of 24 slides (such as that in Figure 3) was presented and participants were required to indicate whether any shapes on the current slide were the same as those in the, ‘slide-before-last.’ Each slide remained on screen until the participant had responded.

The dependent variable within this study was the levels of brain activity across Brodmann areas in the brain measured using EEG and source localization techniques described in detail below.

2.4 Apparatus and Stimuli

Participants were presented with visual displays of random shapes in differing colours emerging in a 3x3 grid (figure 1) in groups of six (1 visual display per second) prior to a fixed interval of one minute during which the 3x3 grid remained but no objects were displayed. Some slides contained many of the same shapes, with a few consisting of all the same shapes. The variety of these slides served only to keep the participant mildly engaged during the initial stages of the investigation to ensure an efficient EEG reading of brain activity whilst participants’ brains were neither at rest nor cognitively engaged. The first slide, used for the visual task, was intended as promotion for visual engagement ie: the participant would be processing the recognisable shapes as they appeared but without the need for intensive processing. The second slide had no shapes on it whatsoever. It was intended that the participant would not have cognitive engagement and therefore increase the likelihood of daydreaming. The third slide related to the N-Back task. The intention behind this was the participant’s ability to recall recognisable shapes which had previously appeared in slide one. This required more engagement of cognitive faculties and utilising a degree of working memory (Kane, Conway, Miura & Colflesh, 2007).

A follow-up questionnaire (Appendix 2) was also used to allow for comparisons between self-report data and source localisation output. For example, the second question – "…were there any occasions where you caught your mind wandering without intending it to?" - was intended to provide a marker by which to compare the participant's answer with the source localisation output at specific points during the procedure. By way of illustration, for instance, the reporting from the second question can be compared to brain activity during the period in which the participant was looking at the slide with no shapes on it.

Brain activity was recorded with an Electrical Geodesics Incorporated™ (EGI) EEG apparatus which consisted of 128-channel HydroCel Geodesic Sensor Net(s) (with a reference/vertex [Cz] sen- sor) connected to a wall-mounted NetAmps™ amplifier. The dense geodesic array of the net (Figure 2) optimizes accurate recording. The 128 high-impedance electrodes with sponge inserts (with HydroCel saline electrolyte) include eye-blink and eye-movement sensors. The signals from the 128 sensors were sent to a Macintosh computer running Netstation™ software for obtaining, assessing, and navigating the data. Additional source localization was performed using the GeoSource 2.0™ software that has received both U.S. Food and Drug Administration and European Medical Device Directive clearance (http://www.egi.com/home/385-geosource-fda).

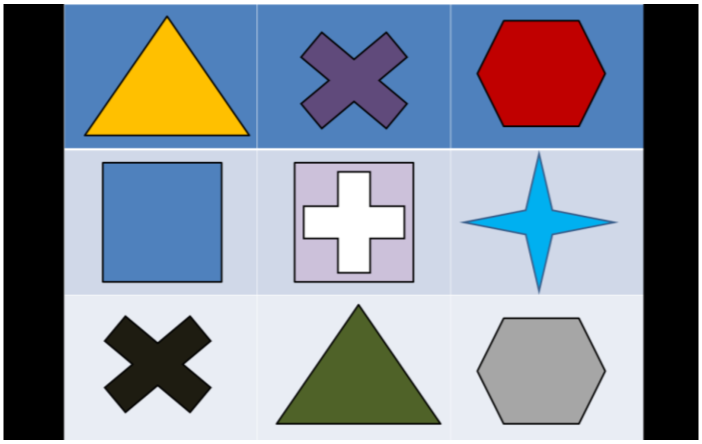

Figure 1 - Example of slide in visual task containing 9 random shapes in the 3x3 grid

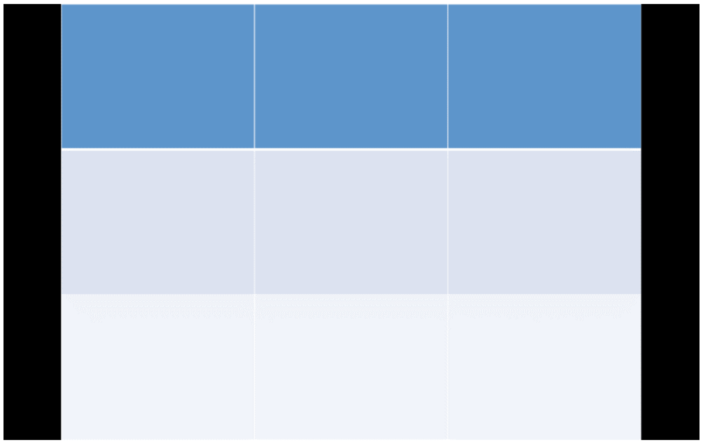

Figure 2: *Example of slide in day-dreaming task displaying an empty 3x3 grid*

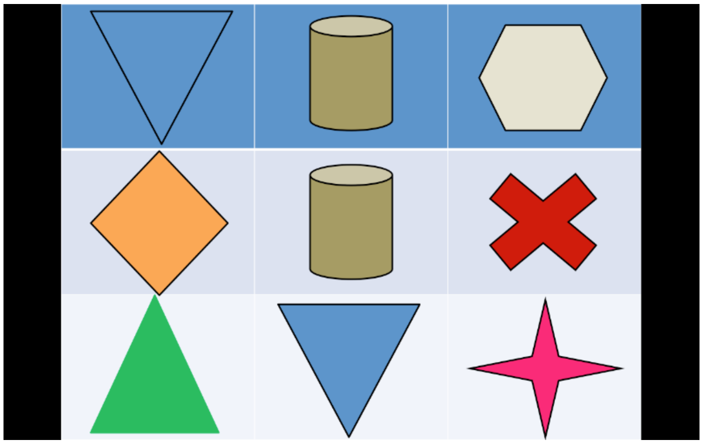

Figure 3: Example of slide in N-Back phase whereby participants had to answer whether the current slide contains any shapes also present in the slide shown at Figure 1.

2.5 Procedure

Participants arrived in the EEG lab and were presented with the consent form (Appendix 1) explaining the course of the investigation after which they were given an opportunity to ask any questions they may have. If consent was given, necessary skull measurements were taken and the appropriate-sized EEG net fitted. The EEG cap was fitted in accordance with the measurements taken of the nasion, inion and pre-auricular clefts, with the central reference electrode covering the pre-marked area on the centre of the scalp. Basic instructions of the experiment were presented to participants on a PC screen via E-prime™ software, the experiment in E-prime was navigated via the PC keyboard. Scalp impedances were attuned to below 100 kΩ. The experimental procedure took place in a darkened room with two practice trials taking place before experimental trials began.

Whilst seated, the participants were advised to minimise body and head movements, as well as frequent blinking or jaw clenching to ensure an efficient EEG reading as possible. The 3x3 grid slides were presented in series of six (1 per second) after which there was an interval of one minute during which no additional visual stimuli was presented, leaving a blank screen. The elongation of simplistic tasks have been demonstrated to bring about higher rates of task-unrelated thoughts (Grodsky & Giambra, 1990). With this in mind, this process took place 10 times in order to maximise the probability of more prominent fluctuations between attending internal and external domains. This first part of the task served to document the brain activity corresponding with the visual emergence of simple shapes. This also served as an initial means to keep the participant mildly engaged, in that their attention was essential but no real cognitive faculties required. The second part of the experiment however was much more dependent on working memory systems. Participants were instructed that similar to the first phase, nine random objects will fill a 3x3 grid, this time however, participants had to press left arrow (correct) or right arrow (incorrect) based upon whether the current slide contained any of the shapes that also appeared in the slide two previous to the current slide. With this being the case, there was no correct answers for the two initial slides. No interval periods were present during this part of the experiment, a one second delay however took place between the choosing of the arrows and the onset of the next visual slide. Assembling these respective stages of this investigation served as a means to observe brain activity in three different states: during exposure to emerging shapes (visual phase), during rest when no shapes were present (daydreaming phase), and during a visual task (visual phase) which required enhanced cognitive engagement. Accuracy feedback and reaction time were not a fundamental area of analysis, although necessary connections were made when either seemed to be connected with mind wandering thoughts.

After this task participants were given a question sheet compromised of five questions (Appendix 2) concerning the presence or frequency of any daydreaming experiences they had during the investigation, as well as how often they themselves think, or find themselves daydreaming. An additional question sought to ascertain whether any common themes were present within these thought processes, such as family, the self, or solely the past or potential future. This was followed by the debrief form (Appendix 3), which outlined the true aim of the investigation.

2.5.1 Source Localisation and Brodmann areas

Brain activity in this investigation was mapped via source localisation with standardised low-resolution electrical tomography (sLORETA) algorithm. This methodological approach best allow for brain activity to be assessed in terms of Brodmann areas, which are beneficial to understanding the circuitry and networks underlying brain function (Amunts, Schliecher & Zilles, 2007).

Key Brodmann areas of interest as stated in the introduction will include BAs 23 and 31 (posterior cingulate and precuneus regions), BAs 6, 8 and 9 which have commonly emerged in previous-dreaming research. BA 10 is central to the gateway hypothesis and will therefore be another key area of interest.

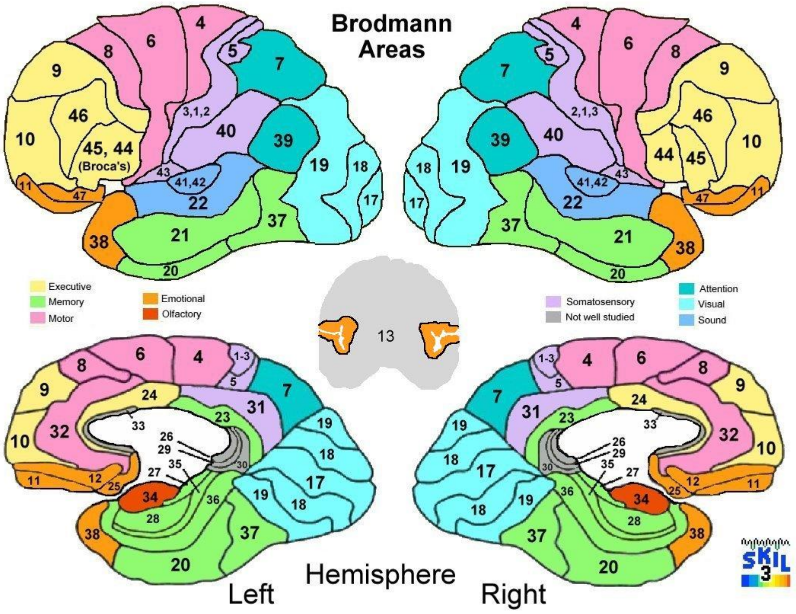

Figure 4- Illustration of the locations of Brodmann areas

2.6 EEG recording and source localization methods

The 128-channel apparatus (Figure 6) and Netstation software were used. EEG was recorded at a 1000 Hz sampling rate. Raw data obtained from the scalp was processed by the software in these individual procedures: Filtering (notch filter was fixed at 50 Hz in order to eradicate U.K mains noise), epochs were divided as necessary in accordance with the events that outlined the course of the procedure (onset and offset of visual stimulus, fixed intervals, etc), poor channel (electrode) alternatives (switching of data received from flawed channels with interpolated data received from adjoining channels), automatic artifact identification (detection of the segments and channels corresponding to natural processes including bodily movement blinking of the eyes, etc), ocular artifact exclusion (ejection of electrodes responsible for the movement and blinking of the eyes so as to ensure no data segments were skewed, this was performed in accordance with an eye-blink frequency of 14mV/ms, implementing respective algorithms for both movement and blinking of the eyes in accordance with the eye movement correction procedure; Gratton, Coles & Donchin, 1983; EGI, 2006), poor segments or channels overwritten by artifact detection, additional poor channel replacement after this process, establishing averages and average re-adjustments (via Polar Average Reference Effect (PARE) correction alongside spherical spline interpolation in order to predict a zero reference value for the brain), as well as baseline correction to confirm brain activity prior to stimulus onset. Following this, obtained data was explored and examined via Geo-Source 2.0 software (EGI, 2011) with the use of necessary calculations as a means to localise regions of brain activity in order to map them in accordance to BA's. The major calculations were achieved through source localisation on the GeoSource 2.0 software.

This entailed a forward head model (conjectures concerning transmission between scalp electrodes and dipoles/ source localisation) as well as an inverse solution (best approximation for sources as a result of measured scalp activity). Geosource 2.0 provides a dense dipole set to characterise common cortical distances as proposed by Montreal Neurological Institute MRI data (EGI, 2011).

The inverse solution employed the minimum norm least squares inverse method, a procedure of particular use for establishing the sources of EEG data as obtained from the scalp. This does have a bias however in favour of the weaker or trivial sources, thus sLORETA was implemented to regulate amplitude (current density) for the more profound and superficial sources, respectively (Pasqual-Marqui, 2002). Additionally, distortion from small noise variations was eradicated using the Tikonov (1x 10 and -2) regularisation strategy. From this, the standing data serves as an estimation of the sources of brain activity (with amplitude being mirrored in the standardised current density estimates). Both left and right hemisphere BA's and the hippocampus (total of 90 regions) were mapped via the statistical extraction tool in Geosource 2.0 software, this software was also used to establishing the mean amplitudes of activity (mean standardised density estimates) in these regions throughout respective stages of the procedure. The forward head model for source localisation however employed the Sun-Stok four-shell sphere model characterising cerebrospinal fluid, skull, brain and scalp; a particularly popular approach when concerning computational efficacy (Michel et al, 2004).

Only estimations can be achieved through source localisation algorithms, however sLOTERA is a more advanced algorithm compared to those previous, including LORETA (Pascual-Marqui, 2002), having no localisation error in noise-free simulations (Michel et al, 2004; Sekihara, Sahani & Nagarajan, 2005) and performs more efficiently in conditions of noise (Abe, Ogawa, Nittono & Hori, 2008), ensuring these signals are largely independent from each other (Wagner, Fuchs & Kastner, 2004). Added support can be proposed from the union of intracranial EEG and sLORETA solutions for scalp EEG in the establishment of epileptogenic zones (Ramatani et al, 2013; Stern et al, 2009). Further merits for EEG alongside sLORETA includes the accumulation of MRI and positron emission tomography data, allowing for additional source analysis of brain regions including the hippocampus (Maillard et al, 2009; Ramatani et al 2013). Using sLORETA it is also achievable to localise brain regions implicated in visual-perceptual and cognitive processing (Schendan & Lucia, 2010) such as the anterior cingulate cortex (Herrmann, Römmler, Ehlis, Heidrich & Fallgatter, 2004) and other frontal regions (Cao & Slobounov, 2010; Ocklenburg, Güntürkün & Beste, 2012) majorly associated with stimulus-independent thought and day-dreaming (Bar, Aminoff, Mason & Fenske, 2007; Mason et al, 2007; Smallwood et al, 2008; Barron et al, 2011). This being said, electroencephalographic methodologies would appear most suited for localising the brain regions and Brodmann areas most intimately linked with day-dreaming.

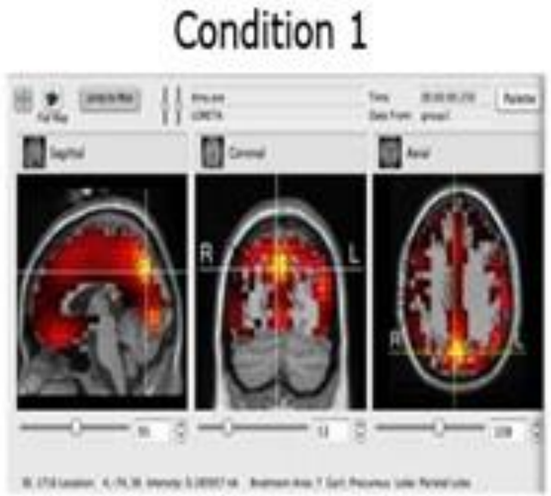

Figure 5: Example of brain activity in MRI during the daydreaming task

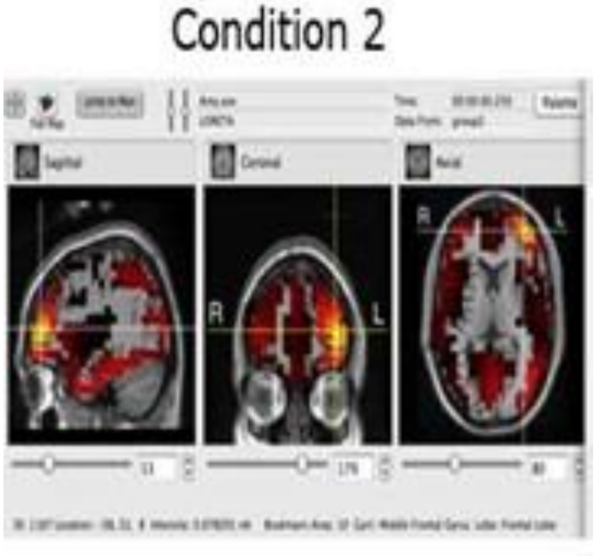

Figure 6: Example of brain activity in MRI during the visual task

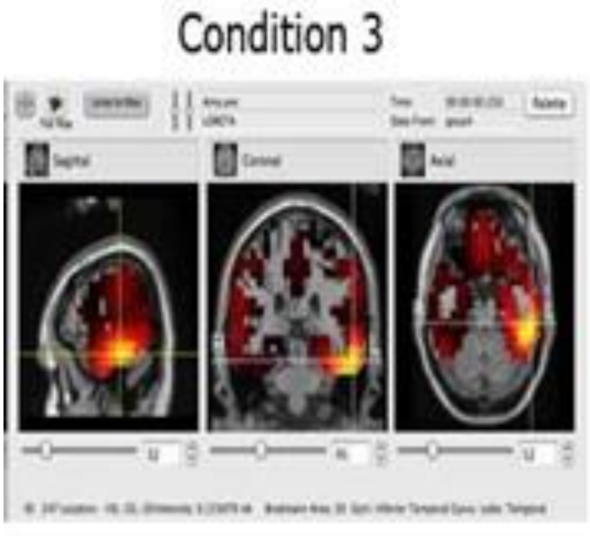

Figure 7: Example of brain activity in MRI from during the N-Back task.

Figure 8. Example of the Electrical Geodesics Incorporated 128-channel electroencephalographic Geodesic Sensory Net participants wore throughout the experiment.

Chapter 3

Results

3.1 EEG Data

Figure 3.1 outlines measured activity in some BA’s representing key areas of interest identified from previous research. Output of all BA’s can be found in Appendix D. Key regions of interest include BA’s 9, 23 25, 27 and 31 and the rationale for their inclusion in the analysis is explored in the introduction (1.11 Key issues yet to explore). An enlarged version of Figure 3.1 can be found in Appendix 10. Brodmann area 10 was a key region of interest. However, due to poor findings within this area, no significant statistical analyses were undertaken.

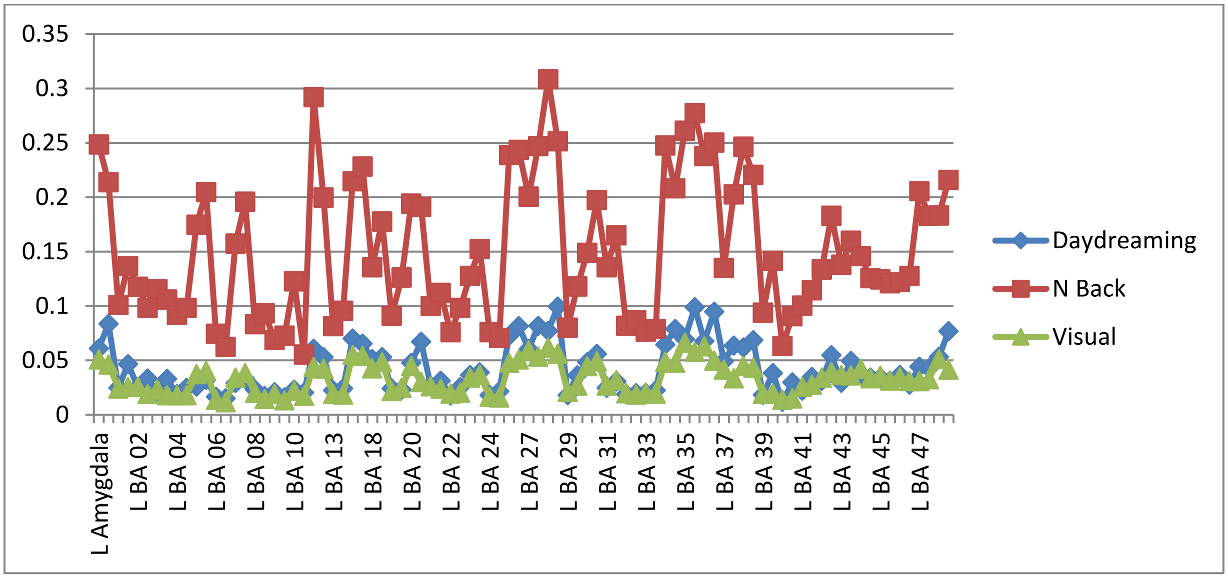

Figure 3.1: Data showing to the level of activity brain exhibited (y-axis) by Brodmann areas in each phase of the investigation.

The EEG samples which make up these data are made up of respective 10ms intervals extracted from the three phases of the procedure (visual, daydreaming and N-back). In the daydreaming condition, there was one 10ms sample every ten seconds throughout six 60 second intervals of daydreaming; equating to 72 samples in all. Similarly, in the visual condition. The 10 ms EEG sample starts with stimulus onset at the start of each of the 72 visual stimuli, equating to another 72 samples in the visual condition. As a means to increase the probability of observing brain activity corresponding to cognitive activity rather than early visual processing - the 10 ms samples received from the N-Back phase were not extracted until 500ms after stimulus onset, giving 24 N-Back samples.

Geosource 2.0 Software with sLORETA was used to compute standardised current density scores (as estimates of amplitude in each Brodmann area). The data will be considered in terms of both overall activity (amplitude) levels for each BA across tasks and also the ranked BAs for each task to reveal the patterns of brain activity for each task.

3.2 Hypothesis testing for the EEG data

The experimental (H_1) hypothesis for this investigation stated that differences brain differences in brain activity would be measured across the three phases of the procedure. Conversely, the (H_0) null hypothesis for this experiment proposed that no such differences would be found. It is evident from Figure 3.1. that clear distinctions of brain activity were found in the N-Back phase in comparison to the daydreaming and visual stages, which often elicited very similar activity.

In sum, the overall pattern of brain activity across key regions of interest is that the day-dreaming and visual phases were very similar and both showed markedly lower activity relative to the N-Back task phase. This suggests that the null hypothesis may be rejected as there are some differences in activity across the phases; although further statistical analysis was conducted to examine the differences in brain activity between task phases in more detail. It would have been unwise to have made comparisons across all BAs as the likelihood of a Type I error would be high. Therefore, certain BAs were selected *apriori* for detailed analysis. Given that the BAs are mirrored across brain hemispheres, the analysis focused on the right hemisphere as this was found *post hoc* (see Section 3.4.) to show the greatest level of activity in daydreaming.

3.3. Analysis of activity in key Brodmann areas.

3.3.1. Brodmann Area 28

3.3.1.1. Rationale for selection

The daydreaming phase of the experiment elicited most activity from right Brodmann area (BA) 28 (M; 0.099384; SD; 0.111752), a region corresponding to the entorhinal cortex heavily implicated in episodic memory (Eichenbaum et al, 2012). Source localization suggests that this BA was most active during the phase of the experiment designed to elicit daydreaming, which may well indicate day-dreaming activity involving episodic recall. Nevertheless, the highest level of activity in this area was in the N-Back task. The entorhinal cortex is also linked to the hippocampus (Buzsáki & Moser, 2013; Suh et al, 2011) which has been shown to aid memory consolidation (Bambah-Mukku et al, 2014) and recall (Østby et al 2012)., it is conceivable that significant neuronal firing occurred in this region strongly associated with memory faculties. Although no instructions were given, it is possible participants spent this time mentally revising the shapes they had previously seen and from there experienced task-unrelated thoughts. Conversely, the variety of shapes in changing colours may have also led participants to evaluate whether these randomizations had any hidden meaning important to the procedure, which would also give good reason as to why BA28 exhibited the greatest activity. Of particular interest however, is the literature that links hippocampal activity with fearful memory recall (Zelikowsky, Hersman, Chawla, Barnes & Fanselow, 2014). Stimulation of hippocampal engrams has also brought about fearful memory recalls (Liu, Ramirez, Pang, Puryear, Gorindarajan, Deisseroth & Tonegawa, 2012). This may be particularly insightful as such data is consistent with a great deal of literature theorising wandering minds as often negative.

3.3.1.2. Statistical analysis of the activity levels in right Brodmann Area 28 (RBA 28)

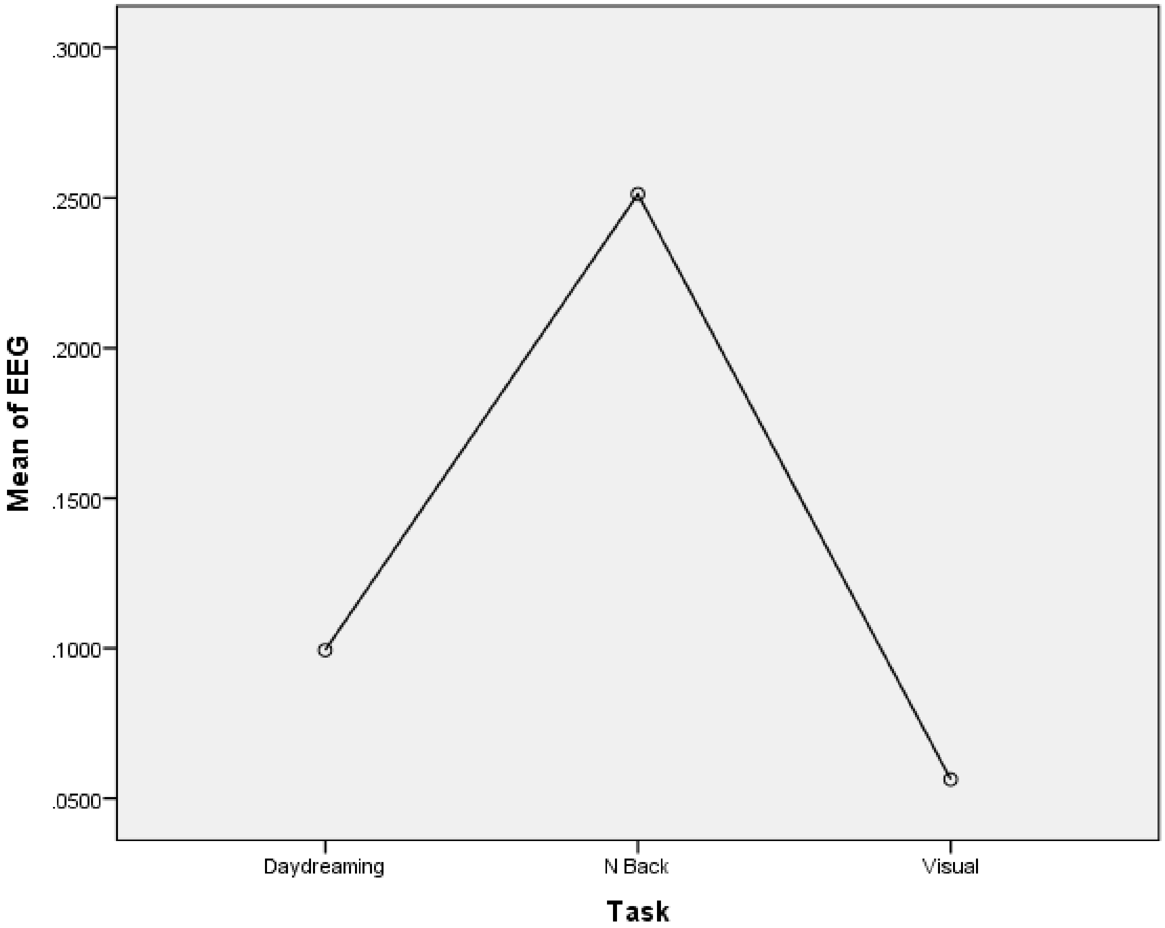

Figure 3.3.1.1. *Brodmann area 28 activity across phases of the experimental procedure*

Figure 3.3.1.1. Demonstrates that BA28 showed substantially greater activity in the N-Back task, with the daydreaming task eliciting proportionately more than the visual task.

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming	12	.0994	.11175	.01	.44
N-Back	12	.2513	.14219	.11	.60
Visual	12	.0563	.02241	.02	.11

***Table 3.3.1.1**. Descriptive statistics for activity in RBA28 across task phases*

Given that the data violated the parametric assumptions, the data were analysed using a Friedman test (see Appendix 4). This test revealed that the level of activity in rBA 28 varied significantly (χ^2 (2, N=12) = 16.468, $p < 0.0005$)) across the phases of the task. Inspection of means demonstrates that the measured activity in R BA28 was highest in the N-Back phase compared to daydreaming and visual. Pairwise comparisons across task phases were conducted using a Wilcoxon test. These comparisons are shown below.

Test Statistics[a]

	N-Back RBA 28 - Daydreaming RBA 28	Visual RBA 28 - Daydreaming RBA 28	N-Back RBA 28 - Visual RBA 28
Z	-2.845[b]	-1.647[c]	-3.059[b]
Asymp. Sig. (2-tailed)	.004	.099	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

This suggests there was activity in RBA 28 over the three task phases (daydreaming, visual and N-back). It is clear that the greatest activity in BA28 occurred during the N-Back task. Further research has demonstrated the importance of BA28 in episodic memory (Lipton & Eichenbaum, 2008), and how entorhinal atrophy as a result of Alzheimer's disables episodic memory (Di Paolo, et al, 2007). This data were therefore consistent with previous research into BA28. Output from *post hoc* pairwise comparisons would suggest the major significant difference concerned the rate of activity within the N back phase compared to both daydreaming and visual stages. In sum, this could reflect the relatively higher demand on working memory in the N-back task. When referring to the previously discussed literature concerning the function of BA 28, it is to have been expected that the major difference in activity should be between the cognitively demanding (N-Back) and cognitively undemanding tasks (Daydreaming, Visual).

Within-Subjects Factors

Measure: EEG_Output

rba28	Dependent Variable
1	Daydreaming
2	NBack
3	Visual

Pairwise Comparisons

Measure: EEG_Output

(I) rba28	(J) rba28	Mean Difference (I-J)	Std. Error	Sig.^{b}	95% Confidence Interval for Difference^b	
					Lower Bound	Upper Bound
1	2	-.151*	.043	.014	-.272	-.030
	3	.044	.028	.446	-.036	.123
2	1	.151*	.043	.014	.030	.272
	3	.195*	.039	.001	.085	.305
3	1	-.044	.028	.446	-.123	.036

2	-.195*	.039	.001	-.305	-.085

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Pairwise comparisons were conducted in order to ascertain the closeness of mean Brodmann area 28 activity among the three respective tasks. As expected, the daydreaming and visual tasks elicited much closer levels of Brodmann area 28 activity compared to the N-Back task.

3.3.2. Brodmann Area 23

3.3.2.1. Rationale for selection

Another key area of interest is BA23, this BA corresponds to the posterior cingulate cortex (Vogt et al, 2003), a region considered to characterise a good proportion of the default-mode network (Bluhm et al, 2011) which has also been implicated in task switching which involves colour (Leech et al 2012). With regard to the set-up and procedure of this experimental investigation, this BA may make for a particularly interesting area of analysis when comparing the brain activity across the three phases of the procedure.

3.3.2.2. Statistical analysis of the activity levels in right Brodmann Area 23 (RBA 23)

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming RBA 23	12	.0388	.03747	.01	.15
N-back RBA 23	12	.1523	.11863	.05	.44
Visual RBA 23	12	.0369	.02392	.01	.09

***Table 3.3.2.1**. Descriptive statistics for activity in RBA23across task phases*

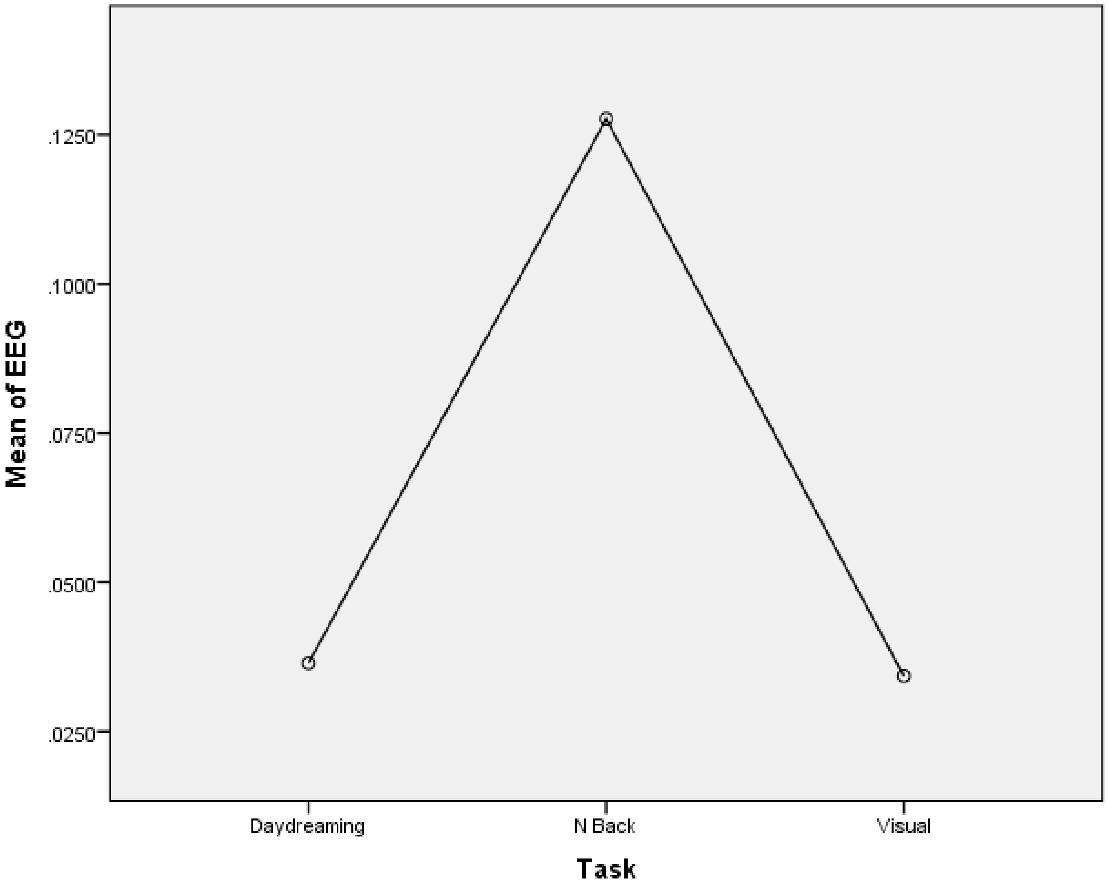

***Figure 3.3.2.1**. RBA23 activity across phases of the experimental procedure.*

Given that the data violated the parametric assumptions, the data were analysed using a Friedman test (see Appendix 5). This test revealed that the level of activity in rBA 23 varied significantly (χ^2 (2, N=12) = 16.894, $p < 0.0005$)) across the phases of the task. Pairwise comparisons across task phases were conducted using a Wilcoxon test. These comparisons are shown below.

Test Statistics[a]

	N-back RBA 23 - Daydreaming RBA 23	Visual RBA 23 - Daydreaming RBA 23	Visual RBA 23 - N-back RBA 23
Z	-2.934[b]	.000[c]	-3.059[d]
Asymp. Sig. (2-tailed)	.003	1.000	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. The sum of negative ranks equals the sum of positive ranks.

d. Based on positive ranks.

It is clear the N-Back task elicited significantly higher rates of activity compared to other two tasks. The posterior cingulate cortex (BA23) operates within the default network which makes for an interesting find when comparing its activity between visual and day-dreaming tasks. Moreover, this region is also involved in detecting targets and activating the pre-frontal cortex (Small et al, 2003). The vitality of the prefrontal cortex in cognitive control and general cognition (Koechlin et al, 1999; Koechlin et al, 2003), gives reason for the surge of increased activity during the cognitive-demanding task.

Within-Subjects Factors

Measure: EEG_Output

rba23	Dependent Variable
1	Daydreaming
2	NBack
3	Visual

Pairwise Comparisons

Measure: EEG_Output

(I) rba23	(J) rba23	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.113*	.036	.026	-.214	-.013
	3	.002	.007	1.000	-.018	.022
2	1	.113*	.036	.026	.013	.214
	3	.115*	.034	.017	.020	.210
3	1	-.002	.007	1.000	-.022	.018
	2	-.115*	.034	.017	-.210	-.020

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Due to the similar levels of activity found in Brodmann area 23 in the investigation, pairwise comparisons were conducted in order to compare the levels of activity found in Brodmann area

23. As expected, over the three tasks, both daydreaming and visual tasks displayed closer levels activity compared to the N-Back task.

3.3.3. Brodmann Area 31

3.3.3.1. Rationale for selection

Coupled with BA23, BA31 largely cover the posterior cingulate cortex (Dragoi et al, 2013), and is thus fundamental to the default-mode network of the resting brain (Fransson, 2006; Fransson et al, 2008; Leech et al, 2012), performing similar functions to that of BA23. With this being the case, BA31 may also be a key area of interest to this investigation.

3.3.3.2. Statistical analysis of the activity levels in right Brodmann Area 31 (RBA 31)

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming RBA 31	12	.0308	.03461	.01	.14
N-back RBA 31	12	.1650	.16343	.03	.52
Visual RBA 31	12	.0319	.02984	.01	.09

Table 3.3.3.2. *Descriptive statistics for RBA31*

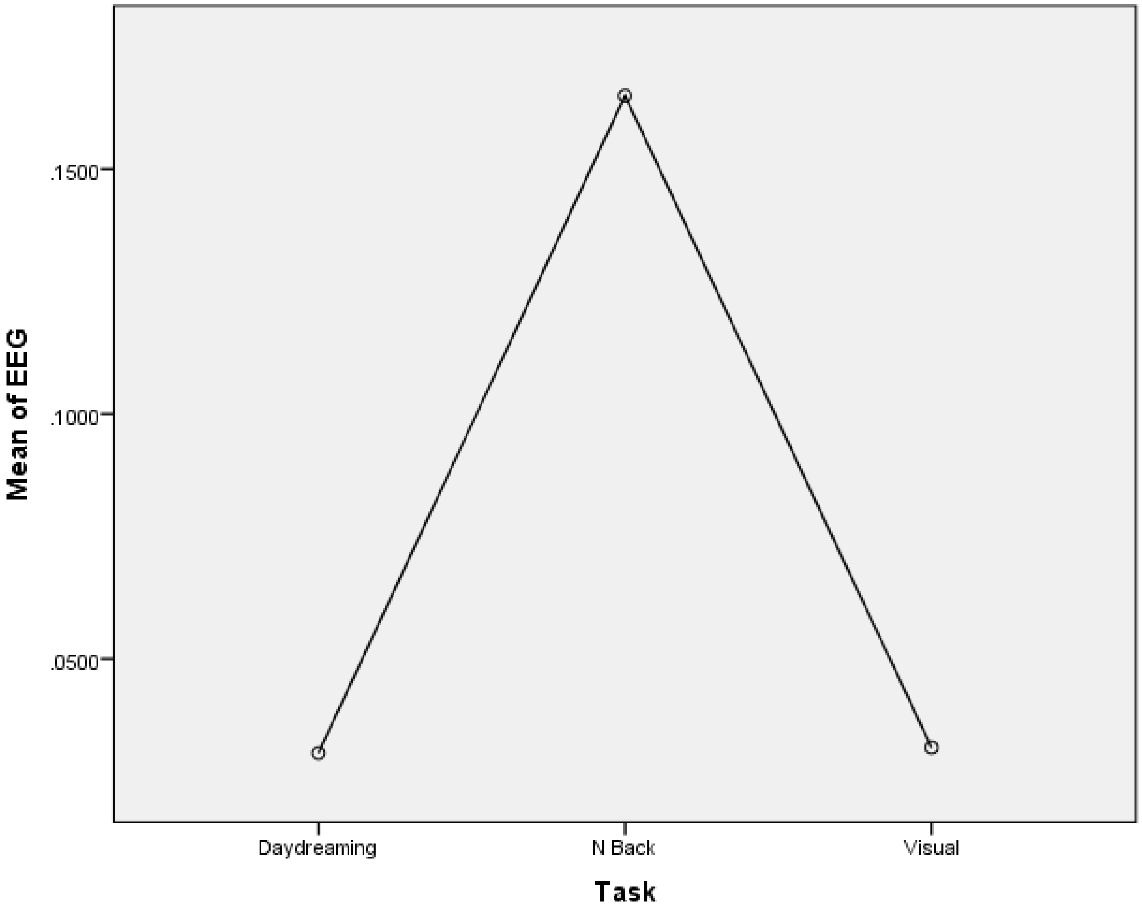

Figure 3.3.3.2. *RBA31 activity over phases*

Given that the data violated the parametric assumptions, the data were analysed using a Friedman test (see Appendix 6). This test revealed that the level of activity in rBA 31 varied significantly (χ^2 (2, N=12) = 17.149, $p < 0.0005$)) across the phases of the task. Pairwise comparisons across task phases were conducted using a Wilcoxon test. These comparisons are shown below.

Test Statistics[a]

	N-back RBA 31 - Daydreaming RBA 31	Visual RBA 31 - Daydreaming RBA 31	N-back RBA 31 - Visual RBA 31

Z	-2.934[b]	-.314[c]	-3.059[b]
Asymp. Sig. (2-tailed)	.003	.754	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Of interest is the small range between visual and day-dreaming output. Again N-Back task displayed over double the activity similar to that in BA23. This is of interest as both BA23 and31 showed very similar activity within respective conditions. Similar scores between BA's 23 and 31 were to be expected however, as both these areas correspond to the posterior cingulate cortex and thus facilitate similar functions. BA31 has also been suggested to be a component of the default-mode network (Leech et al, 2011; Leech et al, 2012; Korgaonkar et al, 2014).

Within-Subjects Factors

Measure: EEG_Ouput

rba31	Dependent Variable
1	Daydreaming
2	NBack
3	Visual

Pairwise Comparisons

Measure: EEG_Ouput

(I) rba31	(J) rba31	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.134	.048	.051	-.269	.000
	3	-.001	.008	1.000	-.023	.020
2	1	.134	.048	.051	.000	.269
	3	.133*	.044	.034	.009	.257
3	1	.001	.008	1.000	-.020	.023
	2	-.133*	.044	.034	-.257	-.009

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Pairwise comparisons were conducted in order to ascertain the closeness of mean Brodmann area 31 activity among the three respective tasks. In this instance, the daydreaming and visual tasks displayed almost identical levels of Brodmann area 31 activity. As expected, the N-Back task demonstrated noticeably different levels of activity when compared to the other two conditions.

3.3.4. Brodmann Area 09

3.3.4.1. Rationale for selection

BA9 corresponds to the dorsolateral prefrontal cortex (Petrides & Pandya, 1999; Fitzgerald et al, 2006), an area of the brain implicated in key functions such as attention and monitoring (Johnson et al, 2007; Halperin & Schultz 2006) working memory (Qin, Hermans et al, 2009; Mulquiney et al, 2011) and task switching (Bunge & Zalazo, 2006). Based on this understanding, BA9 is *a priori* predicted to demonstrate peak activity in the N-Back task where working memory and attention is required.

3.3.4.1. *Statistical analysis of the activity levels in right Brodmann Area 9 (RBA 9)*

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming RBA 09	12	.0160	.01435	.01	.06
N-back RBA 09	12	.0727	.04186	.02	.16
Visual RBA 09	12	.0134	.01370	.00	.06

Table 3.3.4.1. *Descriptive statistics for activity in RBA 9*

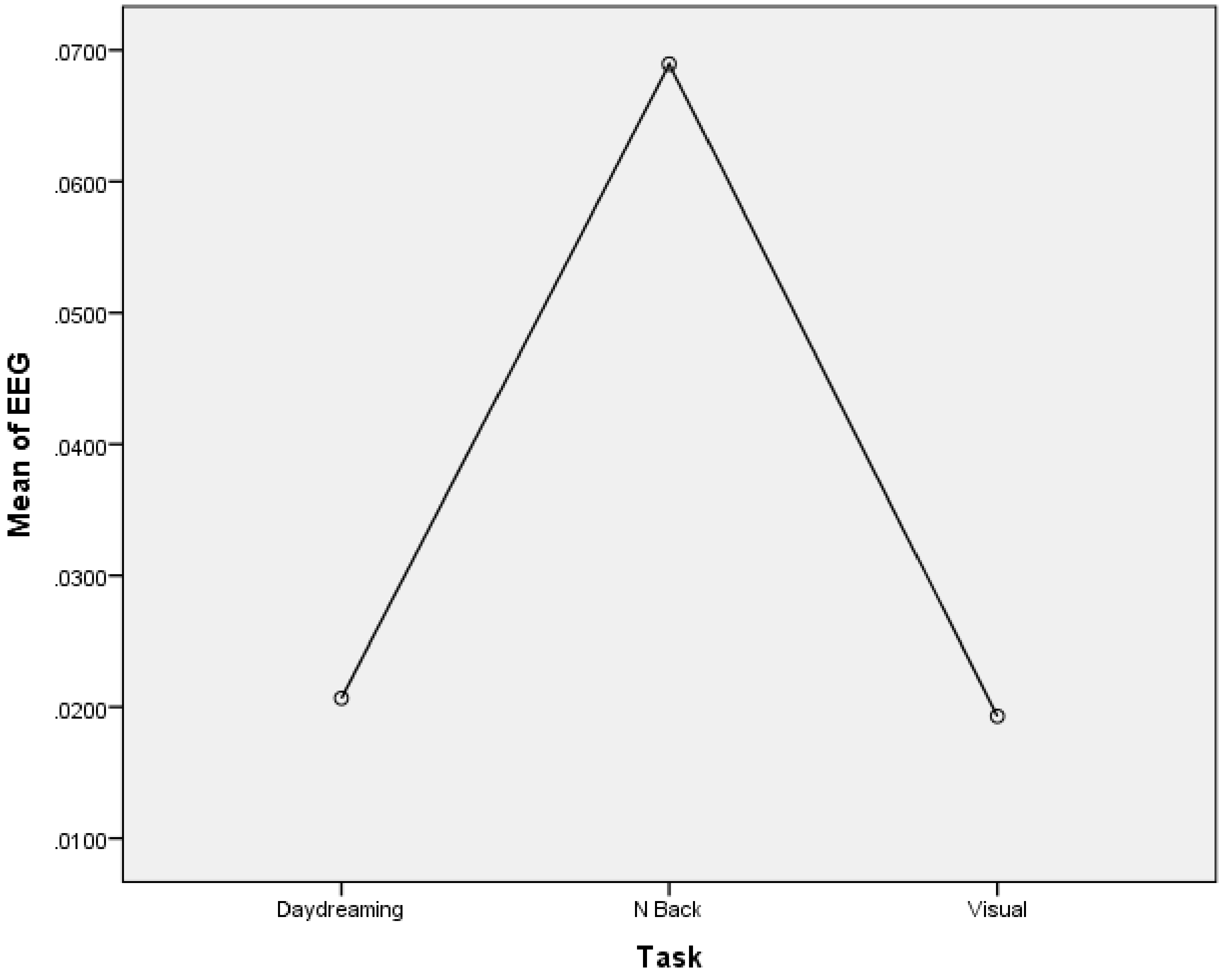

Figure 3.3.4.1. Average BA9 activity across the three tasks

Given that the data violated the parametric assumptions, the data were analysed using a Friedman test (see Appendix 7). This test revealed that the level of activity in rBA 09 varied significantly (χ^2 (2, N=12) = 17.149, $p < 0.0005$)) across the phases of the task. Pairwise comparisons across task phases were conducted using a Wilcoxon test. These comparisons are shown below.

Test Statistics[a]

	N-back RBA 09 - Daydreaming RBA 09	Visual RBA 09 - Daydreaming RBA 09	Visual RBA 09 - N-back RBA 09
Z	-2.934[b]	-1.412[c]	-3.059[c]
Asymp. Sig. (2-tailed)	.003	.158	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Of interest is that BA9 is implicated in spatial working memory (Ricciardi et al, 2006) and attention monitoring (Kane et al, 2002). As a result, it is somewhat surprising to see, again, so similar scores between visual and day-dreaming tasks. This may indicate that participants were not actually allocating attention to the emerging shapes in the visual task, which may explain why BA's between these two tasks displayed similar patterns of activity.

Within-Subjects Factors

Measure: EEG_Output

rba09	Dependent Variable
1	Daydreaming
2	NBack
3	Visual

Pairwise Comparisons

Measure: EEG_Output

(I) rba09	(J) rba09	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.057*	.013	.004	-.094	-.020
	3	.003	.001	.278	-.001	.007
2	1	.057*	.013	.004	.020	.094
	3	.059*	.013	.002	.023	.096
3	1	-.003	.001	.278	-.007	.001
	2	-.059*	.013	.002	-.096	-.023

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Again, due to similar levels of activity found in Brodmann area 09 in the investigation, pairwise comparisons were conducted in order to compare the levels of activity found in Brodmann area 09. As expected, over the three tasks, both daydreaming and visual tasks displayed much closer levels activity compared to the N-Back task.

3.3.5. Brodmann Area 25

3.3.5.1. Rationale for selection

BA25 refers to the anterior cingulate cortex (Botvinick, Cohen & Carter, 2004), which is implicated in processing attention (Pardo, Pardo, Janer & Raichle, 1990), cognitive control (Macdonald et al, 2000) and performance monitoring (Holroyd & Yeung, 2012). This identified BA25 as an a priori area for investigation across phases of the experiment. Ventral regions of the anterior cingulate cortex also make up a sector of the default-mode network (Leech et al, 2011; Christophe Habas, Shirer & Greicius, 2013), which was suggested a priori to be fundamental to the resting brain state, and thus equally fundamental to day-dreaming.

3.3.5.2. Statistical analysis of the activity levels in right Brodmann Area 25 (RBA 25)

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming RBA 25	12	.0815	.07703	.02	.31
N-back RBA 25	12	.2434	.14653	.05	.50
Visual RBA 25	12	.0510	.02394	.03	.11

***Table 3.3.5.2**. Descriptive statistics for activity in RBA 25 across task phases.*

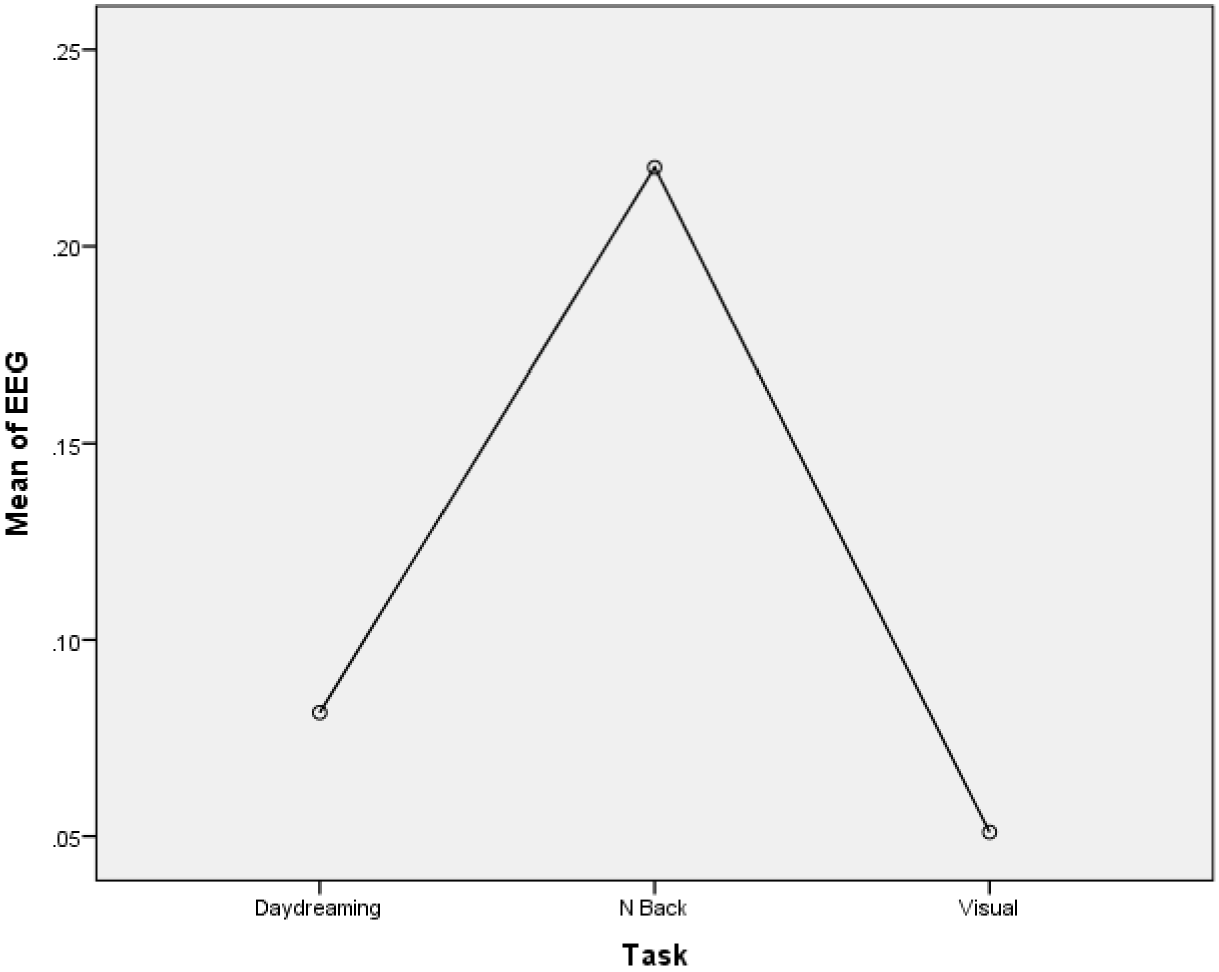

Figure 3.3.5.2. RBA25 activity throughout phases of the experimental procedure

Given that the data violated the parametric assumptions, the data were analysed using a Friedman test (see Appendix 8). This test revealed that the level of activity in rBA 25 varied significantly (χ^2 (2, N=12) = 16.894, $p < 0.0005$)) across the phases of the task. Pairwise comparisons across task phases were conducted using a Wilcoxon test. These comparisons are shown below.

Test Statistics[a]

	N-back RBA 25 - Daydreaming RBA 25	Visual RBA 25 - Daydreaming RBA 25	Visual RBA 25 - N-back RBA 25
Z	-2.934[b]	-.941[c]	-3.059[c]
Asymp. Sig. (2-tailed)	.003	.347	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

RBA25 was most active during the N Back phase, exhibiting significantly increased activity compared to the daydreaming and the visual phases.

Within-Subjects Factors

Measure: EEG_Output

rba25	Dependent Variable
1	Daydreaming
2	NBack
3	Visual

Pairwise Comparisons

Measure: EEG_Output

(I) rba25	(J) rba25	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.162*	.042	.008	-.279	-.045
	3	.030	.022	.599	-.032	.093
2	1	.162*	.042	.008	.045	.279
	3	.192*	.043	.003	.072	.313

3	1	-.030	.022	.599	-.093	.032
	2	-.192*	.043	.003	-.313	-.072

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

3.3.6. Brodmann Area 27

3.3.6.1. Rationale for selection

BA27 corresponds to a section of hippocampal formulation within the medial temporal lobe (Darachi et al, 2003), as is predominantly linked to decision making (Guitart-Masip et al, 2013) and working memory systems (Berch & Smith, 2008; Woodward et al , 2013). Considering this investigation concerns how such processes may be involved in day-dreaming behaviours, particularly in light of such previous research, BA 27 may be key to uncovering potential differences within brain activity over a range of visual tasks which vary with cognitive demand. Despite not being a priori, BA27 was one of a few regions implicated in memory to demonstrate top-ranked activity, and may therefore be of use to this investigation.

3.3.6.2. Statistical analysis of the activity levels in right Brodmann Area 27 (RBA 27)

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming RBA27	12	.0817	.09592	.02	.38
N-back RBA 27	12	.2470	.15602	.09	.63
Visual RBA 27	12	.0536	.02189	.02	.09

Table 3.3.6.2. *Descriptive statistics for RBA27*

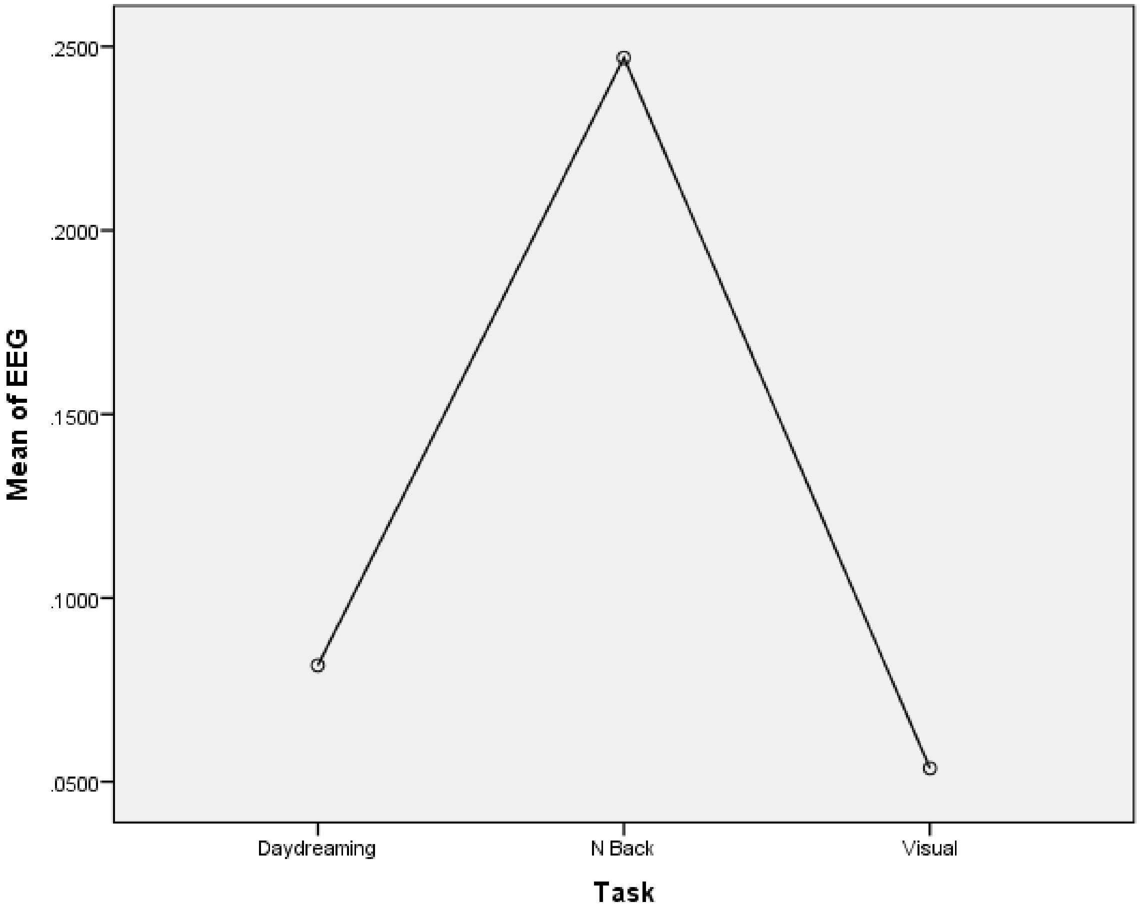

Figure 3.3.6.2 RBA27 activity throughout phases of the experimental procedure

Given that the data violated the parametric assumptions, the data were analysed using a Friedman test (see Appendix 9). This test revealed that the level of activity in rBA 27 varied significantly (χ^2 (2, N=12) = 17.149, $p < 0.0005$)) across the phases of the task. Pairwise comparisons across task phases were conducted using a Wilcoxon test. These comparisons are shown below.

Test Statistics[a]

	N-back RBA 27 - Daydreaming RBA27	Visual RBA 27 - Daydreaming RBA27	Visual RBA 27 - N-back RBA 27
Z	-2.934[b]	-1.020[c]	-3.059[c]
Asymp. Sig. (2-tailed)	.003	.308	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Based on the understanding that BA27 is multifaceted, with respective regions of BA27 being responsible for different functions (Bakker et al, 2008), it is of little surprise that this region showed varying activity over the three tasks.

Within-Subjects Factors

Measure: EEG_Output

rba27	Dependent Variable

1	Daydreaming
2	NBack
3	Visual

Pairwise Comparisons

Measure: EEG_Output

(I) rba27	(J) rba27	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.165*	.046	.013	-.295	-.036
	3	.028	.024	.829	-.041	.097
2	1	.165*	.046	.013	.036	.295
	3	.193*	.045	.004	.068	.319
3	1	-.028	.024	.829	-.097	.041
	2	-.193*	.045	.004	-.319	-.068

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Pairwise comparisons were conducted in order to assess how Brodmann area 27 activity varied throughout the three tasks of the procedure. Again, as expected, the daydreaming and visual phases displayed markedly similar levels of acitivity in comparison to the N-back phase of the procedure.

3.4 Brodmann Areas ranked by level of activity in each task phase

Task	Daydreaming	EEG	N-Back	EEG	Visual	EEG
Brodmann Areas Ranked in Order						
1st	R BA 28	.099384	L BA 28	.308356	L BA 35	.066313
2nd	R BA 35	.09887	L BA 11	0.29192083	L BA 36	0.0630325
3rd	R BA 36	.094693	R BA 35	0.27735667	L BA 28	0.06180833
4th	R Amygdala	.083465	L BA 35	0.26119333	L BA 27	0.05927333
5th	R BA 27	.081676	R BA 28	0.25125417	R BA 35	0.05773833
6th	R BA 25	.081477	R BA 36	0.25008	R BA 38	0.04330417
7th	R BA 34	.078843	L Amygdala	0.24843917	L BA 17	0.0550275
8th	L BA 28	.077183	L BA 34	0.24744083	R BA 17	0.0542425

9th	R Hippocampus	.076902	R BA 27	0.2469775	R BA 27	0.05365
10th	L BA 25	.072763	L BA 38	0.24630667	L Hippocampus	0.051355
11th	L BA 17	.070068	R BA 25	0.24342833	R BA 25	0.051035
12th	L BA 35	.069509	L BA 25	0.23061727	L Amygdala	0.0508875

Table 3.4.1 Top ranked Brodmann areas across each task

Chapter 4

Discussion

4.1 Assessing Brodmann area activity

Assessing the top-ranked BA's, clear differences can be seen across respective tasks. Of interest, however, is that some regions, such as BA35, appear highly ranked in all three phases. Despite ranking fourth in its list, N-Back still elicited more activity within respective BA35 hemispheres than both left and right hemispheres combined in visual and daydreaming tasks (Daydreaming BA-35 total = .16846; Visual BA 35 total = .12405133). Coupled with BA 36 which also appears in all three tasks, these regions make up perirhinal cortex (Ding et al, 2010). So, why did the perirhinal cortex appear especially dominant in all three tasks? The perirhinal cortex is known to be particularly active when high ambiguity exists within visual tasks (Bussey et al, 2005), the N-Back task was implemented specifically to fulfil this purpose and to have the participant switch from a resting-based state to one which requires strong cognitive input. This may also give reason to why BA's 35 and 36 in the N-Back task showed more activity compared to the other tasks, although why these regions appear in the other tasks remains somewhat unclear. Fresh research has found evidence to suggest the perirhinal cortex is implicated in within and between domain associations, as well as associative recall and delayed-based persistence (Suzuki et al, 2014). If this is the case, we may propose that daydreaming took place in both visual and daydreaming tasks, as both BA 35 and 36 appear in the top 3 ranked, in both conditions. This could suggest daydreaming occurred in the N-Back phase too. Both left and right BA35 and right BA36 showed substantially increased activity when compared between tasks. If recent research is true, these regions may have displayed high activity as they underwent both complex visual tasks and interchanging domain-specific thought.

4.2 Consideration of individual scores

Concentrating on the respective data sets received from individual participants, a couple of interesting results have been noted. The pattern of data for Participant P1010 is of particular interest. This Participant displayed right amygdala activity at .3743 (M; .0834) and left amygdala activity at .1805 (M; .0604).What is more, this participant was one of the few to answer the follow-up questions with the answer that their day-dreaming experiences were largely concerned with themselves and others - most of which was related to current issues. This is particularly interesting when we consider the role of the amygdala in the limbic system, the valance specific hypothesis and the notion of the wandering mind being largely negative about the world. This participant also registered a score of .4365 (M; .0993) in BA 28, an area linked to episodic memory faculties (Szpunar et al, 2009), and so this could be argued to exemplify a sample of brain activity retrieved from a daydreaming mind. That this individual exhibited significantly greater activity within BA 28 and amygdala regions can be seen to be consistent with daydreaming literature that implicates episodic memory (BA 28) and valence-specific negativity (amygdala) with daydreaming. Answers provided from the follow-up questions arguably support this data, as the post-test self-report data remains consistent with both previous literature and what may have been anticipated based on the initial analysis of the EEG output. This participant also exhibited a proportionately greater rate of hippocampal firing .3792 (M; .0769). Research into hippocampus activity has consistently brought about findings implicating this brain region with working memory faculties. In addition to this, participant P1010 exhibited greater BA25 (anterior cingulate cortex) activity (.2613, M; .07276), increased BA38 activity with an EEG reading of .3063 (M; .0684). BA 38 corresponds to the right temporal pole (Tsapkin et al, 2011) responsible for the integration of visual, auditory, tactile and internal information, indicating this region is particularly important for multi-modal analysis (Haier et al, 2009). The right temporal pole has also been found to be interconnected to other fundamental brain structures such as the amygdala, hippocampus & orbital prefrontal cortex (Blaizot et al, 2010). This could be seen to be potentially significant if we accept the notion of the wandering mind being unhappy - and arguably more so based on the understanding that BA38 is well interconnected with structures responsible for the processing of negative information. These data thus appear consistent with the notion that daydreaming generally concerns emotional issues, or entails them at least - which more often than not appear to be negative.

4.3 Patterns of activity consistent with daydreaming

Of particular concern for this investigation are the key brain areas which were found to be displaying the greatest level of activity during just the daydreaming condition. As for all conditions, many of the BA's exhibiting the greatest rates of neuronal firing appear to be implicated in memory-related processes (see table 3.1) - such as BA-35 which corresponds to the perirhinal cortex (Davies et al, 2009) and is fundamental to visual memory (O'Neil et al, 2009), and item-related features including colour (Staresina & Davachi, 2008). This being said, the right BA 35 and left BA 35 ranked second and 12th in the daydreaming condition, respectively. The presence of other memory-related BA's in close proximity to these however (BA 27, 34, 28 and 36) may indicate strong waves of stimulus-independent thought that were engaging with these regions, allowing for daydreaming to take form and flow. Keeping in mind that participants were informed solely that this investigation sought to establish how the brain responds to the emergence of shapes, it could be argued that the main recruitment of BA's involving memory were done to facilitate the daydreaming that occurred throughout the experiment - rather than the engagement of endogenous attention to aid the recall of the shapes and colours. There were other regions that were particularly strongly active (highly-ranked) for the daydreaming condition that point toward day-dreaming activity. Specifically, BA25 was ranked highest in the daydreaming task than the others, which, according to research, is a reliable indicator of daydreaming.

Considering now the most active BAs in relation to the phases of the task, the seven most actively firing BA's in the visual segment of the procedure contained two BA's from the right hemisphere and five BA's from the left hemisphere. During the N-back phase, four left BA's made up the seven most active, with the other three on the right hemisphere. During the daydreaming condition however, the seven BA's which displayed the highest activity were all situated within the right hemisphere, including the right amygdala (M; 0.083465, SD; 0.077032) which only displayed lesser activity than BA's 28, 35 and 36, respectively. These data provide strong support for the valence-specific hypothesis, which proposes that the brain hemisphere primarily responsible for the processing of emotional information is dependent upon whether this information is negative (right hemisphere) or positive (left hemisphere) (Killgore & Yurgelun-Todd, 2007). This would also fit with the wandering mind being an unhappy mind, as the daydreaming condition shows all of most active BA's being situated within the right brain hemisphere.

Other statistics were not so consistent with previous findings however. Data in this experiment do not replicate previous findings concerning rostrolateral activity (BA 10) and its potential role in facilitating the shift of attention between internal and external domains. What is interesting however, is that of all the BA activity recorded during the N-back phase, the BA to display the least activity, in arguably the only of the three stages that required cemented domain-specific thought, was BA 10 (M; .0554, SD; .0263).With this in mind, there may be room to propose that BA 10 activity within the N Back task may be consistent with the gateway hypothesis.

Most of the data obtained, however, do complement previous research and have provided some interesting insights. Of particular interest was the minimal differences in activity between *apriori* regions of interest between visual and daydreaming tasks – which may suggest the emerging stimuli in the visual task had little effect on the neuronal activity of key BA’s. There is evidence to show that each task recruited different neural regions (Table 3.1). Nonetheless, whilst deviating drastically from the N-Back task, the overall results for daydreaming appear to share major similarities with visual results in terms of both BA's recruited and intensity of activity.

4.4 Study Overview

This study was created with the aim of observing if there were distinct sources of neural activity within the brain associated with the three phases of the procedure (Daydreaming, N-Back, Visual). The regions of interest were initially identified from previous academic research into daydreaming.

Data from EEG source localization would suggest that differing brain activity accompanied the different phases of the procedure, although some were significantly more distinct than others and in particular the data show that (a.) there was generally a higher level of activity in the N-Back phase than in the other two phases and (b.) the daydreaming and visual tasks revealed similar levels and patterns of response. Moreover the pattern of activity showed that although similar regions were most active for all tasks (eg., areas reflecting memory operations) there were nonetheless some differences of note(see discussion below).

Participants were informed that the intention of this investigation was to achieve a reliable EEG reading of brain activity resulting from the emergence and disappearance of different shapes in a 3x3 grid. This being said, particularly when we refer to the data obtained (Figure 3.1) , source localization data would suggest participants were in a similar state of experience during both visual and daydreaming tasks and this was different in character to the N-Back task activity. This similarity between the visual and daydreaming phases could be conceptualized as resulting from either daydreaming- not taking place in either the visual or the daydreaming condition – or taking place in both. Another possible explanation might be that the brain functioning during these two tasks, which require no high level of cognitive engagement, reveals two patterns of neuronal activity when there is no need for the participant to engage cognitively with the outside world - and is therefore, partially at least, in some form of resting state. The formulation of the 3x3 grids in their various patterns and colors were devised with aim of keeping the participant as minimally engaged as possible throughout the visual task. The slide set participants were observing during this procedure was repeated twice. The inclusion of slides such as those in figure 1 and 2 is likely to have given participants some inkling that the slide set (duration approximately 8 minutes) is being repeated. This may offer insight into the mind-set of a participant who, in their fitted EEG net, is sat in front the experimental screen for over 15 minutes observing the onset and offset of shapes which take up 6 seconds of every minute - the remaining 54 seconds of this minute being an empty grid – and not being required to make any response at all. It is therefore possible that participants were daydreaming in both the visual and ‘blank’ (daydreaming) phases of the task. This then provides a potential explanation for the similarity across the visual and daydreaming segments in activity across a range of BAs

The current study was one of a limited number to investigate daydreaming with EEG measures (as opposed to self-report data attained through verbal or visual prods when daydreaming is apparent to the professional observer) and has tried to do so in a manner that encapsulates three distinct forms of brain activity associated with different cognitive and visual conditions. Even with measures of brain activity, however, follow-up questions were imperative as a means of accessing the internal cognition of participants throughout the procedure. Participant feedback could also be useful in devising more robust methods to credibly assess the daydreaming behaviors of the modern day individual. In light of the sample size, the understanding that two of the twelve individuals experienced this may offer insight as to how daydreaming can arise from cognitive overload. This is of particular note when considering the experimental evidence which has demonstrated how the mind can similarly wander when under aroused (Damrad-Fry & Laird, 1989). Coupled together, these cases of evidence appear to encourage academic approaches to daydreaming by concentrating on how solely cognitive factors can manipulate the onset and frequency of day-dreams - Such evidence suggests that studying brain activity in daydreaming needs to consider that daydreaming tendencies may be driven by both under- and over--cognitive arousal.

4.5 Daydreaming vs Visual

A table of mean scores between daydreaming and visual tasks can be found at Appendices 4 – 8 in relation to each BA detailed.

Although the visual and daydreaming phases elicited similar patterns and levels of response across BAs, the response for the two tasks was not identical: for example, for the visual task there was predictably stronger representation of BA17 in the top 10 areas while for the daydreaming task BA25 (ventral ACC) was more strongly represented (LBA25 being ranked 6th and RBA 10th for this task compared to 11th and 10th respectively for the N-Back task and 17th and 11th for the visual task respectively). The stronger representation of BA25 in the daydreaming phase is of interest given the role of this region in the default mode network and its prominence when cognitive demands are low (Greicius et al., 2003). This is the so-called affective division of ACC with links to Autonomic NS and limbic & dopamine systems/networks (Bush, 2000; Luu & Posner, 2003; Paus 2001). It assesses salience of emotional input for current response/motivation and represents active “requirements” (Weston, 2011). This provides a somewhat different quality to the overall pattern of activity for this phase consistent with a low-cognitive focus and possibly heightened affective activity. Nevertheless, despite these differences, there was a strikingly similar pattern and level of activity for the daydreaming and visual tasks with points of interest being as follows.

Largely identical BA activity was also observed in both left and right BA45 between visual and daydreaming segments. BA45 makes up part of Broca's Area (Amunts & Zilles, 2012) and corresponds to the ventro-lateral prefrontal cortex (Plakke, Diltz & Romanski, 2013). BA45 activity is important in aiding abilities that often require higher-level cognition, such as hypothesis testing (Elliott, Dolan & Frith, 2000), and, coupled with BA44 which also displayed very similar firing rates, is heavily implicated in complex rule-based choices (Bhanji, Beer & Bunge, 2010). Thus, although we can only presume so, evidence to suggest brain areas implicated in higher cognition elicited roughly identical activity arguably proposes individuals must have been in a similar state of experience during both visual and daydreaming tasks. Therefore there may be additional room to argue that much of the data collected would support the assumption that the two non-engaging tasks brought about a similar state of mind.

Another key region of interest is BA9. This region has roles for spatial working memory, attention and conflict monitoring, yet despite the dorsolateral prefrontal cortex (BA9) giving rise to such abilities, the mean differences between left and right BA9 activity across visual and daydreaming tasks were minimal - which once again may suggest that daydreaming occurred during the visual task. Despite left and right BA9 regions eliciting the 4th and 6th least activity during the N-Back task, the amplitude of their activity was measured at .0689 and .07269 respectively. Left BA9 elicited a firing rate of .0206 in the daydreaming task and .0192 in the visual, leaving a mean difference of .0014. Right BA 9 exhibited activity at a rate of .0159 in the daydreaming condition and .0133 in the visual task, equated a mean difference of .0026.

Consideration of activity in other BAs may add further support to the claim that the visual and daydreaming tasks created a similar state of mind during this investigation. Turning to the data from left BA 19 - the N-Back task generated a mean score of .0909, whilst the mean scores for the daydreaming and visual tasks were .0243 and .0217 respectively. The difference between N-Back and daydreaming means is therefore .0666, and between N-Back and visual means .0692. The difference between the means of the visual and daydreaming task was .0026, indicating little difference in the level of brain activity in this region for the two tasks. The findings for right BA 19, are similar. With the N-Back task, the difference between means equalled .1034 when compared to the daydreaming task (.1262 - .0228) and .1015 when compared to the visual task (.1262 - .0247). Comparing the means of the visual and daydreaming phases gave a small difference of .0019 (.0228 - .0247). With respect to the brain activity associated with daydreaming, it is of interest that BA 19 (Urgesi, Berlucchi & Aglioti, 2004) makes up part of the default-mode network (Christoff et al, 2009; Hahn et al, 2007; Uddin et al, 2009). Similar activity in both left and right BA19 therefore suggests that at least part of the default mode network was equally active in both the visual and daydreaming phases of the task. Such congruent activity across the phases can also be identified in other BAs in both hemispheres and a table detailing the mean differences of BA activity between hemispheres, for the different phases of the task, can be found at Appendices 4 – 8 in relation to each BA detailed.

Although the activity in many BAs were similar for the daydreaming and visual phases of the task, there were some differences (see Appendices 4-8), particularly across cortical hemispheres. Such differences suggest that the underlying cortical activity may differ in some respects between the visual task and the daydreaming phase of the task, possibly representing the difference between simple passive viewing of visual stimuli and the generation of internal stimuli – daydreaming. If these hemispheric differences suggest that daydreaming didn't occur within the visual task, there appears sufficient evidence to propose that the right hemisphere may be preferentially involved in daydreaming, as a comparison of right hemisphere activity between daydreaming and visual phases generated a large range of mean BA scores. Research suggests that the right hemisphere is dominant in creativity and imagery (Gowan, 1979; Ehrlichman & Barret, 1983), which would appear consistent with the data obtained in this investigation showing right hemisphere activity to be particularly disparate between visual and day-dreaming tasks compared to the left hemisphere activity. This could suggest that although there are many similarities in the brain activity associated with daydreaming and passive viewing of visual stimuli, there may be some differences. Recent research has also implicated the right-hemisphere in depression (Hecht, 2010) and has characterized depression as insufficient functionality of the right hemisphere coupled with physiological over action (Rotenberg, 2004). This supports the idea of the right hemisphere being heavily involved in valence-specific processing and is perhaps consistent with the neural activity recorded in the day-dreaming task with the seven most active BAs situated in the right hemisphere. This is consistent with the idea that a wandering mind is a negative mind.

The similarities and differences between the brain activity found in the visual and daydreaming phases of the task suggest that passively viewing of visual material is underpinned by much of the same activity as in daydreaming, but that it is not identical. This presupposes, of course, that participants were actually daydreaming in the, ‘daydreaming’ phase. Given the nature of the task, (an almost featureless blank screen) it is hard to envisage what else participants might be doing in this phase other than daydreaming. Furthermore, the questionnaire administered as part of the debrief, suggested that participants were, indeed, daydreaming during this procedure. Unfortunately, as discussed below, some participants confirmed to be daydreaming in all phases of the task which does aid the clarification of which BAs specifically corresponded to day-dreaming events.

To further this idea, perhaps the notion of cognitive miser could be applied to give reason to the sum of similar brain activity patterns between visual and day-dreaming phases. Perhaps more commonly known as the principle of least action, this idea has most efficiently been applied to give reason to the declining frequency of task-unrelated thought as age increases (Giambra, 2000). This concept proposes that living organisms maintain the capacity to function using as little energy as possible, and this idea rings true with what has been shown in this investigation. As mentioned, given the nature of the task, it is difficult to predict what participants would have been doing if not for day-dreaming. Additionally, given the lack of activity within BAs implicated in attention and working memory (i.e. BA8 BA19, BA39), it can be strongly assumed participants were in some form resting state. Both visual and day-dreaming tasks can therefore be seen to be consistent with the notion of cognitive miser. This can be assumed as cognitive demand, which was equal between these tasks, appears to have generated similar amplitudes of activity in similar areas. Moreover, when compared to N-Back, a task in which cognitive miser was not achievable, all BA's exhibited greater levels of output. With this in mind, cognitive miser aside, it can be also proposed that a resting-state brain in accordance with previous literature, should have at least been exhibiting greater neuronal activity within BAs shown to be implicated in the default-mode network (Damoiseaux et al, 2008; Greicius et al, 2009).

4.6 The restricted gateway

A key area of interest is BA10 (rostrolateral prefrontal cortex) which, as discussed in the Introduction shows peaks in activity associated with the switching of attention between internal and external domains. As such, BA10 forms a key component of the gateway hypothesis, and is involved in the switching between internal thought and the external environment (Burgess et al, 2007). Comparing EEG activity of right BA10 between the daydreaming and visual phases, the day-dreaming phase was found to elicite greater activity. This does not necessarily support the gateway hypothesis but the similar and low activity in both phases (daydreaming and visual) suggests that there was relatively little switching between internal and external domains in these phases. This was a surprising find in light of previous literature which found the switching of allocated attention to increase as cognitive demand of a task decreases (Greicius et al, 2003). In the N-Back task, however, in which cognition was essential for successful completion of the task, rostrolateral (BA10) activity appears to peak (showing more than double the level of activity compared to that during the other phases) suggestive of a switching of attention between internal and external domains. Again, this conflicts with previous literature which found peak BA10 activity during boring, mundane tasks. Interestingly, two participants self-reported to have experienced more day-dreaming during the N-Back task rather than the visual or day-dreaming intervals. This, they explained, was due to the task being too difficult to cognitively handle - which may also prove consistent with day-dreaming literature. The N-Back task was introduced to this procedure as it has been demonstrated as an ideal task to evoke working memory faculties (Owen et al, 2005; Jaeggi et al, 2010) and executive functioning (Baddeley, 2003). Thus, the instances of more frequent day-dreaming in this phase would appear to arise from issues concerning working memory capacity. This is consistent with findings which have also found working memory to be a key factor in determining the frequency of day-dreaming. In turn, this reinforces the notion of day-dreaming occurring from either too little or too much cognitive arousal. Additionally, in acknowledgment of working memory characterizing an area of cognitive control (Gazzinga, et al, 2013) this study has offered examples of how cognitive control is implicated in the onset of day-dreams. However has failed to establish clear confirmation from the gateway hypothesis.

Given that some participants reported daydreaming in the N-back task, it is of interest to see whether their brain activity showed any differences that may reflect this day-dreaming. One of the participants that reported daydreaming in the N-back task also showed atypically high activity in BA25 (ACC). Participant P1001 registered scores of .5005 for right BA25 activity (M=.2434, SD=.1465) and .6336 (M=.2385, SD=.1730) for left BA25; activity, compared to other regions, this doubled the activity of all other individuals. Thus, self-report data, coupled with EEG output may show how this participant experienced peak day-dreaming in the task with corresponding raised anterior cingulate cortex (ACC) activity. This finding is consistent with the neuroscientific claims that ACC activity increases as cognitive engagement decreases. It is of interest to note that the ACC has also been suggested to be important in emotional processing (Bush et al, 2000). On the other hand however, BA25 has been described as fundamental to somatic marker functioning (Damasio, Everitt & Bishop 1996; Bechara, 2006), which too would justify peaked activity during the N-Back phase.

In addition, Participant P1001 displayed relatively more activity in left BA11 compared to others in the N-Back task. BA11 corresponds to the orbitofrontal region (Toro & Deakin, 2005) and has previously been identified as a region interlinking sensory modalities as well as being intimately linked with the limbic system (Öngür & Price, 2000). Left amygdala activity was also significantly more pronounced in this participant during the N-Back task). Measures of activity of the amygdala using EEG should, however, be treated with caution, as the amygdala lies too deep within the brain for activity to be accurately localized there. Activity in the region of the amygdala can, however, be identified and used in source analysis.

4.7 Questionnaire data

The questionnaire following the investigation was somewhat significant in establishing trends between self-reported data and BA activity. For example, Participant P1007 described themselves as having a particularly active imagination and displayed the greatest level of activity in right BA25 during the daydreaming task. This is consistent with research showing the ACC to be involved in day-dreaming. They did however display the least amount of activity within left BA25. This is of interest when considering evidence to propose how the right hemisphere is dominant in imagination and creativity. This participant also mentioned the duration of their day-dreams being particularly minimal. This would indicate toward increased BA10 activity, as short-lived but regular day-dreams would entail frequent switching between internal and external domains. However, this participant showed relatively weak BA10 activity compared to others. Moreover, participant P1009 stated themselves not prone to day-dreaming, yet displayed 3x greater activity in right BA10 than P1007, who consider themselves fantasy prone. In addition, participant p1009 displayed the third highest activity within right BA27 and stated that only on a few occasions did their mind wander. Right BA27 corresponds to part of the hippocampal formation important to working memory (Goldman-Rakic, 1995; Korotkova et al, 2010). This could demonstrate the participants active working memory faculties inhibited any day-dreaming behavior; and exemplifies how efficient working memory can inhibits such processes(Rummel & Boywitt, 2014) - just as poor working memory has been shown to increase rates of daydreaming (Kane et al, 2007).

Other significant trends were established. P1001 stated they experienced day-dreaming in the first part of the experiment, and that the computer visual display led to thinking about previous skiing holidays. This participant showed greater activity than the rest in BA35 and 36. These regions make up the perirhinal cortex, heavily implicated in semantic memory (Davies et al, 2004; Binder et al, 2011). This participant also showed a degree of BA38 activity. This too is of interest as BA38 aids the memory of unique stimuli such as landmarks (Simmons & Martin, 2009). Then again, this participant documented the high rate of day-dreams they had as well as their proneness to day-dreaming. Despite this, P1001 showed weaker activity in both left and right hemispheres for BA25 compared to others. For example,

Participant P1012 said they are not prone to day-dreaming, but still registered higher right BA25 scores than participants that believe they are. P1012 also documented day-dreaming in the visual phase, alongside others who said they did so on several occasions throughout the three tasks. Additionally, the neuronal firing of right BA38 from participant P1012 equated to less than 10x that of the mean in the day-dreaming task. This may prove consistent with increased BA25 activity but contrasts with the self-report data which followed. The temporal pole (BA38) serves as a key facilitator to both declarative and semantic memory (Blaizot et al., 2010). Right BA27, also fundamental to memory faculties, displayed the second highest activity in the day-dreaming task however. Taken together, data may suggest this participant was recruiting working memory faculties rather than semantic-based areas. This may have been a result of concentrating on the task at hand. Participant P1012 stated to have experienced most day-dreaming throughout the visual task, this corresponded with right BA25 activity only being surpassed by participant P1007, no similar activity was found in left BA25 however. Comparing between conditions, right BA25 exhibited slightly bigger activity in the visual task rather that the day-dreaming phase. It is also interesting to see participant P1012 state only experiences of day-dreaming during the visual task when firing rates were so close between tasks. For participant P1012, the

N-Back task generated by far the most right BA25 output, which would shows to be inconsistent with both the a priori of BA25 and the detailing of most day-dreaming in the visual task.

This self-report data helps validate the similarities which were found between visual and day-dreaming tasks. This being said, the key distinctions between these phases largely entail right hemisphere activity, which again is consistent with literature showing this hemisphere to be especially important for imagination and creativity. Interestingly, participant P1012 displayed high activity in the top-ranked BAs in the daydreaming task - yet reported minimal day-dreaming. Like participant P1009, this would suggest higher rates of working memory inhibiting daydreaming. More consistent with literature, Participant P1000 stated that they day-dreamed on several occasions, and also showed the second highest activity in right BA25 in the day-dreaming phase. This participant also showed the second highest right BA25 activity in the N-Back phase but remained a significantly smaller rank within the visual stage. This may indicate more pronounced activity in right BA19, which also makes up part of the default-mode network. This participant exhibited the third highest level of activity in right BA19 during the day-dreaming phase, sixth in the N-Back phase and ninth in the visual phase. Coupled, this data shows participant P1000 showed significantly more default-mode network activity and reported higher rates of day-dreaming during the day-dreaming task. BA23 is also believed to make up part of the default-mode network and would therefore be expected to rank highly among participants in the day-dreaming phase. Interestingly, right BA23 activity ranked fifth within the day-dreaming condition. When observing the consistency of other default-mode network regions, it would have been expected for right BA23 to show higher levels of

Participant P1000 stated to have only experienced day-dreaming a few times during the procedure, though they did not specify at what point these instances occurred. Interestingly, Participant P1000 displayed second top-ranked BA25 activity in both left and right hemispheres. This is a clear contradiction with previous literature, which would have suggested greater rates of day-dreaming when acknowledging ranked default-mode network output. Similarly, during the N-Back task, Participant P1000 showed the second greatest activity in right BA25 and third in left BA25. For the visual phase however this participant's BA25 scores did not rank and therefore correspond more consistently with the self-reported data given. BA23 of both left and right hemispheres displayed somewhat below average scores during all three tasks which may more closely correspond to the self-report data given. Of interest is the link between decreased experience of day-dreaming and significantly decreased BA23 firing rates across all tasks - especially when compared to the intensity of activity found from left and right BA25. This may suggest BA23 is involved more strongly in day-dreaming due to this apparent correlation. What may also be taken from this data is that Participant P1000 stated that they never really find themselves day-dreaming without the realization that they may have entered one. Taken together, it may even be proposed that BA25 is so strongly interconnected with the networks facilitating the resting brain that prominent BA25 activity with diminished BA23 activity brings about day-dreaming lacking meta-awareness. This may also provide reason to contemplate whether different BAs which make up the default-mode network, facilitate different aspects of day-dreaming experience. BA31 in both hemispheres displayed substantially lesser than mean activity across all three tasks. If meta-awareness was present, it may be proposed that BA31 activity is not necessarily a causal factor in day-dreaming processes.

Considering previous literature, this investigation appears to have evoked varying levels of BA activity from different BAs corresponding to the default-mode network.

With this being said, the inconsistency among evoked signals from these BAs 25, 23, and 31 (particularly during visual tasks) does not appear to give credit to the current theory which suggests the default-mode network is made up of these various BAs.

Additionally, it is of interest to acknowledge the common response given by participants who, according to self-report data, experienced day-dreaming throughout the entire procedure. This may be seen to provide examples of day-dreaming occurring in its own way - at random intervals throughout the time the individual spent in the EEG net. More pertinently, the inconsistency among self-reported rates of randomly occurring day-dreams does not appear to be reflected strongly in the average rate of activity elicited by the BAs believed to correspond to the default-mode network.

4.7.1 Overview of experiment and research findings

Although more distinct patterns of data may have been expected between the three tasks, the commonalities which have been found to exist between brain activity associated with visual and daydreaming task phases generate important questions for future studies of daydreaming. Given future research may choose to adopt a similar methodological approach, but use the data from this study to guide, for example, task design. There were lessons learned in this study that could inform future research. For example, the ratio between exposure time to shapes (6 seconds) and the blank screen (54 seconds) was perhaps too great. While encouraging day dreaming in the blank phase, it is possible that there was insufficient time to fully re-engage in the visual phase.

Another lesson to be learned during this investigation concerned the usefulness of the questionnaire during the debrief. Although still maintained as a good idea - establishing self-report data to compare among source localization output was important to ensure participants consciously experienced some form of day-dream. Although it may be assumed, lacking any confirmation that participants (via the medium of the questionnaire) had some day-dreaming experience leaves only a subjective presumption that all participants did day-dream at some stage. For all intents and purposes - this seemed an appropriate option by which to proceed, and allowed for better comparisons between self-reported experience and BA activity. The lesson to be learned from this, however, is that a more thorough questionnaire, consisting of questions related to each task of the procedure may have allowed for more efficient and clear comparisons between self-reported (subjective) and BA (objective) data sets. Additionally, there is also a lack of contemporary research which has attempted to investigate daydreaming through similar methodologies. Although this may be a merit to the investigative procedure, it may also bring about uncertainties concerning the credibility and usefulness of the data itself.

Given that many modern tasks involve the passive or near-passive monitoring of visual information, the tendency to daydream during such a task is certainly worthy of further investigation. Thus, how the visual sense is truly related to the wandering mind may be a key area for future research and application. Source localization has been of great use in highlighting the brain regions which correspond to variations of a visual task. However, such analysis fails to offer insight as to how activity within these respective areas may be interlinked or how the interactions between BAs vary over a given time-frame. This issue characterises a particular limitation within source localization analysis, and should be investigated further to make sense of the neuronal communications between respective BAs, perhaps investigating whether activity may be ‘time-locked’ across different regions. When such breakthroughs are achievable, the academic world may be one step closer to understanding the specific neural processes that facilitate high order, introspective thought.

Such an understanding is crucial for understanding how humans may interact with modern technology. The current study has investigated the brain activity underpinning simple computer-generated tasks, some of which were designed to encourage daydreaming. Such research begins to provide some insight into how humans may interact with advanced technology.

4.8 A New Age of Thinking

Over more recent years, some have begun to contemplate how the modern way of life and all it entails may be impacting on the way the mind functions and thinks. Neuroscience has long provided reason to propose how the physical structure of the brain can be changed through experience and practice, but it is only of recent years that it has been demonstrated just how malleable the human brain is. From a psychological background, it is relatively old news that the early years of life are crucial to the developing brain and how the physical developments of the brain help facilitate a greater spectrum of cognitive capabilities. Yet it is only of recent years that the classical neuroscientific assumption of the adult brain being a specific-purpose machine which could not be repaired, manipulated or altered (Zuger, 2007) has been readdressed - and the results of such insights may make for worrying comprehension. The modern individual's sensory world may be dominated by the latest smart phone in their pocket, and this radically changes the way in which humans explore, interact with, and ultimately live within, the world. The results of recent insight into how technology impacts on the brain has made it clear that this may very well be the case. However, based on the understanding that the modern world is now so reliant on the technology that is being shown to alter how brain regions communicate and interact, at what point will such findings be acknowledged?

Indeed, technology has eased the academic progression of those with cognitive impairments, and offers a means of information transfer which cannot be rivalled in terms of speed, efficacy or convenience. For example, new technology has been aimed at helping autism spectrum disorder sufferers with attaining, analysing and being able to reflect on sets of social-emotional signals transfered by head and eye movements during live social interaction (Madsen, el Kaliouby, Goodwin & Picard, 2008). Technology has been used to assist those with learning disabilities within environmental contexts (Edyburn, 2000; Lee & Templeton, 2008; Kennedy & Deshler, 2010) as it has with those who experience emotional and behavioural (Fitzpatrick & Knowlton, 2009; Anderson & Anderson, 2008). Assistive technology has been equally as successful in aiding the learning development of those with mental retardation (LoPresti, Bodine & Lewis, 2008; Alper & Raharinirina, 2006). More recent advancements have been successful in using technology to help teach schizophrenia sufferers (Sablier, Stip & Franck, 2009).

Although the merits are self-evident within particular contexts, from a psychological perspective it is becoming increasingly apparent how the modern world, so consumed and now forever dependent on such technology - is becoming progressively less likely to take note of what academic insight suggests may be the implication this may have on the way we view and use technology on a daily basis. Despite not yet being recognised as a disorder, increasing evidence suggests that excessive internet use interferes with the life and work of individuals (Flisher, 2010). The internet may have its uses, yet its convenience, coupled its unrestricting nature poses considerable risks to those with underlying psychological issues, and leaves them at high risk of developing internet addiction (Christakis, 2010). Converging evidence also suggests how behavioural addictions can also result from maladaptive internet usage (Chou, Condron & Belland, 2005). These accounts plausibly demonstrate how the convenience and usefulness of the internet can be detrimental to our psychological well-being. Worryingly, researchers established the neuronal substrates of online gaming addiction, and found the right orbitofrontal cortex, right nucleus accumbens, bilateral anterior cingulate cortex (ACC), medial frontal cortex and right dorsolateral prefrontal cortex to display abnormal activity (Ko et al, 2009). In consideration of these results, the understanding that areas of the brain as fundamental to day-dreaming as the ACC can be affected by the overuse of technology is a particularly concerning outcome -

especially in a society so dependent on the internet and the latest technological hardware. Zhou et al (2011) has also found internet addiction to correspond with grey matter abnormalities. fMRI was performed on 38 college students, 19 made up the control group, with the other 19 students suffering from internet addiction disorder (IAD). Compared to controls, a regional homogeneity method showed IAD sufferers to display increased activity within the cerebellum, right cingulate gyrus, bilateral hippocampus, right frontal lobe, left superior frontal gyrus, right middle occipital gyrus, right inferior temporal gyrus, left superior temporal gyrus and middle temporal gyrus (Liu, Gao, Osunde, Li, Zhou, Zheng & Li, 2010). Internet gaming disorder sufferers have also been shown to have negative functional connectivity between the dorsolateral pre-frontal cortex, temporal lobe and striatal areas (Han et al, 2014). The dorsolateral pre-frontal cortex especially has been shown to be important in day-dreaming. In addition to this, internet gaming disorder is now such prevalent issue that it qualifies as a recognised disorder within the DSM-5 (Petry & O'Brien, 2013).

Whilst the essence of this work is the neurological relationship between daydreaming and cognitive arousal, future research into those areas of the brain structure which may be affected by the use of emerging technologies and it relationship to daydreaming could be conducted on the basis of this research.

Numerous brain regions within those mentioned above have been implicated in how day-dreaming is facilitated and experienced by the individual. IAD sufferers may well experience day-dreams which would appear abnormal to the average individual. In addition to this, if there is truth behind the proposal that day-dreaming results from coherent synchronisation among respective brain regions; evidence to show how so many different brain areas can exhibit abnormal activity as a result of internet overuse would indicate that the issue concerning technology and its effects on the brain is a significantly bigger issue than we realise, or perhaps more appropriately, acknowledge.

Additionally, attentional deficits and depression have been intrinsically linked with IAD (Yen et al, 2007; Young & Rodgers, 1998; Ko et al, 2008) and failures within cognitive control (Brand, Young & Laier, 2014).

Coupled with the research that has already been shown, the understanding that overuse of the technologies can interfere with both the neuroplasticity of the brain and be detrimental to attentional faculties evidently poses great issues for how daydreaming will be manifested in the developing generations. What is perhaps more concerning, is evidence to show how adolescents with IAD showed microstructure abnormalities within the brain (Yuan et al, 2011).

This may be considered particularly vital as it can now be stressed objectively the importance of structural development during adolescence and how neurological complications during this vital stage of development can be devastating for future development. In addition to this, Yuan et al (2011) also obtained evidence to show how time spent using the internet correlates with reduced gray matter volumes in the dorsolateral pre-frontal cortex, rostral anterior cingulate cortex and supplementary motor area.

With this being said, it would seem there has never been a more appropriate time to demonstrate, not only to academic circles, but to the wider society just how much of an impact the 21st century way of life is quite literally altering their brain. Although such information is likely to be interpreted in various ways, the most alarming prospect concerns the new and developing generations which have only ever known to have the latest internet-based hi-fi gadgets that are capable of fulfilling their every need. In acknowledgment of this, it is a clear possibility that research into day-dreaming may reveal insights into the impact of new technology. It would appear, from a neuroscientific perspective at least, that day-dreaming as we know it is changing with the world around us.

4.9 Stimulus-independent thought: day-dreaming or mind-wandering?

The lack of consensus among academics when approaching studies into day-dreaming is evidently a key issue. This problem questionably has an impact on how researchers go about scientifically investigating day-dreaming, as some appear to use key terminologies interchangeably; whereas others appear to stick to specific terms to refer to the experience one has when their mind drifts away from the current task. For example, the term mind-wandering has been applied to describe task-unrelated thoughts and images, as well as stimulus-independent thought, drifting off or zoning-out (Smallwood et al, 2006). Yet new research has proposed that the process of stimulus-independent thought is also known as day-dreaming or mind-wandering (Kucyi et al, 2014). This remains a particular issue when conducting day-dreaming research.

Additionally, if one chooses to view day-dreaming as endogenous-orientated - a means of internalized thought with intentionality, on what basis do researchers separate day-dreaming from introspection? These particular anomalies can be seen to reflect the current position of the phenomenon of day-dreaming in the academic community - and is therefore a major obstacle which needs addressing coherently to allow for more valid and thorough future research.

The knowledge that day-dreaming is a relatively new area for objective psychological investigation may hold promise for more agreeable terminologies in future research. Alternatively, there is an understanding that day-dreaming is spontaneous, private and sometimes ineffable by nature. This indicates no current methodological tool is able to generate consensual, generalisable outcomes that allow for clearer distinctions between the varieties of terms used to describe the same experience.

4.10 Direction for further study and conclusion

Arguably more so now than ever before, there is an imperative to scientifically investigate the neuroscience behind daydreaming. With this being said, there is no question that academic advancement will achieve increased rates of progression. However, the way in which such investigations are devised may dictate how much their outcomes have to offer current understanding. It may be beneficial to future study to adopt an investigative procedure similar to the one devised for this experiment - in that it stands a chance of not only being able to objectively establish the point at which daydreaming occurs, but through the use of modern methodologies can seek to ascertain distinct BA activity corresponding to several tasks of varying visual and cognitive difficulty. Converging evidence is truly bringing to light the neuroscience of daydreaming, yet very little research on daydreaming appears to be putting said principles into experimental contexts to investigate how it takes place in everyday contexts - which would logically appear a primary area for furthering our current view of how daydreaming takes place and why.

The experimental aspects of this thesis sought to establish whether distinct brain activity could be found in the brain during different visual tasks (Daydreaming, N-Back Visual). Combining self-report and source localization data, it has been demonstrated that different participants appeared to enter daydreaming phases through different means; whether these are instances of boredom, over- or under-cognitive arousal or more simply through the naturally occurring process that daydreaming is. The results here offer strength as well as further questioning to many key theories which current reside at the fore-front of daydreaming research. These insights have given good reason to accept some element of truth can be found within several academic explanations - and this perhaps reflects the variety of means through which daydreaming can take form in the human mind.

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Appendix 1

Participant Consent Form

This investigation will monitor brain activity during a visual task. This study is comprised of visual discrimination tasks whereby you will have to remember the information of previously shown slides in order to give the correct answer.

Participation is solely voluntary. You maintain the right, at any time, to ask any questions you may wish and withdraw some, or all information you have contributed if you so choose. At no point will you be exposed to information that may bring you discomfort or distress.

Please note: Data analysis of your results will be undertaken 3 working days after your participation, after which you will no longer be able to withdraw your data. All data is solely for the purposes of research and anonymity will be keep throughout.

Please initial boxes;

I confirm that I have read and understood the aims of the research and what I have been asked to do. I have been given the opportunity to ask questions and have had these answered to my satisfaction. ☐

I understand that my participation in this study is voluntary and I am free to withdraw at any time, without giving a reason. ☐

I understand that any data I provide will be kept secure and no material will be published which will identify me personally, and that my personal details will not be passed to any third party ☐

Signature (participant):

I____________________(print name) agree to take part in the above study.

Signature (researcher):

Date:

For any further information, please contact the researcher: s1008071@connect.glos.ac.uk

Appendix 2

Follow-up questions

1) During this experiment did you experience or go through thought processes unrelated to the task you were assigned?

2) If so, were there any occasions where you caught your mind wandering without intending it to?

3) Were there any common themes within these thoughts? Perhaps they were predominantly concerned with the past, present or future, or about yourself or others. Please specify.

4) As an individual, do you consider yourself to be particularly prone to daydreaming on a daily basis?

5) Do you ever find yourself daydreaming without realising you are doing so?

Appendix 3

Thank you for your participation in this study.

The aim of this investigation is actually concerned with daydreaming and mind-wandering thoughts during visual tasks. Disclosing the true aim of this study prior to participation would have had an impact on how you approach this procedure. With this being the case, it was essential all participants had no knowledge of this prior to taking part.

All information obtained will remain completely confidential and can be withdraw up to three days after taking part.

If you wish to contact the researcher for any reason, please feel free to do so:

S1008071@connect.glos.ac.uk

Appendix 4

Testing of parametric assumptions for RBA 28

Assessing whether the data is normally distributed can be achieved through dividing skewness and kurtosis by their standard errors. Normal distribution may be assumed so long as the critical values of + 2.58 and + 2 are not exceeded respectively. Skewness equates to 4.97964 (1.957/.393) and Kurtosis 4.96484 (3.813/.768), indicating data is not normally distributed.

Test of Homogeneity of Variances

EEG

Levene Statistic	df1	df2	Sig.
4.892	2	33	.014

Table 3.2 - Homogeneity of Variance

The assumption of homogeneity of variance has been violated in all 3 tasks in accordance with Levene's Test of Homogeneity of variances (P .05 <.14).

Robust Tests of Equality of Means

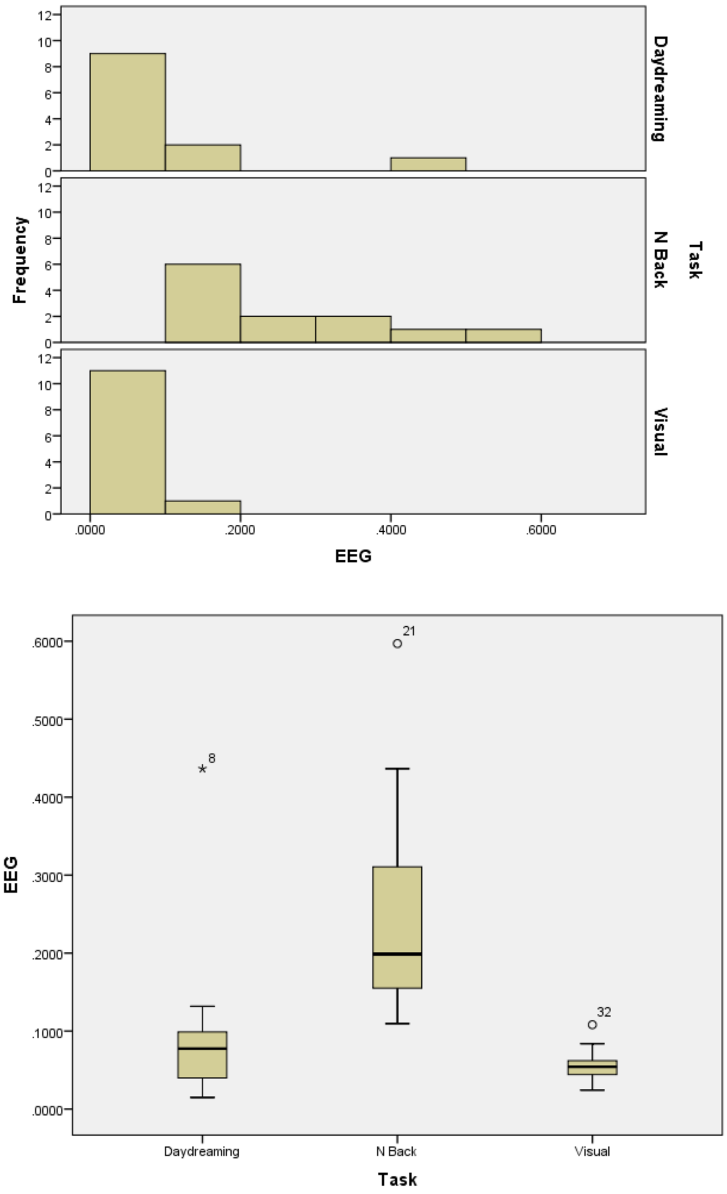
EEG

	Statistic[a]	df1	df2	Sig.
Welch	11.199	2	15.571	.001
Brown-Forsythe	11.365	2	21.470	.000

a. Asymptotically F distributed.

Table 3.3 - Table of equality means

Frequency distributions and box and whisker plots of EEG data for BA 28.



Friedman test for activity levels across task phase in rBA 28

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming	12	.0994	.11175	.01	.44
N-Back	12	.2513	.14219	.11	.60
Visual	12	.0563	.02241	.02	.11

Ranks

	Mean Rank
Daydreaming	1.88
N-Back	2.88
Visual	1.25

Test Statistics[a]

N	12
Chi-Square	16.468
df	2
Asymp. Sig.	.000

a. Friedman Test

Wilcoxon pairwise comparisons for RBA 28

Ranks

		N	Mean Rank	Sum of Ranks
N-Back RBA 28 - Daydreaming RBA 28	Negative Ranks	1[a]	1.00	1.00
	Positive Ranks	10[b]	6.50	65.00
	Ties	1[c]		
	Total	12		
Visual RBA 28 - Daydreaming RBA 28	Negative Ranks	9[d]	6.67	60.00
	Positive Ranks	3[e]	6.00	18.00
	Ties	0[f]		
	Total	12		
N-Back RBA 28 - Visual RBA 28	Negative Ranks	0[g]	.00	.00
	Positive Ranks	12[h]	6.50	78.00
	Ties	0[i]		
	Total	12		

a. N-Back RBA 28 < Daydreaming RBA 28

b. N-Back RBA 28 > Daydreaming RBA 28

c. N-Back RBA 28 = Daydreaming RBA 28

d. Visual RBA 28 < Daydreaming RBA 28

e. Visual RBA 28 > Daydreaming RBA 28

f. Visual RBA 28 = Daydreaming RBA 28

g. N-Back RBA 28 < Visual RBA 28

h. N-Back RBA 28 > Visual RBA 28

i. N-Back RBA 28 = Visual RBA 28

Test Statistics[a]

	N-Back RBA 28 - Daydreaming RBA 28	Visual RBA 28 - Daydreaming RBA 28	N-Back RBA 28 - Visual RBA 28
Z	-2.845[b]	-1.647[c]	-3.059[b]
Asymp. Sig. (2-tailed)	.004	.099	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Appendix 5

Testing of parametric assumptions for RBA 23

Testing for normal distribution was again carried out by divided Skewness and Kurtosis scores by their standard error, equating to 5.10687 (2.007/.393) and 4.88151 (3.749/.768) respectively. These scores are again higher than the necessary critical values; data therefore is not normally distributed.

Test of Homogeneity of Variances

EEG

Levene Statistic	df1	df2	Sig.
16.134	2	33	.000

Homogeneity of Variance

Homogeneity of variance was tested and has been violated according to Levene's Test of Homogeneity of Variances (P.05 <.000)

Robust Tests of Equality of Means

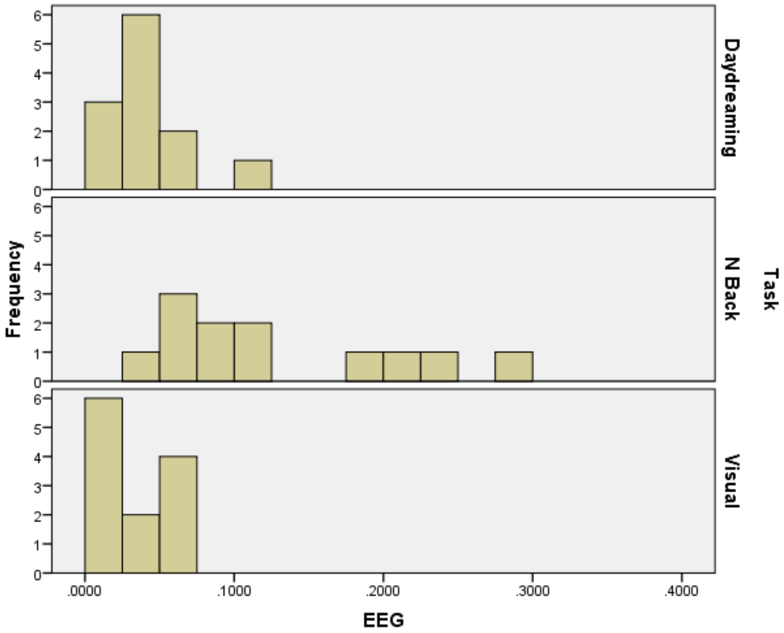
EEG

	Statistic[a]	df1	df2	Sig.
Welch	7.659	2	19.864	.003
Brown-Forsythe	14.072	2	14.640	.000

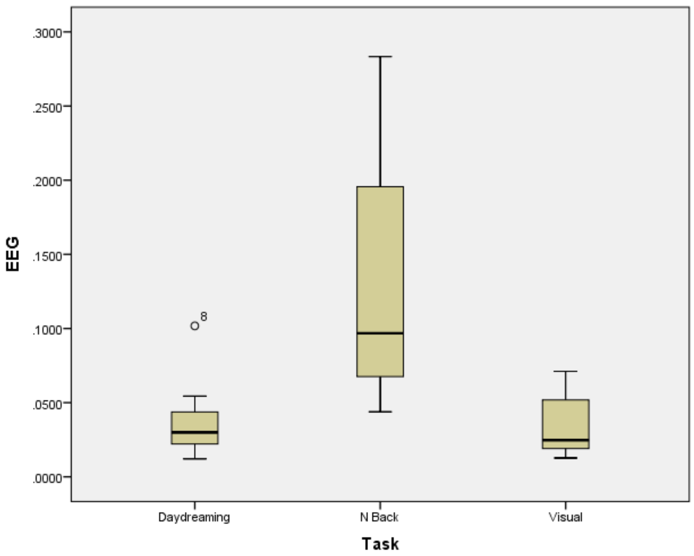
a. Asymptotically F distributed.

Table of Equality of Means

Frequency distributions for activity in RBA23



Outliers in data for RBA23



Friedman test for activity levels across task phase in RBA 23

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming RBA 23	12	.0388	.03747	.01	.15
N-back RBA 23	12	.1523	.11863	.05	.44
Visual RBA 23	12	.0369	.02392	.01	.09

Ranks

	Mean Rank
Daydreaming RBA 23	1.54
N-back RBA 23	2.96
Visual RBA 23	1.50

Test Statistics[a]

N	12
Chi-Square	16.894
df	2
Asymp. Sig.	.000

a. Friedman Test

Wilcoxon pairwise comparisons for RBA 23

Ranks

		N	Mean Rank	Sum of Ranks
N-back RBA 23 - Daydreaming RBA 23	Negative Ranks	0[a]	.00	.00
	Positive Ranks	11[b]	6.00	66.00
	Ties	1[c]		
	Total	12		
Visual RBA 23 - Daydreaming RBA 23	Negative Ranks	6[d]	6.50	39.00
	Positive Ranks	6[e]	6.50	39.00
	Ties	0[f]		
	Total	12		
Visual RBA 23 - N-back RBA 23	Negative Ranks	12[g]	6.50	78.00
	Positive Ranks	0[h]	.00	.00
	Ties	0[i]		
	Total	12		

a. N-back RBA 23 < Daydreaming RBA 23

b. N-back RBA 23 > Daydreaming RBA 23

c. N-back RBA 23 = Daydreaming RBA 23

d. Visual RBA 23 < Daydreaming RBA 23

e. Visual RBA 23 > Daydreaming RBA 23

f. Visual RBA 23 = Daydreaming RBA 23

g. Visual RBA 23 < N-back RBA 23

h. Visual RBA 23 > N-back RBA 23

i. Visual RBA 23 = N-back RBA 23

Test Statistics[a]

	N-back RBA 23 - Daydreaming RBA 23	Visual RBA 23 - Daydreaming RBA 23	Visual RBA 23 - N-back RBA 23
Z	-2.934[b]	.000[c]	-3.059[d]
Asymp. Sig. (2-tailed)	.003	1.000	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. The sum of negative ranks equals the sum of positive ranks.

d. Based on positive ranks.

Appendix 6

Testing of parametric assumptions for RBA 31

Testing for normal distribution, Skewness and Kurtosis values again were conducted, equating to 7.45038 (2.928/.393) and 11.32942 (8.701/.768) respectively. These scores would suggest that data in this analysis was not evenly distributed as both critical values were exceeded by a considerable margin, 4.87038 and 9.32942 respectively.

Test of Homogeneity of Variances

EEG

Levene Statistic	df1	df2	Sig.
12.730	2	33	.000

Table 3.2.3 – Homogeneity of Variances

Homogeneity of variance required testing as an assumption, and has been violated according to Levene's Test of Homogeneity of Variances (P<.000)

Robust Tests of Equality of Means

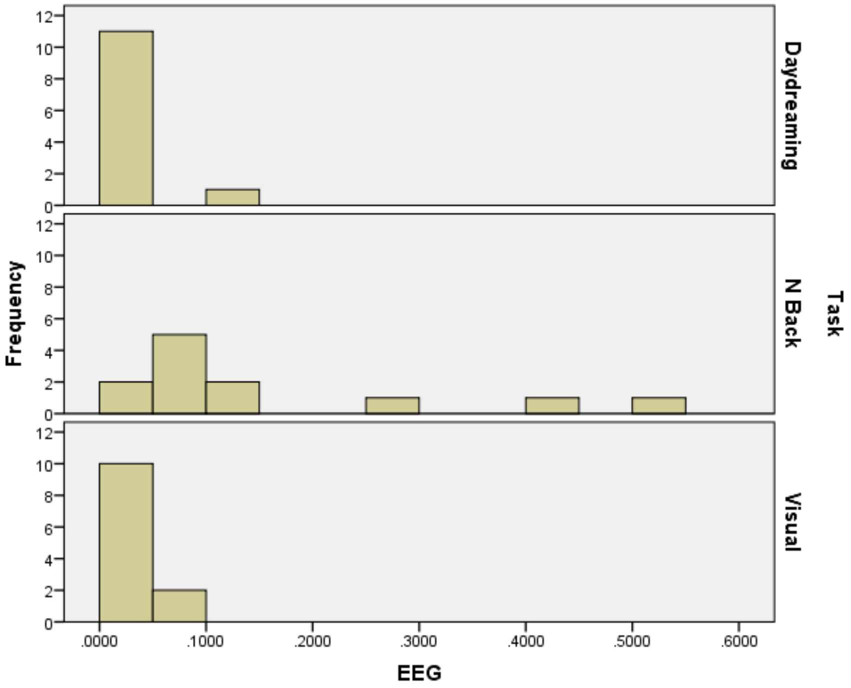
EEG

	Statistic[a]	df1	df2	Sig.
Welch	3.807	2	19.658	.040
Brown-Forsythe	7.444	2	12.748	.007

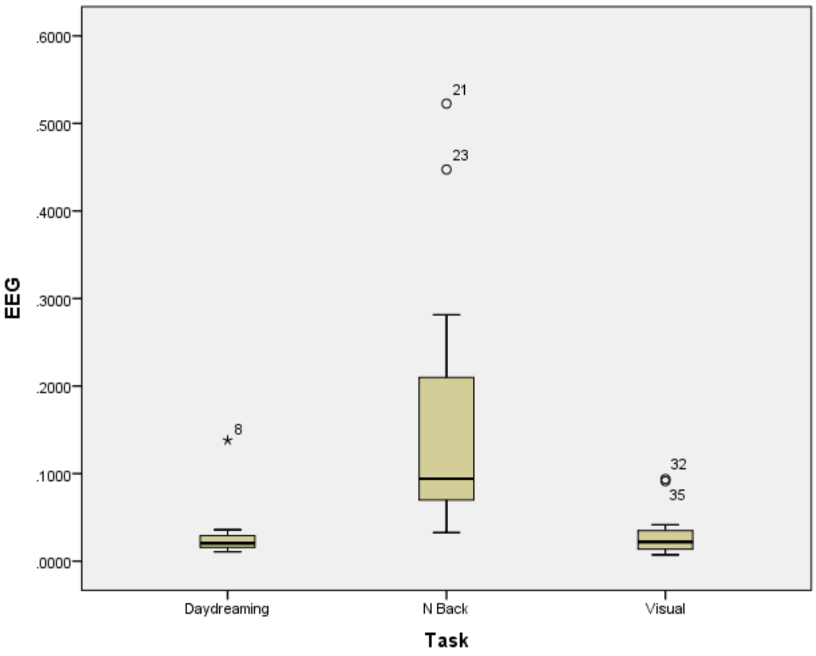
a. Asymptotically F distributed.

Table 3.2.4 – Equality of Means

Frequency distributions for activity in RBA 31



Outliers in data for RBA31



Friedman test for activity levels across task phase in RBA 31

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming RBA 31	12	.0308	.03461	.01	.14
N-back RBA 31	12	.1650	.16343	.03	.52
Visual RBA 31	12	.0319	.02984	.01	.09

Ranks

	Mean Rank
Daydreaming RBA 31	1.63
N-back RBA 31	2.96
Visual RBA 31	1.42

Test Statistics[a]

N	12
Chi-Square	17.149
df	2
Asymp. Sig.	.000

a. Friedman Test

Wilcoxon pairwise comparisons for RBA 31

Ranks

		N	Mean Rank	Sum of Ranks
N-back RBA 31 - Daydreaming RBA 31	Negative Ranks	0[a]	.00	.00
	Positive Ranks	11[b]	6.00	66.00
	Ties	1[c]		
	Total	12		
Visual RBA 31 - Daydreaming RBA 31	Negative Ranks	7[d]	6.14	43.00
	Positive Ranks	5[e]	7.00	35.00
	Ties	0[f]		
	Total	12		
N-back RBA 31 - Visual RBA 31	Negative Ranks	0[g]	.00	.00
	Positive Ranks	12[h]	6.50	78.00
	Ties	0[i]		
	Total	12		

a. N-back RBA 31 < Daydreaming RBA 31

b. N-back RBA 31 > Daydreaming RBA 31

c. N-back RBA 31 = Daydreaming RBA 31

d. Visual RBA 31 < Daydreaming RBA 31

e. Visual RBA 31 > Daydreaming RBA 31

f. Visual RBA 31 = Daydreaming RBA 31

g. N-back RBA 31 < Visual RBA 31

h. N-back RBA 31 > Visual RBA 31

i. N-back RBA 31 = Visual RBA 31

Test Statistics[a]

	N-back RBA 31 - Daydreaming RBA 31	Visual RBA 31 - Daydreaming RBA 31	N-back RBA 31 - Visual RBA 31
Z	-2.934[b]	-.314[c]	-3.059[b]
Asymp. Sig. (2-tailed)	.003	.754	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Appendix 7

Testing of parametric assumptions for RBA 9

To test for normal distribution, skewness and kurtosis scores were divided by their standard error. Skewness totalled 7.70992 (3.030/.393) and Kurtosis 13.10156 (10.062/.768). These results therefore indicate that data corresponding to BA 9 is not distributed, and as a result would be advised to treat with caution.

Test of Homogeneity of Variances

EEG

Levene Statistic	df1	df2	Sig.
6.722	2	33	.004

Homogeneity of Variances

The assumption of homogeneity of variance has been violated in accordance with Levene's Test of Homogeneity of variances (P . <.004).

Robust Tests of Equality of Means

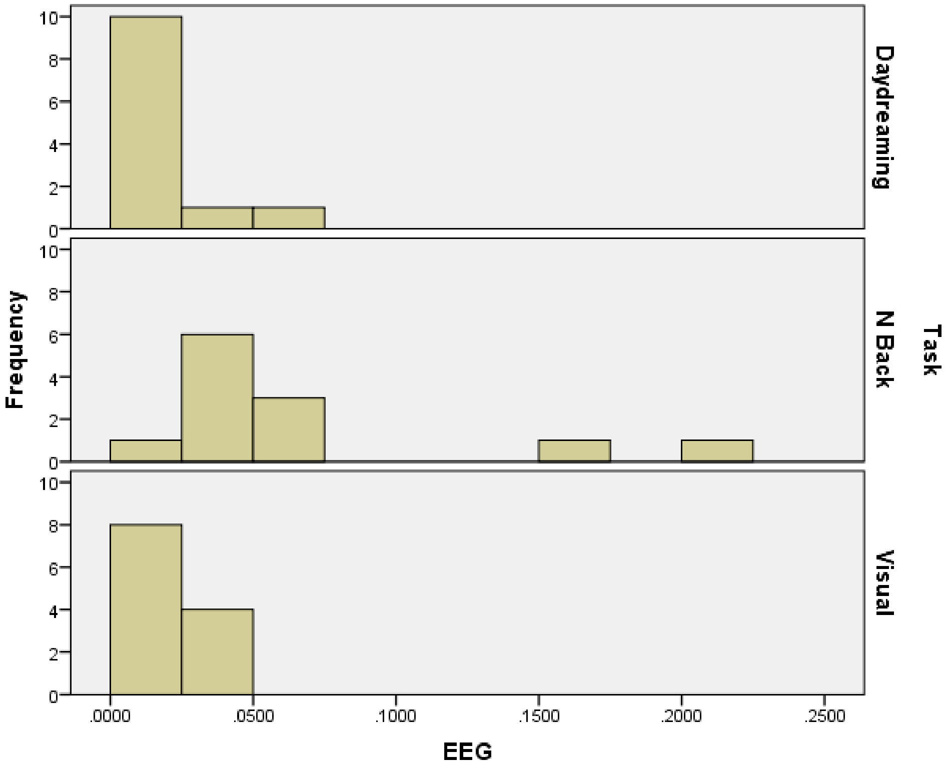
EEG

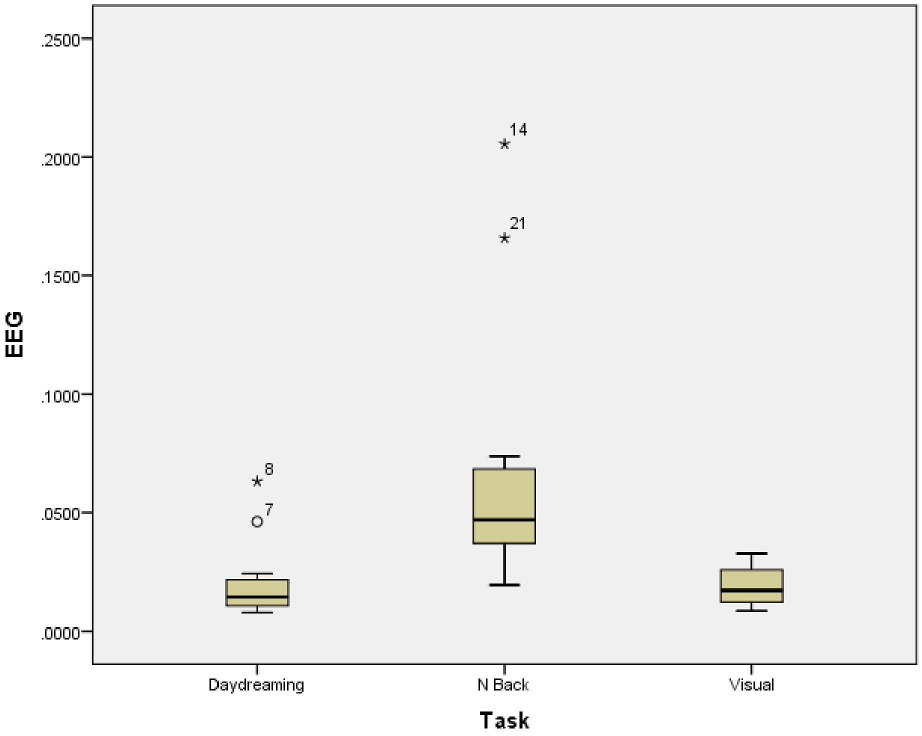
	Statistic[a]	df1	df2	Sig.
Welch	4.300	2	17.498	.030
Brown-Forsythe	7.991	2	13.401	.005

a. Asymptotically F distributed.

Equality of Means

Frequency plots for activity across phases in RBA9


Frequency
10
8
6
4
2
0
Daydreaming
N Back
Visual
Task
.0000
.0500
.1000
.1500
.2000
.2500
EEG



Friedman test for activity levels across task phase in RBA 09

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming RBA 09	12	.0160	.01435	.01	.06
N-back RBA 09	12	.0727	.04186	.02	.16
Visual RBA 09	12	.0134	.01370	.00	.06

Ranks

	Mean Rank

Daydreaming RBA 09	1.63
N-back RBA 09	2.96
Visual RBA 09	1.42

Test Statistics[a]

N	12
Chi-Square	17.149
df	2
Asymp. Sig.	.000

a. Friedman Test

Wilcoxon pairwise comparisons for RBA 09

Ranks

		N	Mean Rank	Sum of Ranks
N-back RBA 09 - Daydreaming RBA 09	Negative Ranks	0[a]	.00	.00
	Positive Ranks	11[b]	6.00	66.00
	Ties	1[c]		
	Total	12		
Visual RBA 09 - Daydreaming RBA 09	Negative Ranks	7[d]	8.14	57.00
	Positive Ranks	5[e]	4.20	21.00
	Ties	0[f]		

	Total	12		
Visual RBA 09 - N-back RBA 09	Negative Ranks	12[g]	6.50	78.00
	Positive Ranks	0[h]	.00	.00
	Ties	0[i]		
	Total	12		

a. N-back RBA 09 < Daydreaming RBA 09

b. N-back RBA 09 > Daydreaming RBA 09

c. N-back RBA 09 = Daydreaming RBA 09

d. Visual RBA 09 < Daydreaming RBA 09

e. Visual RBA 09 > Daydreaming RBA 09

f. Visual RBA 09 = Daydreaming RBA 09

g. Visual RBA 09 < N-back RBA 09

h. Visual RBA 09 > N-back RBA 09

i. Visual RBA 09 = N-back RBA 09

Test Statistics[a]

	N-back RBA 09 - Daydreaming RBA 09	Visual RBA 09 - Daydreaming RBA 09	Visual RBA 09 - N-back RBA 09
Z	-2.934[b]	-1.412[c]	-3.059[c]
Asymp. Sig. (2-tailed)	.003	.158	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Appendix 8

Testing of parametric assumptions for RBA 25

The parametric assumptions for ANOVA of BA25 were tested. In order for initial assumptions to be met. Skewness and Kurtosis values must be divided by their standard error and not exceed the critical values of +2.58 and +2, respectively. The skewness value (1.953/.393) 4.96946 exceeds its critical value of +2.58, showing this parametric assumption has been violated. The kurtosis value (3.463/.786) 4.50911 exceeds its critical value also.

Test of Homogeneity of Variances

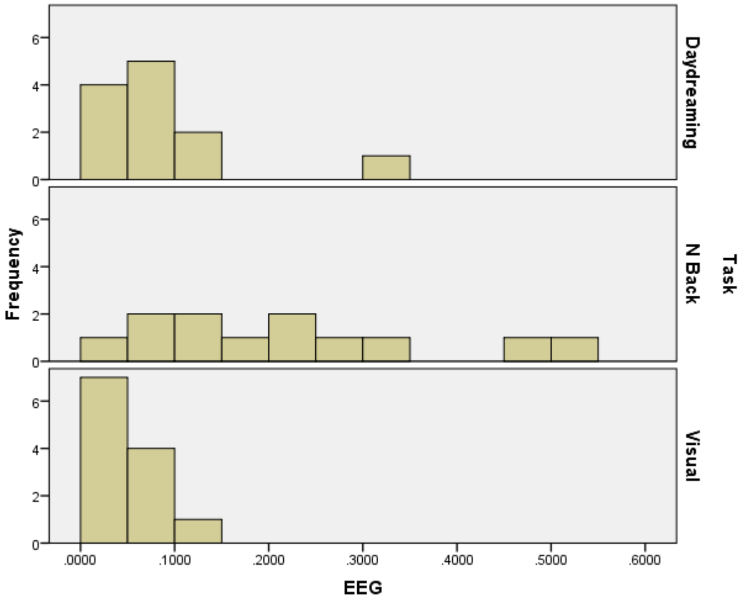
EEG

Levene Statistic	df1	df2	Sig.
7.574	2	33	.002

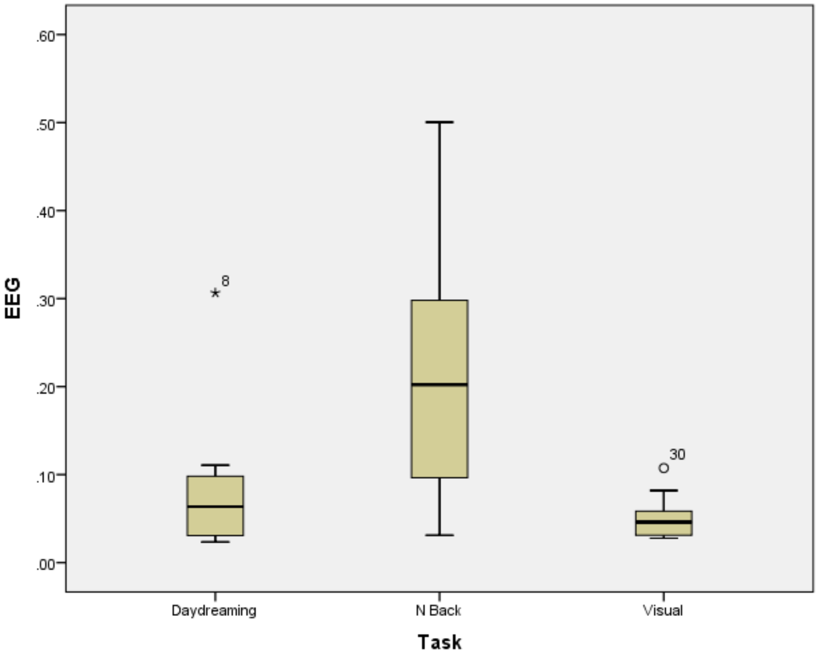
Table 3.4.2 - Homogeneity of Variances

The assumption of homogeneity of variance was violated in accordance with Levene's Test of Homogeneity of variances (P = .002).

Frequency plots for activity across phases in RBA25



Outliers within BA25



As can be seen from the graph above, two outliers were present in this study - one of which however was relatively extreme in the daydreaming condition. This graph therefore shows the data not to be evenly distributed.

Friedman test for activity levels across task phase in RBA 25

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming RBA 25	12	.0815	.07703	.02	.31
N-back RBA 25	12	.2434	.14653	.05	.50
Visual RBA 25	12	.0510	.02394	.03	.11

Ranks

	Mean Rank
Daydreaming RBA 25	1.54
N-back RBA 25	2.96
Visual RBA 25	1.50

Test Statistics[a]

N	12
Chi-Square	16.894
df	2
Asymp. Sig.	.000

a. Friedman Test

Wilcoxon pairwise comparisons for RBA 25

Ranks

		N	Mean Rank	Sum of Ranks
N-back RBA 25 - Daydreaming RBA 25	Negative Ranks	0[a]	.00	.00
	Positive Ranks	11[b]	6.00	66.00
	Ties	1[c]		
	Total	12		
Visual RBA 25 - Daydreaming RBA 25	Negative Ranks	6[d]	8.50	51.00
	Positive Ranks	6[e]	4.50	27.00
	Ties	0[f]		
	Total	12		
Visual RBA 25 - N-back RBA 25	Negative Ranks	12[g]	6.50	78.00
	Positive Ranks	0[h]	.00	.00
	Ties	0[i]		

Total	12		

a. N-back RBA 25 < Daydreaming RBA 25

b. N-back RBA 25 > Daydreaming RBA 25

c. N-back RBA 25 = Daydreaming RBA 25

d. Visual RBA 25 < Daydreaming RBA 25

e. Visual RBA 25 > Daydreaming RBA 25

f. Visual RBA 25 = Daydreaming RBA 25

g. Visual RBA 25 < N-back RBA 25

h. Visual RBA 25 > N-back RBA 25

i. Visual RBA 25 = N-back RBA 25

Test Statistics[a]

	N-back RBA 25 - Daydreaming RBA 25	Visual RBA 25 - Daydreaming RBA 25	Visual RBA 25 - N-back RBA 25
Z	-2.934[b]	-.941[c]	-3.059[c]
Asymp. Sig. (2-tailed)	.003	.347	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Appendix 9

Testing of parametric assumptions for RBA 27

Test of Homogeneity of Variances

EEG

Levene Statistic	df1	df2	Sig.
6.557	2	33	.004

Table 4.1.3 - Homogeneity of Variances for BA27

In order for normal distribution to be accepted, skewness and kurtosis values must be assessed. The Skewness value equates to 5.42493(2.132/.393), significantly higher that the critical value of +/-2.58. The Kurtosis value for BA 27 was 6.14843 (4.722/.768), also considerably higher than its critical value of +/- 2, showing data has in this case is not normally distributed and therefore leaves the parametric assumptions violated.

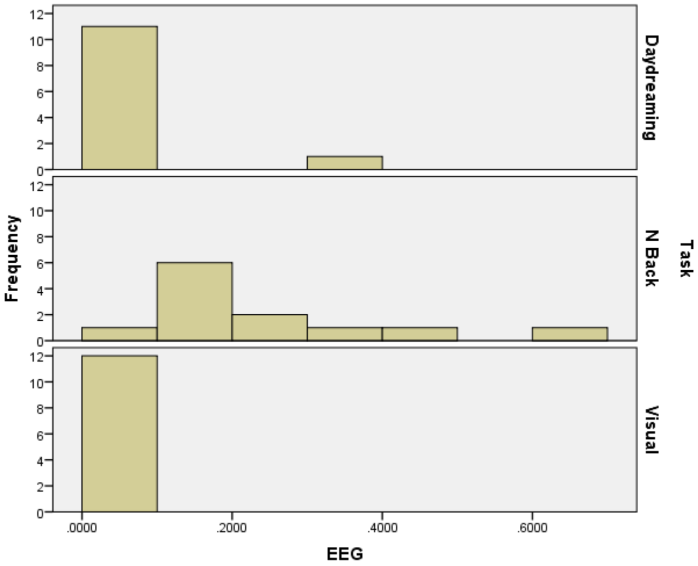
Robust Tests of Equality of Means

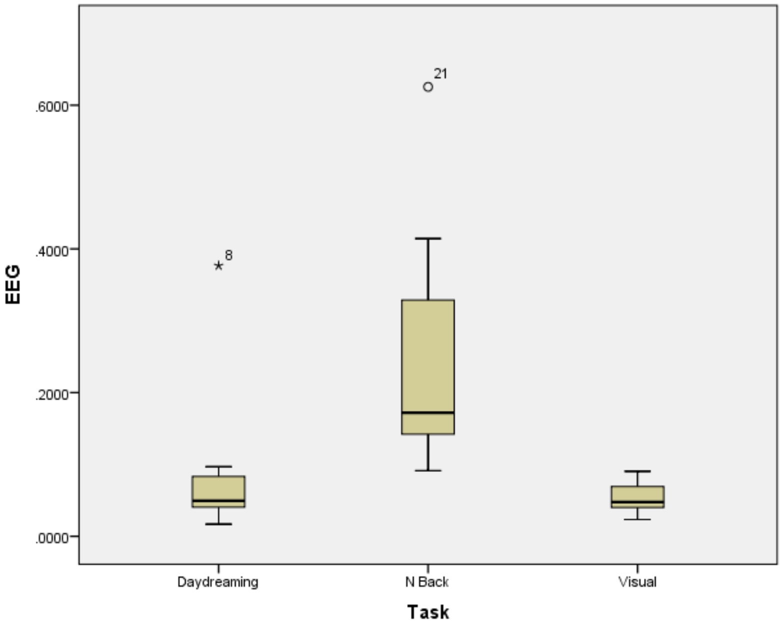
EEG

	Statistic[a]	df1	df2	Sig.
Welch	9.017	2	15.659	.002
Brown-Forsythe	11.549	2	18.796	.001

a. Asymptotically F distributed.

Table 4.1.4 - Equality of Means for BA27





Friedman test for activity levels across task phase in RBA 27

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Daydreaming RBA27	12	.0817	.09592	.02	.38
N-back RBA 27	12	.2470	.15602	.09	.63
Visual RBA 27	12	.0536	.02189	.02	.09

Ranks

	Mean Rank
Daydreaming RBA27	1.63
N-back RBA 27	2.96
Visual RBA 27	1.42

Test Statistics[a]

N	12
Chi-Square	17.149
df	2
Asymp. Sig.	.000

a. Friedman Test

Wilcoxon pairwise comparisons for RBA 27

Ranks

		N	Mean Rank	Sum of Ranks
N-back RBA 27 - Daydreaming RBA27	Negative Ranks	0[a]	.00	.00
	Positive Ranks	11[b]	6.00	66.00
	Ties	1[c]		
	Total	12		
Visual RBA 27 - Daydreaming RBA27	Negative Ranks	7[d]	7.43	52.00
	Positive Ranks	5[e]	5.20	26.00
	Ties	0[f]		
	Total	12		
Visual RBA 27 - N-back RBA 27	Negative Ranks	12[g]	6.50	78.00
	Positive Ranks	0[h]	.00	.00
	Ties	0[i]		
	Total	12		

a. N-back RBA 27 < Daydreaming RBA27

b. N-back RBA 27 > Daydreaming RBA27

c. N-back RBA 27 = Daydreaming RBA27

d. Visual RBA 27 < Daydreaming RBA27

e. Visual RBA 27 > Daydreaming RBA27

f. Visual RBA 27 = Daydreaming RBA27

g. Visual RBA 27 < N-back RBA 27

h. Visual RBA 27 > N-back RBA 27

i. Visual RBA 27 = N-back RBA 27

Test Statistics[a]

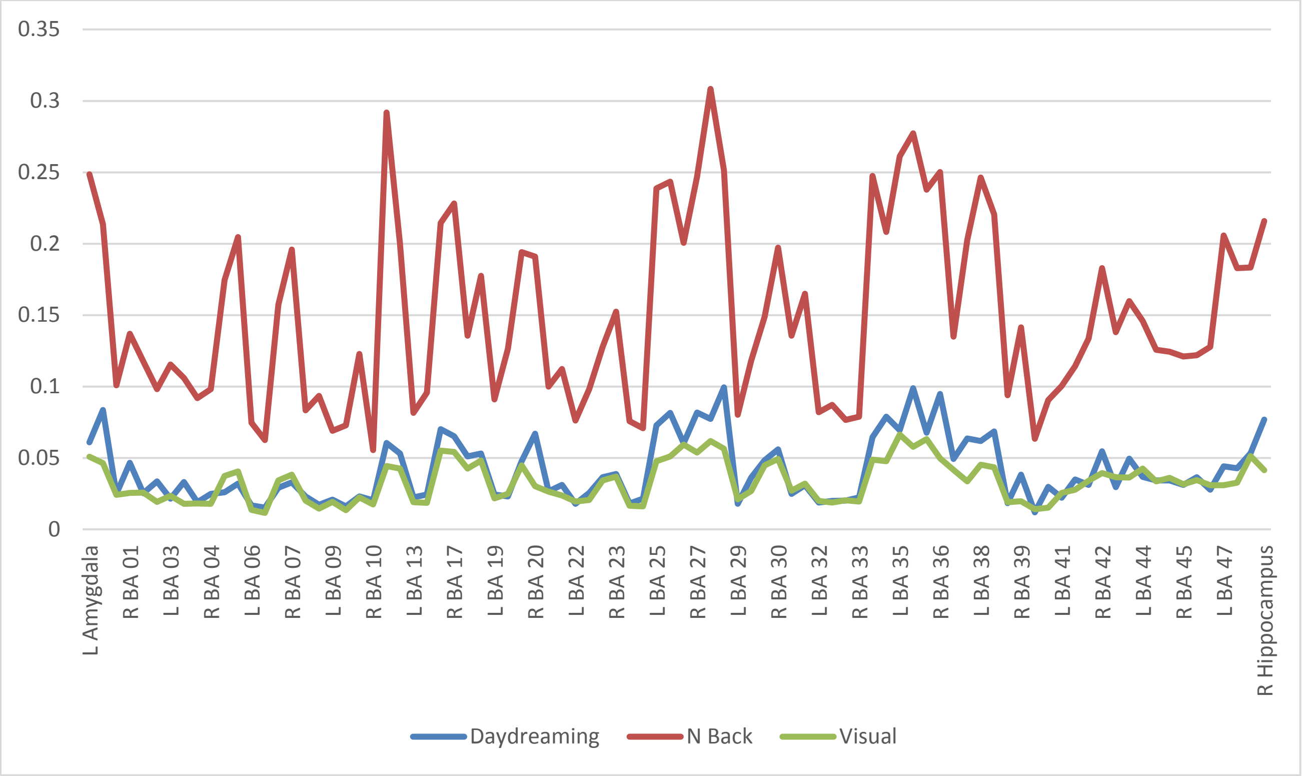
	N-back RBA 27 - Daydreaming RBA27	Visual RBA 27 - Daydreaming RBA27	Visual RBA 27 - N-back RBA 27
Z	-2.934[b]	-1.020[c]	-3.059[c]
Asymp. Sig. (2-tailed)	.003	.308	.002

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

Appendix 10


0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
L Amygdala
R BA 01
L BA 03
R BA 04
L BA 06
R BA 07
L BA 09
R BA 10
L BA 13
R BA 17
L BA 19
R BA 20
L BA 22
R BA 23
L BA 25
R BA 27
L BA 29
R BA 30
L BA 32
R BA 33
L BA 35
R BA 36
L BA 38
R BA 39
L BA 41
R BA 42
L BA 44
R BA 45
L BA 47
R Hippocampus
Daydreaming
N Back
Visual