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RESEARCH REPORT

INSIDE OUR HEADS: AN INVESTIGATION INTO VISUAL ANALYSIS AND DETECTION USING THE EEG

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A research project submitted in partial fulfilment of the requirements for the degree of MA by coursework and Research Report in the field of Organisational Psychology in the Faculty of Humanities, University of the Witwatersrand, Johannesburg

Declaration

I declare that this research is my own, unaided work. It has not been submitted before for any other degree or examination at this or any other University

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Abstract

The aim of this research is to examine the neurological processes involved in visual analysis tasks in terms of networks within the brain. It aims to examine these processes while considering the antecedents of visual analysis skills; specifically concentration spans, properties of the target, and signal detection characteristics such as the hit rate and reaction time. It posited that detection is positively associated with neural activity.

A Pseudo quasi-experimental, cross sectional, within subject's design that utilises a quantitative method of investigation was undertaken in order to determine whether this postulation held any merit. The study involved the participation of 8 volunteer students; each participant completed a demographic questionnaire as well as the New General Self-Efficacy Scale. They then underwent EEG recording while completing a 30 minute visual analysis task – ScanX.

Results drawn from this research indicate that there is some association between neural activity and detection within the Alpha 1 and Theta frequency band. Time on task results in decreased neural activity in the Alpha 1, Alpha 2 and Beta 1 frequency band. False alarms had no significant associations with neural activity; yet neural activity indicated an association with misses. Self-efficacy was assessed in terms of reaction time and this yielded no significant result.

Limitations, as well as theoretical and practical implications, of this study are considered. Finally, the study suggests further possible lines of research that could elaborate on the relationship between detection and neural activity.

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Chapter One: Introduction and Rationale

The search for and detection of visual stimuli is ubiquitous within everyday tasks and functions, it pervades everyday task behaviour; it is also involved in a number of professed vigilance intensive jobs (e.g. military surveillance, air-traffic control, cockpit monitoring, seaboard navigation, industrial process/quality control, nuclear power plant regulation, robotic manufacturing) (Reinerman-Jones, Matthews, Langheim, & Warm, 2011; Wickens & McCarley, 2008). It is a procedure involving “the processing of many complex, constantly changing visual networks” (Howard, Troscianko, Gilchrist, Behera, & Hogg, 2009, p.1); hence it involves an array of visual analysis skills. These skills encompass those associated with attention, perception, vigilance, and visual search; and while the visual systems and neurological processes associated with these constructs have been studied extensively over the years, relatively little is known about the neurological processes in visual analysis type tasks (Parasuraman, 2011).

Attention and perception are the overarching paradigms within which visual analysis would be considered (Parasuraman, 1998). “Attention is not a single entity but the name given to a finite set of brain processes that can interact, mutually and with other brain processes, in the performance of different perceptual, cognitive, and motor tasks” (Parasuraman, 1998, p. 3) and perception involves the analysis of the sensory information attended to – it is entirely dependent on an individual’s ability to attend and retain attention (Pike & Edgar, 2005; Naish, 2005). Attention and perception allow us to “break down the problem of understanding a visual scene into rapid series of computationally less demanding, localised visual analysis problems” (Itti & Koch, 2001, p.2). In this sense, visual analysis occurs when smaller facets of information are loaded onto a pre-existing notion – it is thus a form of visual mapping (Itti & Koch, 2001; Koch & Ullman, 1985).

Visual analysis is a relatively new conceptualisation associated with tasks that involve signal detection skills; as such it can be considered a facet of visual search (Itti & Koch, 2001). Visual search is defined by Wickens and McCarley (2008, p. 63) as “an effort to detect or locate an item whose presence or position within the search field is not known a priori”. Visual analysis facilitates this task by breaking the visual spectrum into parts, analysing the components, and comparatively determining whether the item identified matches the one which the individual is searching for (Mangun, 1995). It is thus generally considered to be a procedure involving "sustained attention and the processing of many complex, constantly changing visual elements" (Howard, Troscianko, Gilchrist, Behera, & Hogg, 2009, p. 1).

Due to the fact that effective visual analysis involves sustained attention, the term is often connected to that of vigilance (Zentall, 1985). Vigilance is a construct that was studied extensively in the proverbial early days of human factor research; at which time it was considered as a process of sustaining attention while monitoring a prescribed visual field in an effort to detect signals (Mackworth, 1957 as cited in Mackworth, 1969; Donald, 2001). Vigilance is thus a fundamental component of attention; it has a significant impact on performance in a variety of situations and contexts (Breckel, Giessing, & Theil, 2011); the knowledge accumulated regarding its premises spans decades (Procter & Vu, 2010). Research on vigilance has never ceased, yet its prominence within psychological literature did decrease around the 1980s and early 1990s (Proctor & Vu, 2010). That being said, there has been a recent resurgence of interest in the construct, and more specifically contemporary research has increasingly focused on the underlying concept of visual analysis and detection in the vigilance process (Donald, 2011).

There are multiple reasons for this reoccurrence and deeper inquiry into vigilance. Specifically, Procter and Vu (2010) suggest that the prominence of automation – which redefines the role of operator from "active controller to passive monitor" (p. 629) – within modern industry has prompted this reinvestigation. Moreover, the changing contextual dynamics within industry have made jobs associated with visual analysis and vigilance more complex. It is thus necessary to consider that effective detection of stimuli rests on more than merely vigilance levels. Other processes such as visual analysis are also important, as well as the nature of the displays being monitored or searched, and the properties of the target (Donald, 2011).

In addition to this, relatively little is known about the neurological processes in visual analysis type tasks, although the visual systems associated with perception and vision in the brain have been studied extensively (Parasuraman, 2011). Furthermore, "the detection of stimuli involves decision processes as well as sensory processes" (Weiten, 2007, p. 121) and it is therefore required that one considers how this has a bearing on visual analysis activities.

It is thus necessary to situate vigilance and visual analysis within an area of investigation that takes into account its multifaceted nature, one way of doing this is to consider it within a new field of inquiry known as – neuroergonomics. Neuroergonomics is a relatively new discipline in the realm of organisational psychology and it focuses on the "neural basis of perceptual and cognitive functions associated with seeing, hearing, attending, remembering, deciding and planning in relation to technologies and settings in the real world" (Parasuraman & Rizzo, 2007, p. 3).

In essence, neuroergonomics advocates investigation into processes, such as vigilance and visual analysis, utilising brain imaging techniques in a real world context (Parasuraman & Rizzo, 2007; Parasuraman, 2011). Due to advancements in brain imaging technology, in that "an incredible amount of reliable and worthwhile research of the human EEG has been accomplished, particularly during the last decade" (Kaiser, 2000, p. 71), researchers have identified various networks within the brain associated with vision (Posner & Raichle, 1994). These networks specify which areas of the brain are associated with attention, vigilance, and visual perception respectively. Despite the extensive research conducted to determine these networks, relatively little is known about how these networks interact and process information in a visual analysis type task – explicitly these processes in relation to perception and decision making (Itti & Koch, 2001). Moreover, previous research in vigilance studies have used considerably simpler stimuli and thus the context in which the construct has been tested is simplistically simulated, in order to garner more real world knowledge, it is necessary to utilise complex visual stimuli which replicate the ambiguity of real world tasks (Donald, 2011).

Due to the fact that visual analysis is inherent in numerous everyday activities and is a fundamental component of an array of vigilance intensive jobs; this study aims to examine the neurological processes involved in visual analysis tasks in terms of networks within the brain. It aims to examine these processes while considering antecedents of visual analysis skills; specifically concentration spans, properties of the target, and signal detection characteristics such as the hit rate and reaction time (Donald, 2011). Additionally, it aims to briefly consider how the decision processes aforementioned manifest themselves in neurological activity. In order to garner a deeper understanding of visual analysis processes an EEG machine was used. The findings of this research may have implications for the way in which jobs that require a high level of visual analysis are designed.

Chapter Two: Theoretical and Conceptual Background

In order to investigate a concept it is necessary to ascertain what spheres of research underpin the conceptualisation thereof, to explore the ways in which previous researchers have defined and negotiated that topic, and to critically examine the various methods utilised to reach that conceptualisation. The following explores the foundational research associated with visual analysis and detection, it surveys associated elements, and it demonstrates appropriate methods of investigation.

Visual Analysis and Effective Detection

Effective detection is largely linked to *accuracy* in perceiving a provided stimulus (MacMillan, 2002). For the purposes of this research it refers to the ability to correctly identify or perceive a change in a target object. In considering effective detection there are several ways to categorise the degree to which it occurs. The possible outcomes associated with effective detection include: hits, misses, false alarms, and correct rejections (Weiten, 2007). A change in a target object – an object wherein a change is expected to occur (Wickens & McCarley, 2008) – elicits one of these responses. A hit occurs when an individual correctly identifies a change in a target object; conversely a miss occurs when an individual fails to detect a change (Wickens, 2001). A false alarm is an error that arises when the occurrence of a target object is reported despite the fact that it did not occur, and a correct rejection refers to an event where no change is reported due to the fact that no change occurred (Wickens, 2001; Abdi, 2007).

Critically, in order for detection to be effective it needs to be attended to (Smith & Ratcliff, 2009; Nickerson & Olariu, 2007). Given this notion that detection is mediated by "attention," it is important to specify exactly what is meant by this term, because according to Rensink (2002), several different meanings can be ascribed to it. The spectrum of definitions that exist for attention include: "attention is the process of concentrating on specific features, or on certain thoughts or activities" (Goldstein, 2008, p. 100); "dynamic processes of vision, which are able to select some information at the expense of or to the neglect of other information" (Enns, 2004); and, "continuous mental activity" (Wickens & McCarley, 2008, p. 2). In examining these definitions it is evident that cumulatively they represent the various aspects of attention: focused attention, selective attention, switched attention, divided attention, and sustained attention (Wickens & McCarley, 2008).

These varieties of attention presented by Wickens & McCarley (2008) build upon an infrastructure provided by Parasuraman and Davies (1984, as cited in Wickens & McCarley, 2008) and developed by Parasuraman in 1998. In an effort to devise a taxonomy of attention Parasuramen and Davies (1984, as cited in Parasuraman, 1998) distinguished three independent components of attention: selection, vigilance, and control. Each of which, have been considered to embody individual functional characteristics of attention which serve to facilitate the achievement of perceptual goals (Parasuraman, 1998). By tracking the progression of these varieties of attention it is evident that selective attention evolved out of selection, switched and divided attention developed as conceptualisations of controlled attention, and focused and sustained attention delineated themselves from the notion of vigilance.

Historically, it is this aspect of attention – vigilance level – that has been considered central to examining the effective detection of stimuli on vigilance intensive tasks (Parasuraman, 1998). Research on vigilance primarily concerned itself with establishing an understanding of why certain individuals performed better over time on stimulus detection tasks; it sought to determine what the necessary precursors to effective detection were. Moreover, it inherently linked the notion of *reaction time* – how long does it take a participant to perceive a change in the provided stimulus? (MacMillan, 2002) – to the effectiveness of detection.

The famous British neurologist Henry Head first described studies of vigilance in brain-injured patients in the 1920s (Davies & Tune, 1970). Head saw vigilance as a state of maximum physiological efficiency (Davies & Tune, 1970) yet the notion has undergone a rather significant transformation and taken on a rather different connotation in the ensuing years (Parasuraman, Warm, & See, 2000). Norman Mackworth, a neurologist–turned human factors psychologist, is credited with the modern conceptualisation of vigilance held today (Mackworth, 1969). He initiated a systematic study of vigilance during World War II; "his experiments sought to determine why airborne radar and sonar operators on antisubmarine patrol missed weak signals on their displays signifying the presence of enemy submarines in the sea below, particularly toward the end of a watch" (Warm, Parasuraman, & Matthews, 2008, p. 433-434) . In his initial explorations into the field of vigilance Mackworth (1948, as cited in Warm et al., 2008) confirmed suspicions that vigilance wanes quickly. "He found that the accuracy of signal detections declined by about 10% to 15% after only about 30 min and then showed a more gradual decline over the remainder of the watch period" (Warm et al., 2008, p. 434).

Mackworth defined vigilance as "a state of readiness to detect and respond to certain specified small changes occurring at random intervals in the environment" (1957, as cited in Mackworth, 1969, p. 18). These early experiments undertaken by Mackworth prompted a considerable body of empirical work by both basic experimental psychologists and human factors researchers (Warm et al., 2008). This research has concluded the following over the years: it is difficult to remain attentive in a situation that is not stimulating and in a situation where the occurrence of trigger factors is infrequent (Parasuraman, 1984); the maintenance of a steady state of vigilance is referred to as the vigilance level (Wickens & Hollands, 2000); and when this vigilance level wanes after a certain amount of time, it is known as a vigilance decrement (Wickens & Hollands, 2000). More specifically, "studies of sustained attention distinguish between overall vigilance, reflecting the overall level of performance on a sustained attention task, and the vigilance decrement, reflecting the ability to sustain attention over time on task" (Davies & Parasuraman, 1982, as cited in Berardi, Parasuraman, & Haxby, p. 20).

A state which characterised effective signal detection was established within the literature (the vigilance level), however recent studies have indicated that there are other factors that influence effective signal detection – factors associated with visual analysis skills (Blumberg & Kreiman, 2010; Weiten, 2007; Grill-Spector & Malach, 2004). The fact that there are multiple theoretical models associated with vigilance and the occurrence of a vigilance decrement is "testimony to how little is actually understood about what is going on at the time of watch" (Koelega, 1996, p. 280). Critically, "an individual's level of arousal is seen to impact on the motivational intensity and the individual's level of alertness, but there is not always a simultaneous change in detection efficiency during reduced arousal" (Donald, 2011, p. 69). Thus, vigilance is not a necessary prerequisite for effective detection, rather it is an element associated with effective detection. Subsequently, it is necessary to examine the wider field of visual analysis and attention in an attempt to remedy the inconsistent findings associated with what constitutes effective detection.

Visual analysis can be considered as the process whereby individuals monitor the contextual environment for various cues indicating change or activity, it refers to the process of breaking down a visual stimulus with the intention of detecting an event or change (Donald, 2011).

According to Donald (2011) and Rhyne (2006) the visual analysis skill set comprises the ability to make quick and accurate comparisons between objects, identify specific objects that are hidden or concealed in other objects, apply existing rules and procedures to find solutions to novel problems, visualise, and to make a decision where there is no clear answer or information is complete. The effectiveness of this analysis process has previously been determined by a number of elements associated with detection – eye movements, concentration spans, properties of the target, signal detection characteristics, situational awareness, goal driven attention, and task engagement (Donald, 2011). Significantly, visual analysis accounts for the fact that individual differences, in terms of decision making, have an impact on differences in detection effectiveness (Weiten, 2007).

Ballard (1996, as cited in Rose, Murphy, Byard, & Nikzad, 2002) claims ‘subject characteristics’ or individual differences influence vigilance levels. Moreover, he suggested that a clear understanding of vigilance was not possible without examining individual differences in conjunction with variables such as task parameters and environmental factors. “A greater research focus on individual fluctuations in performance over time rather than the traditional vigilance decrement curve would create an understanding of processes that reduce overall detection rates” (Donald, 2011, p. 207). Ballard (1996, as cited in Rose et al., 2002) suggested that one way in which to consider the individual differences that affect vigilance levels is from a physiological stance. Considering antecedents of vigilance levels, such as subject characteristics, that affect effective detection, falls within the realm of visual analysis research as individual characteristics influence the way a person breaks down a visual stimulus.

A significant body of literature exists, which propounds looking at the physiological or biological indicators of visual analysis facets (Koelega, 1996; Breckel et al., 2011; Pattyn, Neyt, Henderickx, & Soetens, 2007; Bearden, Cassisi, & White, 2004; Parasuraman & Rizzo, 2007; Valentino, Arruda, & Gold, 1993; Arruda, Amoss, Coburn, & McGee, 2007). For instance, researchers have examined biological gauges such as blood-flow velocity and its relationship to vigilance and task demands (Procter & Vu, 2010); they have examined eye movements in relation to vigilance and visual analysis effectiveness (Corbetta & Shulman, 2002); and more recently, researchers have begun to consider the neurobiological indicators of vigilance and visual analysis (Parasuraman et al., 2000). One of the primary ways in which this is being done, is through the use of neuroimaging technology (Parasuraman et al.., 2000).

The notion of using neuroimaging techniques to understand engineering psychology principals and fields associated with ergonomics, such as vigilance and situation awareness, is prominent in a developing discipline within organisational psychology, known as neuroergonomics. "Neuroergonomics focuses on investigations of the neural bases of such perceptual and cognitive functions as seeing, hearing, attending, remembering, deciding, and planning in relation to technologies and settings in the real world" (Parasuraman & Rizzo, 2007,p. 3).

In considering the neurobiological processes associated with visual analysis it is possible to examine both the physiological or sensory processes associated with effective detection, as well as physiological indicators of other processes associated with visual analysis. For instance, which task characteristics are associated with increased neurological activity, the degree to which decision making is evident in the time frames associated with detection and response, and the way in which task engagement and disengagement occurs during the duration of a visual analysis task.

Decision Making and Self-Efficacy

Cognitive theorists (Shalden & Newsome, 1996; Schall & Thompson, 1999; Sahraie, Weskrantz, Barbur, Simmons, Williams, & Brammer, 1997; Nichols & Newsome, 1999; Romo & Salinas, 1999) propound a distinction between two different mechanisms associated with visual processing and analysis, they suggest: "a perceptual process extracting information about different properties of the visual input", followed by a "second higher-level decision process evaluating the relevance of this visual information, in terms of the goals and expectations of the subject, in order to prepare and generate the appropriate behavioural response" (VanRullen & Thorpe, 2001, p. 454). A decision is a deliberative process that results in the commitment to a categorical proposition and it comprises diverse neural activity within the brain (Gold & Shadlen, 2007). Thus in examining visual analysis neurologically, it is critical to recall that multiple decision making networks may indicate increased neural activity despite that fact that there is no corresponding hit response (Padmala & Pessoa, 2010). It is therefore necessary to investigate factors that may influence this.

Critically, the decision making processes associated with effective detection are associated with a number of individual factors or motivational factors. Specifically, response inhibition – wherein a participant observes a change but does not indicate that a change was observed

(Padmala & Pessoa, 2010) – is a common feature associated with ineffective detection. "An implicit assumption amongst most psychological theories is that observed choices, decision times, and confidence ratings tap the same latent process" (Pleskac & Busemeyer, 2010, p. 864). That is to say that examining decision time (i.e. the time between detection and response) in conjunction with confidence or self-efficacy levels may allow for an indication of the role that personality variables may have in effective detection during a visual analysis task.

Self-efficacy is a term that was devised by Albert Bandura in the 1980s (Stajokovic & Luthans, 1998); and it refers to a personal judgement regarding "how well one can execute a course of action" (Bandura, 1982, as cited in Stajokovic & Luthans, 1998, p. 240). In other words, it refers to the level of confidence one has in one's abilities. If an individual has a strong belief in their abilities theoretically there exists more motivation to indicate a signal has been detected, as he/she is confident of their competence (Baron, 2004). Thus this study will examine whether reaction time is associated with higher levels of self-efficacy, as this is a facet that needs to be considered in terms of the individual differences that affect whether a decision is made, and how it is made.

Measuring Vigilance Performance and Visual Analysis

Due to the long standing inquiry into vigilance, there exists a multitude of methods associated with measuring vigilance levels, each of which utilises a different measure of the vigilance construct. It is necessary to consider how one defines the appropriate indices of vigilance performance and to evaluate the effectiveness of these measures. Furthermore, it is necessary to consider how the way in which we measure vigilance has changed over the years; and how the focus on the way in which effective detection is analysed lies with factors other than the vigilance level. As aforementioned, there are several key words and phrases associated with assessing effective detection within a visual analysis task, specifically the measurement of detection performance is traditionally described in terms of hits, misses, false alarms and correct rejections.

The probability of detection during some interval and the latency of the hit response (or reaction time) were initially the principal means of gauging performance (Koelega, 1996). Furthermore, false alarms were often used, sometimes combined with omissions, yielding an unintelligible 'error' measure, due to the fact the false alarms have been shown to not only be the by-product of inattention, but other personality factors such as impulsivity (Koelega, 1996). Similarly, omissions not only characterise inattention but response inhibition due to an array of underlying personality characteristics.

Critics often see these measures of vigilance as dubious and believe them to be overemphasised. This is due to the fact that recent undertakings have demonstrated that the relationship between signal detection methods and a measurement of event-related potentials is inhibited by the fact that there are various aspects of processing involved in signal detection and thus the measure has been called into question (Koelega, 1996). That is to say that, the unidimensional approach to vigilance measurement, fails to account for the other factors of effective detection that are considered to fall more within the realm of visual analysis. Hence, a wider investigation in to additional visual analysis processes is necessary.

The Quantitative EEG

> EEG is the measurement of the brain-generated electrical potential between locations on the scalp and/or with respect to a reference. Quantitative EEG (qEEG) involves the use of computers to precisely quantify electrical potentials of approximately 1–300 Hz, representing sub second measures of summated local field potentials generated in groups of cortical pyramidal neurons (Thatcher, 2011, p. 496)

This means that an EEG records the electrical energy or voltage fluctuation that occurs between two points on the scalp; this is compared to a reference where there is no electrical activity (i.e. between a point on the scalp and the earlobe) in order to determine the electrical potentials (Kold & Whishaw, 2009). A qEEG transforms this information into a numerical value representing all the frequency activity recorded over a certain period of time (Fisch, 1999).

Traditionally, vigilance studies have utilised a method of Event Related Potentials (ERPs). “Event-related potentials (ERPs) are very small voltages generated in the brain structures in response to specific events or stimuli” (Blackwood & Muir as cited in Sur & Sinha, 2009, p.70). They are time locked to a wide range of sensory, motor or cognitive events (Sur & Sinha, 2009). “They are thought to reflect the summed activity of postsynaptic potentials produced when a large number of similarly oriented cortical pyramidal neurons fire in synchrony while processing information (Sur & Sinha, 2009, p. 70).

However ERP measures have a number of drawbacks, specifically the difficulty associated with getting artefact free EEG recordings (Fu & Parasuraman, 2007). Artefact refers to the eye blinks and body movements which heavily influence the readings obtained from the EEG (Fu & Parasuraman, 2007). Moreover, ERPs are not accurate in inferring the anatomy of the underlying neural activity and they are associated with poor spatial resolution (Fu & Parasuraman, 2007). Thus ERPs were not utilised for the purposes of this study.

Quantitative EEG studies have been conducted since the 1970s, and researchers claim that in essence the qEEG offers a "real-time movie of the electrical activity of the preconscious and conscious mind at frequencies of approximately 1-300Hz" (Thatcher, 2011, p. 495). Advantages associated with using a qEEG measure of vigilance include the fact that "multi-channel EEG is digitised, edited or adjusted to remove extra cerebral artefact" (Johnstone & Gunkelman, 2003, p. 32).Explicitly, a qEEG serves as a summation of brain activity rather than at isolated areas of neural activity and it is formatted so that artefacts have little bearing on the results. Moreover, a qEEG offers the advantage of analysing EEG components that are not available through visual inspection of the EEG alone (Thatcher, 2011).

Of critical importance is the fact that the qEEG has been extensively studied and well validated, and research has found the qEEG to have reliability (Hammond, Walker, Hoffman, Lubar, Trudeau, Gurnee, & Horvat, 2004; Thatcher, 2010). qEEG provides an additional computerised, quantitative, and objective evaluation of the EEG; it represents an evolution and advancement in EEG technology that now enables one to examine statistical comparisons between groups of individuals (Hammond et al., 2004).

According to Hammond et al. (2004, p. 11) "qEEG lets us examine measures such as amplitude, absolute and relative power, power ratios across different frequency bands, inter- and intra-hemispheric asymmetries, coherence and phase-lag measurements, co-modulation, mean frequencies, and even analysis at single hertz levels". Finally, the characteristic that makes it so well suited to vigilance inquiry is its ability to localise sources of EEG activity through the use of Laplacian (source derivation), weighted average, and other montages, as well as low resolution electromagnetic tomography (LORETA) (Hammond et al., 2004) – all of which serve to render a three dimensional representation of brain activity. Thus, the level of neural activity within the vigilance network can be determined.

Furthermore, "in comparison with costly and less available neuroimaging modalities, some of which require exposure to radioactive material, the qEEG provides a relatively inexpensive, culture-free, non-invasive assessment of brain function" (Hammond et al., 2004, p. 11-12).

Thus, EEG sensitivity in identifying changes produced by a specific event may be improved by methods of quantitative EEG analyses, such as event-related spectral perturbation (ERSP). "ERSP represent analysis of event-related changes in spectral power and phase consistency across single trials time-locked to experimental events that can characterize event-related perturbations in the oscillatory dynamics of ongoing EEG signals" (Silva, Arias-Carrion, Paes, Velasques, Teixeira, Basile, Cagy, Piedade, Nardi, Machado, & Ribeiro, 2011, p. 1) Generally, ERSP is used to determine increases or decreases in power/amplitude, in a given frequency band, that reflect a decrease or increase of the underlying neuronal populations, depending on the frequency band (Silva et al, 2011).

The Visual Analysis Networks and the Vigilance Network

As early as 1970, a series of studies had demonstrated that changes in detection rates were associated with electrical activity recordable from the scalp (Davies & Tune, 1970) – electrophysiological studies support the conclusion that cortical arousal is functionally related to the overall level of vigilance or visual analysis (Parasuraman, et al.., 2000). This demonstrates the various attempts "correlate changes in various physiological measures with changes in detection rates. If changes in detection rate can be regarded as reflecting changes in the vigilance level (…) then physiological changes may also be considered to reflect changes in vigilance level" (Davies & Tune, 1970, p. 28). Moreover, studies which have utilised neuroimaging techniques (Magnetic Resonance Imaging, Electroencephalography, Magnetoencephalography, Positron Emission Tomography scans, etc.) to investigate vigilance have built a framework within which it is possible to investigate the implications of vigilance activities on certain regions of the brain (Kolb & Whishaw, 2009). These investigations firstly provided information on networks of attention within the brain and secondly isolate those specific regions of the brain that comprise the vigilance and associated visual analysis network.

According to Kold & Whishaw (2009) to date, research on attention networks have deduced the following: electrophysiological evidence from monkeys shows four different attention mechanisms – (1) a mechanism in the parietal cortex which enhances spatial attention, (2) a mechanism in the visual and posterior temporal cortex which selects objects features, (3) one in the inferior temporal region which selects objects themselves, and (4) one in the frontal eye fields which selects movements; these results are paralleled in humans when investigated utilising a PET scan; regions of the frontal lobe are also activated during response selection; and, more specifically, the anterior cingulate cortex is activated in tasks that require a response selection.

This is further reinforced by research from Posner and Rothbart (2007); Codispoti, Ferrari, Junghöfer, & Schupp (2006); and Posner (2012).

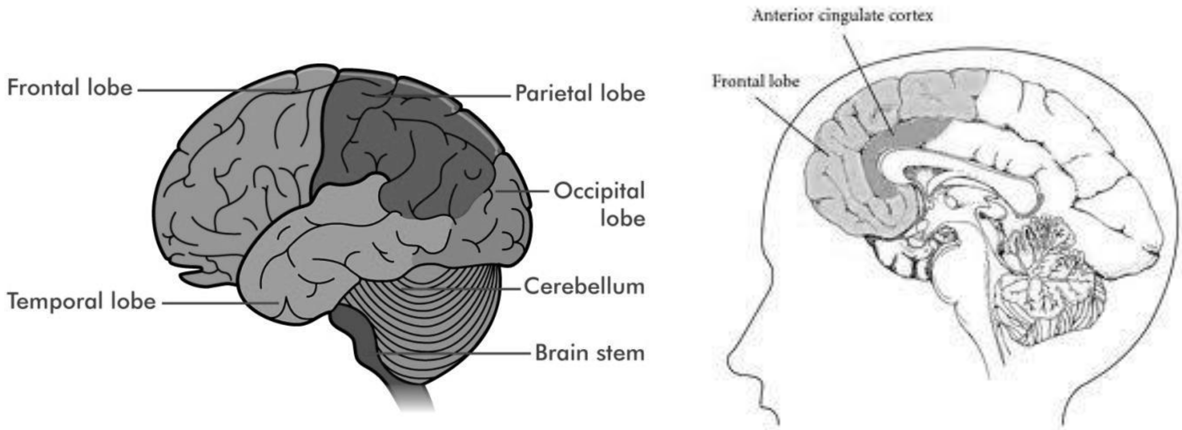


Figure 1: Diagrammatic representations of the Brain (MacMillan, 2012; Chan, Cheung, Sze, Leung, & Shi, 2011)

Due to the fact that "a major problem of attention is maintaining a sustained state of alertness" (Posner & Raichle, 1994, p. 41) the aforementioned network of attention is further deconstructed into a vigilance specific network. It is postulated that a right lateralised fronto-parietal network contributes to sustained attention or vigilance (Posner and Peterson, 1990, as cited in Breckel et al., 2011; Parasuraman et al., 2000). Within this model, "parietal regions are postulated to be associated with sensory representations of the world and spatial attention, and the frontal cortex with motor representations and planning" (Parasuraman et al., 2000, p. 236). Furthermore, Posner & Raichle (1994), and later Mulert, Jager, Schmitt, Bussfeld, Pogarell, Moller, Juckel, & Hegerla (2004), noted that the anterior cingulate quietens at the point of detection which would be consistent with its involvement in a vigilance network – "in tasks where one needs to suspend activity while waiting for infrequent signals, it is important not to carry out mental activity that might interfere with detecting the external event" (p. 175).

What is critical regarding these studies is that they have either examined the broad sphere of attention neurologically or they have taken a narrow approach and examined merely the areas associated with vigilance. As noted previously visual analysis considers a broader spectrum of facets associated with effective detection, in fact previous psychophysical studies conducted have suggested that vigilance and visual analysis involves multiple neural processes and multiple brain regions rather than a single area, as demonstrated above (Parasuraman et al., 2000), it is thus necessary to look at overall neural activity, hence the use of a full head of electrodes. That being said, the aforementioned areas have been demonstrated to be strongly related to aspects of visual analysis and recognition hence specific attention will be allocated to observing activity at and between the Fz, Cz, C3/4 (anterior cingulate gyrus), Fp2, F4, F8 (right frontal lobe), Pz, P4 (right parietal lobe) electrodes (Fisch, 1999; Thatcher, 2011; Ergenoglu, Demiralp, Bayraktaroglu, Ergen, Beydagi, & Uresin, 2004) – see figure 2. Utilising these specific regions in unison is a particularity of this research.

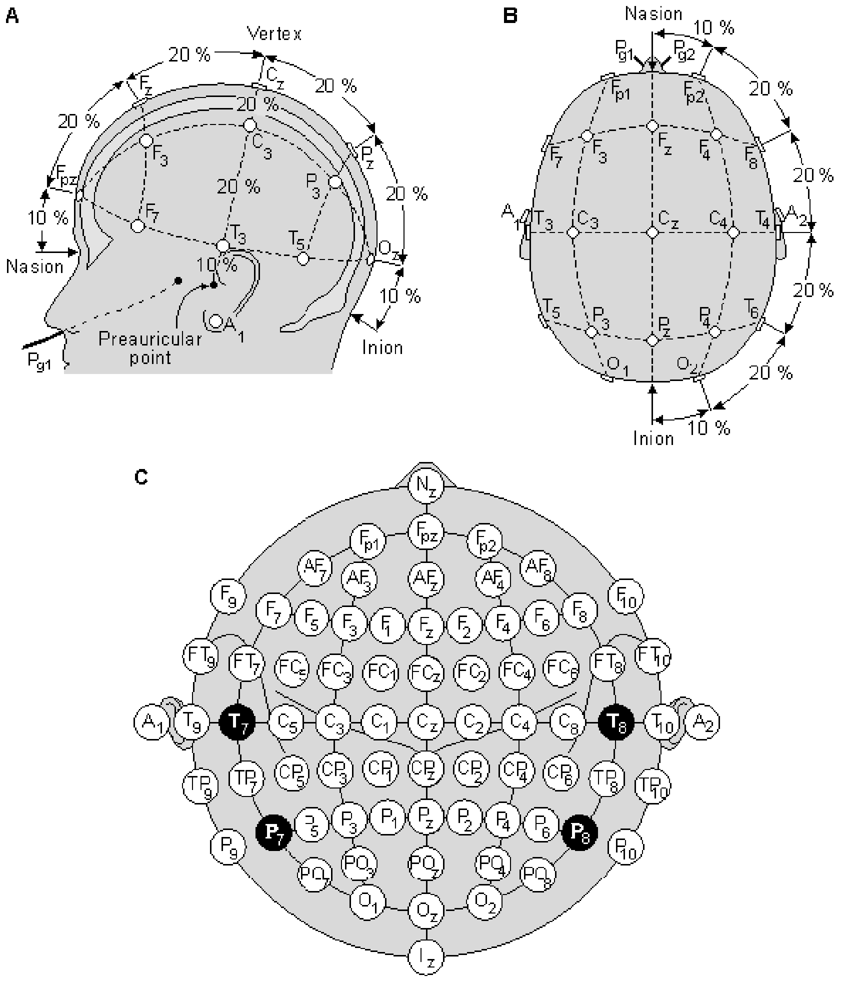


Figure 2: Electrode Placement: The international 10-20 system seen from (A) left and (B) above the head. A = Ear lobe, C = central, Pg = nasopharyngeal, P = parietal, F = frontal, Fp = frontal polar, O = occipital. (C) Location and nomenclature of the intermediate 10% electrodes, as standardized by the American Electroencephalographic Society. (Redrawn from Sharbrough, 1991)

To investigate these brain regions' involvement in visual analysis different neuroimaging approaches, such as those listed above, have been used. Yet, only a few studies (Valention, Arruda, & Gold, 1993; Arruda, Amoss, & Coburn, 2007; Breckel et al., 2011; Bearden et al., 2004; and Berka, Levendowski, Cvetinovic, Petrovic, Davis, Lumicao, Zivkovic, Popovic, & Olmstead, 2004) have investigated changes in neural activity over time and compared it to the parallel behaviour occurring as a result of a change in the vigilance level associated with ineffective detection (Breckel et al., 2011; Ergenoglu et al., 2004). Doing so with any other neuroimaging technology is difficult due to the characteristics of the technology – see below.

Table 1: Comparison of Neuroimaging Tools

		fMRI	PET	EEG	MEG
Theoretical Background	Signal Property	Magnetic property	Uptake of ligand marked positron	Collection of neural activity	Magnetic Fields produced by brain's electrical energy.
	Measurement Area	**Whole Brain Region**	**Whole Brain Region**	Surface of the cortex	Surface of the Cortex
	Time Resolution (s)	2-3	≥10	**0.01**	0.01
	Spatial Resolution	**5**	10	20	10
	Effect of extra-cortical tissue	Little	Little	Some	**None**
Measurement Setting	Invasiveness	**No**	Intravenous injection of radioactive ligand	**No**	**No**
	Body Movement	No	No	**Minor**	No
	Head Restraint	Yes	Yes	**No**	Yes
Instrument	Size	Large, fixed	Large, fixed	**Small, movable**	Large, fixed
	Transportability	No	No	**Limited**	No
	Initial Cost	Several million USD	Several million USD	**100 000 – 300 000 USD**	Several million USD
	Measurement and Maintenance cost	Moderate	Very Expensive	**Reasonable**	Moderate

(Koike, Nishimura, Takizawa, Yahata, & Kasai, 2013)

It is not always possible to simultaneously measure neurological activity and perform a visual analysis task; moreover, EEG methods are more cost effective and accessible; and, finally, it is more possible to replicate the conditions within which one would be performing a visual analysis task using an EEG machine. These “studies analysing changes in neural activity as a function of time on task reported mainly decreases in neural activity in several brain regions including the right inferior parietal cortex, the right dorsolateral prefrontal cortex, the thalamus and the posterior cingulate cortex” (Breckel et al., 2011, p. 1754).

These studies utilise coherence values between interhemispheric electrode sites – “EEG coherence is a measure of the degree of association or coupling of frequency spectra between two different time series” (Thatcher, Biver, & North, 2004, p. 2). Previous studies have identified coherence values in the “theta (4-7.5 Hz), alpha 1(8-10 Hz), alpha 2 (10.5-12.5 Hz), beta1 (13-21 Hz), and beta 2 (21.5-32 Hz) frequency bands” (Bearden, Cassisi, & White, 2004, p. 181). Beta rhythms are generally associated with states of alertness and arousal; and theta waves with less activity (Kolb & Whishaw, 2009).

It is necessary to consider whether neuroimaging indicates ineffective detection, which regions of the brain are associated with the array of processes associated with visual analysis, and how individual differences in decision making processes are reflected neurologically in order to provide a deeper understanding of the way in which attention resources wax and wane during a visual analysis task over a period of time.

Hypotheses

Given the aforementioned aim of this research is to determine whether neuroimaging indicates ineffective detection, which regions of the brain are associated with the array of processes associated with visual analysis, the central hypotheses of this research endeavour are:

Hypothesis One: *Detection is positively associated with increased neural activity in areas associated with vigilance and visual processing, specifically the anterior cingulate gyrus, the right frontal lobe, and the right parietal lobe.*

Hypothesis Two: *Detection is positively associated with the occurrence of beta activity*

Hypothesis Three: *Levels of neural activity change during the time on task*

Hypothesis Four: *High rates of false alarms are associated with lower levels of neural activity in the specified regions compared with low rates of false alarms*

Hypothesis Five: *Misses are negatively associated with neural activity*

Moreover, it aims to examine how individual differences in decision making processes affect the reaction times in a visual analysis tasks, hence:

Hypothesis Six: *Reaction time is positively associated with self-efficacy levels*

Chapter Three: Methodology

This section describes the research design, sample, procedure, analysis methods, and ethical issues associated with this study.

Research Design

This research involves manipulating an independent variable – visual analysis levels or detection, in the sense that whether detection occurs is manipulated by having participants engage in a visual analysis task. Due to the fact that data is collected for the duration of the exercise it is possible that a control exists in terms of the items for which no response is required; it is thus considered a pseudo quasi-experimental, cross sectional, within subjects design (Whitley, 2002). Furthermore both descriptive research strategies and correlational research strategies are used within this study (Whitley, 2002). Finally, the neurological nature of this study, and the subsequent small sample utilised, to lead to the study resembling a case study design (Hanley, 1996).

Sample and Sampling

This study made use of non-probability, convenience, sampling as it includes volunteer sampling and thus relied on the willingness of individuals to respond and participate.

By reason of the fact that visual analysis skills are associated with a number of different tasks and jobs, this study used a non-specialised sample, consisting of individuals with an array of different backgrounds. However, various implications ought to be considered as a result of the decision to use a non-specialised sample. Firstly, it is necessary to consider task performance. Previous studies have demonstrated that students and novices perform differently from job incumbents on visual analysis tasks that job incumbents are trained to perform in the course of their work (Donald, 2011). Secondly, participants who fall between the ages of 18 and 25 have not yet reached cortical maturity and this could affect whether neural activity is perceived in the areas previously stipulated to be associated with attention, vigilance and visual analysis (Sowell, Peterson, Thompson, Welcome, Henkenius, & Toga, 2003; Gogtay, Giedd, Lusk, Hayashi, Greenstein, Vaituzis, Nugent III, Herman, Clasen, Toga, Rapoport, & Thompson, 2004). Finally, age is often linked to facets of memory, and the effectiveness of an individuals' working memory may have a bearing on this area of inquiry (Sowell, Peterson, Thompson, Welcome, Henkenius, & Toga, 2003). That being said, these features of a diverse sample are not likely to obscure the way in which visual processing occurs, due to the fact that all participants were of a similar age and thus outliers as a result of the aforementioned considerations are unlikely in this instance.

In view of the fact that this is a neurological study, and preceding literature in the area promotes the notion that neurological studies require fewer participants to gather meaningful data, it only required a small sample (Hanley, 1996), and thus the sample consisted of eleven participants. However, due to faults with the EEG equipment three of the data sets were obscured and thus had to be neglected from the final data set – yielding a final sample size of eight participants. This may impose several limitations too this research endeavour these will be discussed in the subsequent chapter, however, it is important to remain cognisant of the fact that the increased sensitivity of EEG measures has allowed researchers to argue that fewer research participants are required (Cohen, 1988).

All participants were between the ages of 18 and 26, with a mean age of 22.6 and a standard deviation of 2.11. In terms of gender, 54.55% of the sample where male and the remaining 45.45% were female. Racially, the sample was majority white (72.73%) with the remaining participants (27.27%) being of African ethnicity. The highest level of education associated with this sample was an Honours degree (36.36%) and the lowest level of education was a Matric or grade 12 certificate (18.18%). The sample was predominantly English speaking (72.73%).

With regards to the frequency with which individuals played video games the following data emerged:

Table 2: Frequency with which participants participated in video games

Participant	Frequency (1 – Never, 5 – Often)
1	3
2	2
3	1
4	3
5	2
6	3

7	4
8	4
9	3
10	2
11	3

The mean frequency with which video games were reported being played was 2.73 thus video games were reported as played seldom to sometimes.

Procedure

The initial step in the procedure of this investigative inquiry was to approach the Human Research Ethics Committee (non-medical) of the University of the Witwatersrand and obtain clearance to carry out the research. Also of significant importance, was that a pilot study was conducted to ensure that the qEEG machine and ScanX were correctly synchronised and that all equipment was working according to the required specifications. This was done by getting the participant to start the ScanX process while I simultaneously started the qEEG recording – the motion of initiating the process would yield a larger recording than the subsequent detection, this allowed opportunity to see where the recording started and subsequently for the readings to be in sync with the ScanX analysis – this procedure was tested in the pilot and replicated in the actual study. After this, it was then necessary to get in contact with potential participants via social networking media and other networking avenues, and explain who I am, and what I intend to do with regards to my research. It was essential to explain the purpose of the research unambiguously due to the nature of data collection hence an additional information sheet explaining the process of gathering data using an EEG was provided (Appendix B).

A participant information letter (Appendix A) explaining why the topic is important, how the results of the study are useful, why individual response is important, what exactly would be required should they choose to participate, and who to contact should there be any queries regarding the research was issued. Additionally a letter of informed consent – which stated explicitly that the participants agree to undergo an EEG assessment while performing the SAMAE test (Appendix C) – was gathered. Individual sessions were conducted were participants were first asked to complete a demographic questionnaire and a Self-Efficacy scale (Appendix D); following this participants were seated in front of a laptop which had the ScanX program on it, participant information was logged on the ScanX program and the EEG machine. Participants were then linked to the EEG machine, which involved cleaning the scalp with alcohol swabs, before attaching electrodes in the 10-20 formation. Electrodes were placed were in the anterior cingulate gyrus region (Fz, Cz, C3/4), the right frontal lobe (Fp2, F4, F8), and the right parietal lobe (Pz, P4), all referenced to Cz (the reference electrode), and a forehead grounding electrode. A1 and A2 were attached for the purpose of impedance checks (as required by the Electroencephalogram). In order to comply with standards associated with EEG testing it was necessary to run an impedance test to make sure impedance was under 5Ω, in some instances it was slightly over, thus it was critical to clean the dataset and filter the data from the noise that may have been recorded.

In addition to this, due to the nature of EEG recordings, it was necessary to turn off the lights so as to avoid electrical interference. Thus, the conditions wherein the EEG was recorded were characterised by semi-darkness (limited natural light entered the room), and the room was considerably warm due to the sessions being conducted in mid-summer without an air conditioner.

In order for participants to get used to the characteristic of the task, they performed a ScanX practice exercise prior to the recording of EEG data. Participants were then asked whether they had any questions before the researcher administered the EEG recording. The researcher administered EEG recordings to 12 individuals while they performed ScanX. Twelve sessions were conducted comprising a 30 minute ScanX exercise and a demographic questionnaire (Appendix D). Unfortunately, the machine short circuited with one of the participants due to the heat and thus only 11 sets of data were collected, an additional three data sets were also obscured as a result of the electrical short circuit.

Once data had been collected from all the participants, it was formatted into a data base. This involved constructing a timeline of ScanX Triggers and establishing the hit/miss/false alarm ratio, as well as the reaction time for each of the participants. The EEG data was then analysed using the various methods indicated below and added to the data base. Analysis was then conducted in terms of the statistical tests laid out below. Results were drawn up, and a comparison of the expected versus the actual results was negotiated within the discussion associated with this research endeavour.

Measuring Instruments

This research measures two variables – visual analysis levels (in term of detection rates and effective detection quantifiers) and Neurological activity – using the SAMAE exercise (Leaderware, 1998) in conjunction with an EEG (Electroencephalography) in order to determine detection rates and the neural activity at the various instances of detection and around the instances of detection. Thus, within this research analysis levels manipulated by the visual analysis task are considered the independent variable and the dependent variable is neurological activity elicited. Further, in order to account of the vigilance or sustained attention associated with visual analysis, reaction times are considered.

Additionally, this study collected demographic information regarding the participants age, gender, home language, level of education, and frequency with which they play video games. Finally, it measured self-efficacy with a short, simplistic scale.

Demographics. The study included a short demographic questionnaire in order to ascertain the participants' age, gender, home language, education level, and the frequency with which they are exposed to video games. This was done so as to examine whether any of these factors influence the way in which the participants approach the visual analysis task; and whether this method of approach is subsequently reflected in the neural processes examined (Appendix D).

Visual analysis, detection and vigilance. Visual analysis was assessed using the Surveillance and Monitoring Assessment Exercise (SAMAE), "a computer-based exercise designed specifically for CCTV operators by Leaderware cc" (Donald, 1998, as cited in Donald, 2011, p. 108). "SAMAE evaluates the ability of individuals to stay constantly vigilant, to process and analyse visual information effectively on a sustained basis, and to rapidly detect, identify and react to incidents and anomalies" (SAMAE, n.d.). The constructs measured by SAMAE are scanning and dynamic attention (Donald, 1998). This research made use of the scanning component of the programme – ScanX.

Scan X "evaluates a person's ability to rapidly scan a situation and detect a range of subtle to obvious deviations from a defined standard" (Donald, 1998, p.1). This task involves monitoring a constantly moving object which can change in a number of ways at any stage and identifying when it is dissimilar to the initial standard image which is continually available for comparison purposes (Donald, 1998). A range of factors contribute to the dissimilarity which occurs, specifically: elements of colour are manipulated, positioning of objects relative to one-another changes, rotation occurs, there is a loss of information; the skill being analysed is whether an individual can thus evaluate the system as a whole (Donald, 1998). Hits, misses, false alarms and reaction times are automatically logged by the computer, allowing for accurate measurement.

The exercise lasts for 30 minutes. This was considered a sufficient duration to examine visual analysis processes at the neurological level as well as possible changes in detection rates and reaction times over time – which reflect decreased performance and less effective detection due to the occurrence of a vigilance decrement. This is based on previous research which has demonstrated that vigilance decrements typically set in from 20 to 35 minutes (Sawin & Scerbo, 1995). According to Nuechterlein, Parasuraman, and Jiang (1984, as cited by Donald, 2011) reduced performance has been found after only five minutes of observation in some laboratory experiments.

“SAMAE demonstrates acceptable reliability with Kuder Richardson reliability coefficients of .83 and .86 for the scanning and dynamic attention exercises respectively” (Donald, 1998, as cited in Donald, 2011, p. 109). Of critical importance with regards to this study is that “SAMAE scores are strongly related to various indicators of performance on real world surveillance tasks, such as monthly recorded detection rates, performance appraisals, overall management evaluation scores and non-verbal behaviour recognition training assessments” (Donald, 1998, as cited in Donald, 2011, p. 109). Finally, SAMAE demonstrates differential validity, due to the fact that “it does not correlate with performance on tasks not related to surveillance” (Donald, 1998, as cited in Donald, 2011, p. 109).

Neural activity. A Nihon Kohden Neurofax Electroencephalograph was used to record neuroelectric activity from silver-silver chloride disc electrodes individually attached at predetermined positions in accordance with the international 10-20 classification system (Jasper, 1958), with a sampling rate was 1000 Hz. Due to the impracticality of utilising an entire head of electrodes stemming from the fact that individual electrode placement was utilised as opposed to utilising an electrode cape; electrode placements were in the anterior cingulate gyrus region (Fz, Cz, C3/4), the right frontal lobe (Fp2, F4, F8), and the right parietal lobe (Pz, P4), all referred to Cz (the reference electrode), and a forehead grounding electrode. A1 and A2 were attached for the purpose of impedance checks (as required by the Electroencephalogram). This EEG machine was used in order to perform a Quantitative EEG (qEEG). “qEEG lets us examine measures such as amplitude, absolute and relative power, power ratios across different frequency bands, inter- and intra-hemispheric asymmetries, coherence and phase-lag measurements, co-modulation, mean frequencies, and even analysis at single hertz levels” (Hammond et al, 2004, p. 11). A method of signal analysis commonly used to perform quantitative EEG analysis is analysing spectral power (Fisch, 1999). This is often done using the fast Fourier transform, wherein epochs (periods of time within an EEG) are used to determine the frequency content of analogue signals encountered in circuit simulation, which deals with sequences of time values (Johnstone & Gunkleman, 2003). This means that EEG signals are transferred from a time domain – where signals are described in terms of amplitude versus time – to a frequency domain – where signals are described in terms of amplitude versus frequency; this allows us to quantify the frequency components of the EEG signal (Fisch, 1999). It is advantageous to do this conversion as it (1) allows a great deal of data to be summarised by a few descriptors, (2) it allows certain features in the signal to be examined quantitatively, and finally, (3) the relationship between signals can be revealed more precisely than by visual inspection (Fisch, 1999).

The Fast Fourier transform (FFT) calculates coherence values between interhemispheric electrode sites – “EEG coherence is a measure of the degree of association or coupling of frequency spectra between two different time series” (Thatcher, Biver, & North, 2004, p. 2). Previous studies have identified coherence values in the “theta (4-7.5 Hz), alpha 1(8-10 Hz), alpha 2 (10.5-12.5 Hz), beta1 (13-21 Hz), and beta 2 (21.5-32 Hz) frequency bands” (Bearden, Cassisi, & White, 2004, p. 181). Beta rhythms are generally associated with states of alertness and arousal; and theta waves with less activity (Kolb & Whishaw, 2009).

This study utilised a similar methodology to one put forward in Kolb and Whishaw (2009) wherein it is necessary to look at control conditions where no events occur and compare them to an experimental condition where visual analysis skill are required. That is to say conditions where in the participant is not required to detect a change in the visual analysis patterns need to be compared to those that contain events or items changing – this is considered a pseudo control condition as it serves as the benchmark against which visual analysis activity is compared. Theta, alpha and beta rhythms relative to that baseline need to be evaluated in order to ascertain whether there was a change in neural activity.

With regards to the validity and reliability of a qEEG, Thatcher (2010) reviewed the literature and ran a series of investigations, wherein he found that: "The review of the scientific literature demonstrated high levels of split-half and test-retest reliability of qEEG and convincing content and predictive validity as well as other forms of validity" (p.122). qEEG was found to have a reliability of greater than .9 with as little as 40-s epochs and remains stable over a significant period of time in terms of test-retest reliability (Thatcher, 2010). Predictive validity of qEEG was established by "significant and replicable correlations with clinical measures and accurate predictions of outcome and performance on neuropsychological tests" (Thatcher, 2010, p. 122). Content validity was established by utilising comparisons with other neuroimaging techniques and neuropsychological tests (Thatcher, 2010).

Self-Efficacy. This study included a short measure of self-efficacy due to the fact that a common feature of vigilance and detection tasks is response inhibition – wherein a participant observes a change but does not indicate that a change was observed (Padmala & Pessoa, 2010). Due to the fact that this is not the main area of investigation in this research, but merely a subsidiary one, a small 8 item measure of self-efficacy was included – the New General Self-Efficacy Scale (Chen, Gully, & Eden, 2001).

This scale has undergone a battery of psychometric tests and has been proved to be "theory based, unidimensional, internally consistent ($\alpha = .86, .90$) and stable over time" (Chen, Gully, & Eden, 2001, p. 69). It has undergone principal components factor analysis which resulted in a single-factor solution for these 8 items on three occasions ($\alpha = .87, .88$, and $.85$) (Chen, Gully, & Eden, 2001). Moreover Chen, Gully, and Eden (2001) have found the scale to have good discriminant validity and predictive validity (Appendix D).

Statistical Analysis

For data analysis, EEGLAB 10.2.2.4 (Delorme & Makeig, 2004), Matlab 2013b And SPSS software were used. Data sets were cleaned and noise and artifacts were limited. Epochs of 15 seconds (the duration of an item) were analysed in order to determine the neurological activity associated with three conditions: firstly, an item that did not elicit a reaction as it was the same as the standard item of comparison, secondly, a target item (i.e. an item that was different to the standard item), and finally, an item that changed during the 15 second interval. The epochs selected were those at the beginning (during the first ten minutes), middle (during the middle ten minutes) and end (during the last ten minutes) where the majority of individuals did not have a false alarm when an item was not present, and where the majority of participants successfully managed to identify a target or an item changing when presented with such. It is critical to note that there was constant dynamic activity during the task, and target items and item changing refer to a disparity between the base, or standard, image of comparison.

The following where the final epochs utilised for analysis:

Table 3: Epochs retained for Statistical Analysis

	No change	Target	Item Changed
Beginning	05:30 – 05:45	06:15 – 06:30	07:00 – 07:15
Middle	12:15 – 12:30	15:45 – 16:00	18:30 – 18:45
End	27:15 – 27:30	29:30 – 29:45	27:00 – 27:15

The retained epochs underwent the Fast Fourier Transformation and the subsequent coherence values were transformed to a normal distribution using Fisher's z transform prior to statistical analysis (Bearden et al, 2004).

Neural activity was measured in terms of the spectral power of each frequency band within a given time period. Results yielded an ERSP (event-related spectral perturbation) score;

> The ERSP measures average dynamic changes in amplitude of the broad band EEG frequency spectrum as a function of time relative to an experimental event. That is, the ERSP measures the average time course of relative changes in the spontaneous EEG amplitude spectrum *induced* by a set of similar experimental events. These spectral changes typically involve more than one frequency or frequency band, so full-spectrum ERSP analysis yields more information on brain dynamics (Makeig, 1993, p. 285)

In order to investigate the aforementioned hypotheses in terms of the data collected descriptive interpretation and various statistical methods were utilised. Hypothesis one and two, were investigated both in terms of graphic representations showcasing the way in which frequency, time, and amplitude interacted; as well as statistically. For hypothesis one and two a paired sample t-test was run (or its non-parametric equivalent the Wilcoxon test) – a statistical procedure which allows the researcher to detect any overall differences between related means (Huck, 2009). Spectral power was compared within the group to determine whether items with targets elicited differing levels of neural activity to items with no targets within each frequency band. Moreover, the sample group was split into a high performing group and a low performing group (based on the frequency of hits and misses), and spectral power between those groups for targets and no targets was compared using a between-subjects ANOVA or its non-parametric equivalent, the Kruskal-Wallis (Huck, 2009). A comparison of these results between frequency bands yielded the results for hypothesis two.

Levels of neural activity were compared against each other in order to ascertain fluctuation patterns in neural activity over the course of the observation task. The non-parametric equivalent of the repeated measures ANOVA (Friedman test) was used to compared the first 10 minutes, the middle 10 minutes, and the final 10 minutes to determine fluctuations in neural activity in relation to time on task (Huck, 2009). Moreover, post hoc independent t-tests were used to determine at which points changes did occur. This served to address hypothesis three.

Hypothesis four and five was assessed by, once again splitting the group, this time in terms of either false alarms or misses – many as opposed to few. An independent t-test, or its non-parametric equivalent the Mann-Whitney U test, was used to determine whether lower levels of neural activity were associated with increased false alarms and misses (Huck, 2009).

Additionally, the study ran Pearson’s and Spearman’s correlation co-efficient tests between reaction times and self-efficacy levels, demographic variables and detection and neural activity.

Ethical Considerations

Concerning ethics, his research needed to consider various issues in order to comply with American Psychological Association Ethical Guidelines Concerning Human Participants in Research. As such ethics clearance was applied for from the Human Research Ethics Committee (non-medical) of the University of the Witwatersrand and the following clearance certificate number was granted – MORG/12/005 IH.

There was no risk of physical or psychological harm or deprivation to the participants within this study; only volunteers were used within this study; and informed consent was provided for. That is to say participants were informed about the purpose of the research, the expected duration and procedures, additionally other factors that may have influenced their decision to participate were disclosed before the research begins. Participation was completely voluntary.

Due to the face-to-face contact required within the researcher anonymity could not be guaranteed, however the confidentiality of the individual results is assured; as the information provided will be used solely for the purpose of the research study. The research reported on general trends as opposed to individual results.

The date collected will be secured securely in a password protected computer until all potential publications and presentations have been completed. During this time the researcher and her supervisor will have access to it, except in an anonymous form. That is to say, additional researchers assisted in the analysis processes, yet they only had access to the data in an anonymous form.

Finally, a summary of the results of the study will be published on a website upon completion of the research report so that participants can obtain feedback on the overall trends; moreover further information will be provided upon request.

Chapter Four: Results

Introduction

In order to address the various hypotheses a battery of descriptive and statistical analyses were undertaken. The results have been split into two sections: one comprising the behavioural data associated with this study, and the other, the data collected from EEG studies. These are then considered simultaneously in order to address the various research hypotheses. In considering these hypotheses, factors associated with the appropriate use of statistical tests, reliability, and extraneous variables are taken into account.

Due to faults with the EEG machine several of the participants (participant 9, 10, and 11) had to be excluded from the dataset, as the data files were corrupted. Thus, this study contained 8 participants.

Behavioural Data

When considering the results of this study it is necessary to consider the context wherein these results were obtained – within a visual analysis and effective detection study. Thus it was critical to consider measures such as: hits, misses, false alarms, and reaction times.

Table 4: Descriptive Statistics of Behavioural Variables

	Range	Min	Max	Mean	Std. Deviation	Variance	Skewness	Kurtosis
False Alarms	6.0	1.0	7.0	3.13	2.36	5.55	.45	-.93
Misses	18.0	2.0	20.0	11.38	6.28	39.41	.059	-.99
Hits	18.0	22.0	40.0	30.63	6.28	39.41	-.059	-.99
Reaction Time	1.05	2.88	3.93	3.27	0.37	.13	.82	-.16

For the purposes of analysing the behavioural data in terms of the neural information collected; the behavioural data was further utilised in order to split the group into two in multiple instances. Firstly, it was split in terms of those that performed well within the detection task and those that did not (henceforth referred to as group 1A and group 2A respectively). This was done in terms of hit and miss scores and resulted in equal groupings of 4 participants each. Secondly, it was split in terms of those that had a high false alarm rate as opposed to those that didn't (henceforth referred to as group 1B and group 2B respectively). This was done in terms of false alarm scores and resulted in equal groupings of four participant each.

Table 5: A Cross-tabulation of Group 1 (High and Low Performers) and Group 2 (High and Low False Alarms)

	False Alarms		
Performance	Low	High	Total
Low	2	2	4
High	2	2	4
Total	**4**	**4**	**8**

There does not appear to be an impact of high performance on false alarms, nor of poor performance on false alarms.

An independent t-test was utilised to determine whether there was a statistically significant difference between the means of both sets of groupings in order to account for the distinction. In order to analyse the data in this way it was necessary to consider parametric assumptions. The following parametric assumptions were assumed: random, independent sampling, additive means and at least an interval scale of measure (Howell, 1997). Normality was ascertained by examining the skewness estimates and measures of central tendency (Howell, 1997). As per Table 4 the variable "hits" is normally distributed, as according to Huck (2009), most researchers consider data to be approximately normal in shape if the skewness and kurtosis value fall anywhere between -1,0 and +1.0. Additionally, "false alarms" is normally distributed in terms of the kurtosis and skewness indicators and thus the independent samples t-test is also used (Huck, 2009). The results of this investigation are illustrated below in Table 6 and 7.

Table 6: Independent Samples Test Grouping A - High Performing versus Low Performing

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Hits	Equal variances assumed	.92	.37	4.42	8	.002**	9.80	2.22	4.69	14.92
	Equal variances not assumed			4.42	7.55	.003**	9.80	2.22	4.63	14.97

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

A further assumption of the independent samples t-test is equality of variance, which is assessed utilising Levene's Test for Equality of Variances (Huck, 2009).

Table 7: Independent Samples Test Grouping B – High False Alarms versus Low False Alarms

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
False Alarms	Equal variances assumed	12.79	.012	3.96	6	.007**	3.75	.95	1.43	6.07
	Equal variances not assumed			3.96	3.45	.022*	3.75	.95	.95	6.55

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

In both instances, $p \leq .05$, in the case of Levene's test therefore equality of variances is not assumed.

Yet, in both cases, there is a statistically significance between the groups ($t = 4.42$; $p = .002$; $t = 3.96$; $p= .022$) $p \leq .05$. They are thus defined as such:

Table 8: Descriptive Statistics of Group 1A – High Performing

Table 9: Descriptive Statistics of Group 2A – Poor Performers

	Range	Min	Max	Mean	Std. Deviation	Variance	Skewness	Kurtosis
False Alarms	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Misses	[illegible]	[illegible]	[illegible]	[illegible]	3.51	[illegible]	[illegible]	[illegible]
Hits	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reaction Time	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 10: Descriptive Statistics of Group 1B – High False Alarms

	Range	Min	Max	Mean	Std. Deviation	Variance	Skewness	Kurtosis
False Alarms	6	1	7	3.75	2.5	6.25	.56	.93
Misses	7	2	9	6.25	3.1	9.58	-1.14	.76
Hits	7	33	40	35.75	3.1	9.58	1.14	.76
Reaction Time	1.05	2.88	3.93	3.44	.45	.20	-.33	-.84

Table 11: Descriptive Statistics of Group 2B – Low False Alarms

	Range	Min	Max	Mean	Std. Deviation	Variance	Skewness	Kurtosis
False Alarms	1	1	2	1.250	.50	.250	2.00	4.00
Misses	11	9	20	15.25	5.19	26.92	-.46	-3.11
Hits	11	22	33	26.75	5.19	26.92	.46	-3.11
Reaction Time	.33	3.05	3.38	3.21	.16	.03	.16	-4.51

EEG Data

Neural activity was measured in terms of the spectral power of each frequency band within 15 second time frames throughout the task. Results yielded an ERSP (event-related spectral perturbation) score.

> The ERSP measures average dynamic changes in amplitude of the broad band EEG frequency spectrum as a function of time relative to an experimental event. That is, the ERSP measures the average time course of relative changes in the spontaneous EEG amplitude spectrum *induced* by a set of similar experimental events. These spectral

changes typically involve more than one frequency or frequency band, so full-spectrum ERSP analysis yields more information on brain dynamics (Makeig, 1993, p. 285)

The averaged results of these measurements were as follows:

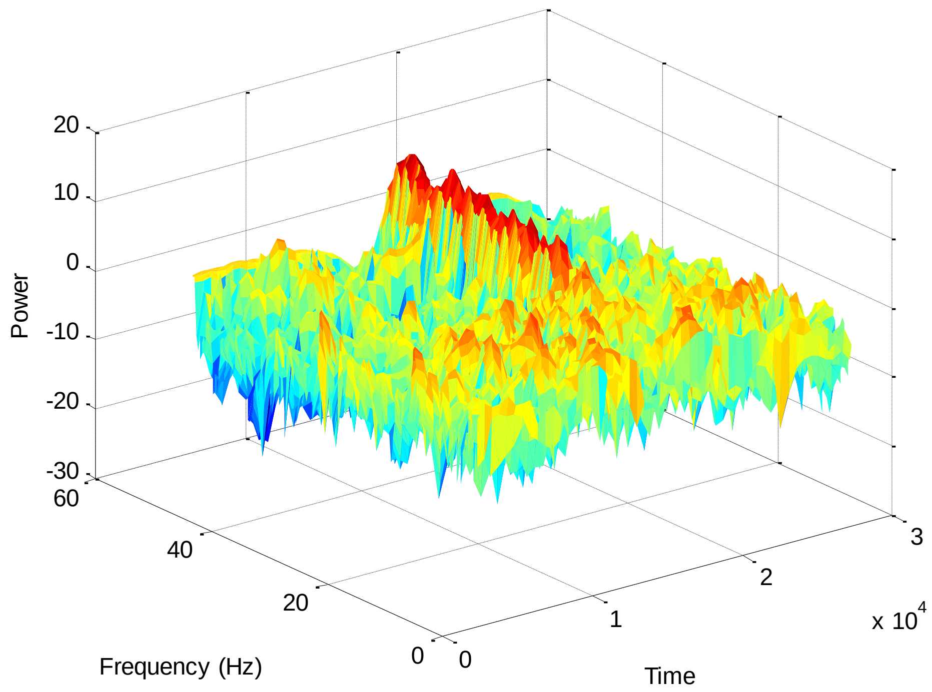
Table 12: Descriptive Statistics of the Averaged ERSP Data

	N	Min	Max	Mean	Std. Deviation	Skewness	Kurtosis
Theta Average	8	2.68	3.73	3.18	.4	.32	-1.22
Alpha1 Average	8	2.64	4	3.23	.54	.28	-1.85
Alpha2 Average	8	2.61	4.14	3.05	.51	1.67	2.79
Beta1 Average	8	2.59	3.80	3.02	.42	.91	.28
Beta2 Average	8	2.55	3.80	3.18	.50	-.09	-1.76

When considering these values, it is critical to note the skewness apparent in the readings for Alpha 2, evident as a result of the value being greater than 1 (Huck, 2007). This implies the lack of a normal distribution in the data and indicates that the values for Alpha 2 may be positively skewed. Moreover, the Kurtosis also indicates deviations from a normal distribution as these values fall outside the -1 - +1 range deemed suitable for normality (Huck, 2007). This was taken in to account when determining whether parametric or non-parametric tests are most applicable for analysis purposes.

In addition to the numerical value of the ERSP generated for various frequency bands, the way in which events affect the spectral power within a frequency band is also represented graphically. Time, frequency and spectral power were plotted against each other to represent the power that occurs in a specific frequency band during a period of time.

Figure 3: Matlab results representing the spectral power associated with a time/frequency band.



Results pertaining to the Various Hypotheses

Hypothesis One: *Detection is positively associated with increased neural activity in areas associated with vigilance and visual processing, specifically the anterior cingulate gyrus, the right frontal lobe, and the right parietal lobe.*

In order to test this hypothesis a paired samples t-test was used, provided parametric assumptions were met, for each frequency band. The following parametric assumptions were assumed: random, independent sampling, additive means and at least an interval scale of measure (Howell, 1997). One independent variable (targets or no targets) with related groups was apparent.

For each frequency band, the assumption of normality and no outliers was tested on the differences between the paired values. For the Theta band no outliers were apparent when inspecting a boxplot for values greater than 1.5 box-lengths from the edge of the box (Howell, 1997). The difference scores for the targets and no targets were normally distributed, as assessed by Shapiro-Wilk's test ($p = .13$).

Table 13: Paired Samples t-test for Theta

		Paired Differences							
					95% Confidence Interval of the Difference				Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	
Theta	Items-Targets	-.10	.12	.04	.003	.20	2.441	7	.045*

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

The targets elicited a statistically significant mean decrease of 0.1 in the ERSP value, 95 %CI (t = 2.441; p = .045) compared to unchanging items within the theta band.

For the Alpha 1 band no outliers were apparent when inspecting a boxplot for values greater than 1.5 box-lengths from the edge of the box (Howell, 1997). The difference scores for the targets and no targets were normally distributed, as assessed by Shapiro-Wilk's test (p = .43).

Table 14: Paired Samples t-test for Alpha 1

		Paired Differences							
					95% Confidence Interval of the Difference				Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	
Alpha 1	Items-Targets	.088	.07	.03	.03	.15	3.422	7	.011*

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

The targets elicited a statistically significant mean increase of 0.088 in the ERSP value, 95 %CI (t = 3.422; p = .11) compared to non-targets within the alpha 1 band.

For the Alpha 2 band no outliers were apparent when inspecting a boxplot for values greater than 1.5 box-lengths from the edge of the box (Howell, 1997). The difference scores for the targets and no targets were normally distributed, as assessed by Shapiro-Wilk's test (p = .39).

Table 15: Paired Samples t-test for Alpha 2

Paired Differences	t	df

					95% Confidence Interval of the Difference				Sig. (2-tailed)
		Mean	**Std. Deviation**	**Std. Error Mean**	**Lower**	**Upper**			
Alpha 2	Items-Targets	.03	.09	.03	-.05	.11	.999	7	.351

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

The targets elicited no statistically significant difference in the alpha 2 band.

For the Beta 1 band one outlier was apparent when inspecting a boxplot for values greater than 1.5 box-lengths from the edge of the box (Howell, 1997). Inspection of its values did not reveal it to be extreme and it was kept in the analysis. The difference scores for the targets and no targets was not normally distributed, as assessed by Shapiro-Wilk's test (p = .021). Subsequently, the non-parametric Wilcoxon signed-rank test was utilised.

Table 16: Wilcoxon Signed Ranks Test for Beta 1

	Beta 1 Items-Targets
Z	-1.12
Asymp. Sig. (2-tailed)	.26

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

The targets elicited no statistically significant difference in the Beta 1 band.

For the Beta 2 band no outliers were apparent when inspecting a boxplot for values greater than 1.5 box-lengths from the edge of the box (Howell, 1997). The difference scores for the targets and no targets were normally distributed, as assessed by Shapiro-Wilk's test (p = .64).

Table 17: Paired Samples t-test for Beta 2

Paired Differences	t	df

					95% Confidence Interval of the Difference				Sig. (2-tailed)
		Mean	**Std. Deviation**	**Std. Error Mean**	**Lower**	**Upper**			
Alpha 1	Items-Targets	.04	.15	.05	-.08	.17	.821	7	.439

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

The targets elicited no statistically significant difference in the Beta 2 band.

In addition to the statistical analysis utilised above, descriptive information relating to the graphic output generated by the data was utilised. First a graph was produced for a time period on ScanX that did not have any target items or item changes during the visual analysis segment, this was then compared to a graphic representation of neural activity when targets were presented in the visual analysis segment. The period with no target or change contained no false alarms, and the period representing the targets was one where in all participants detected the change. The analysed periods were 15 second segments.

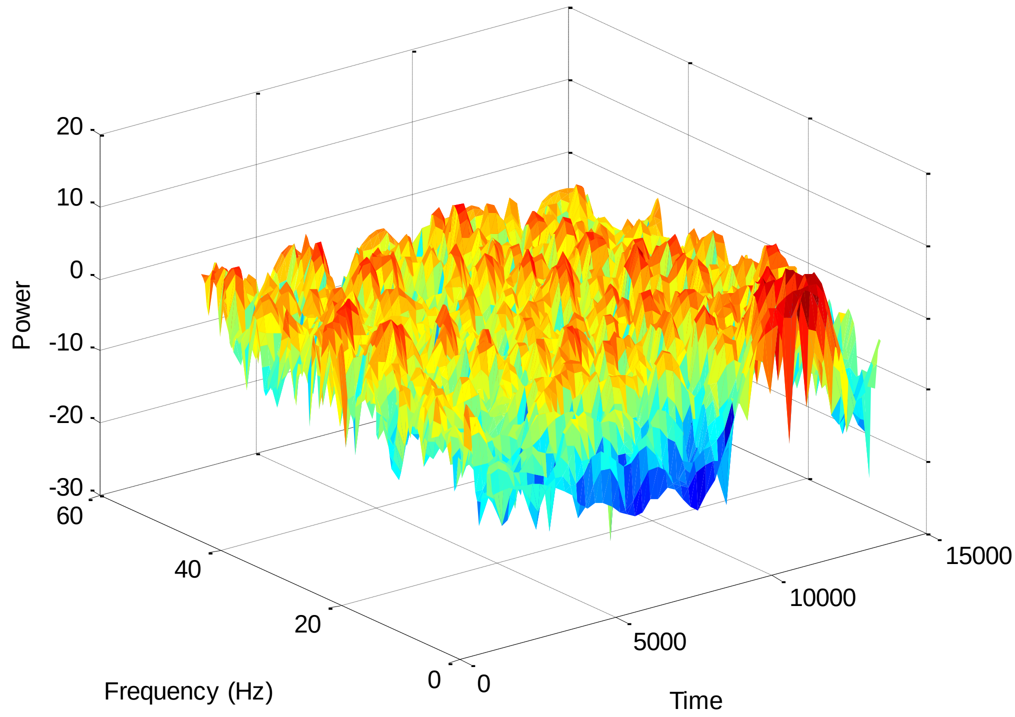


Figure 4: Matlab representation of Neural Activity when there are no target items for detection.

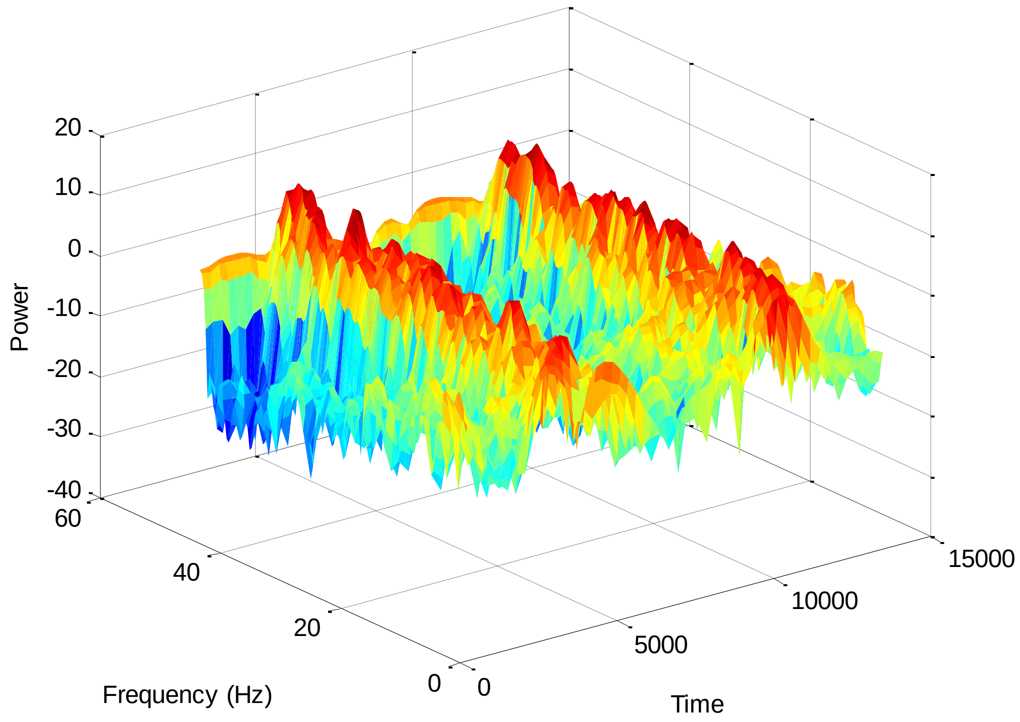


Figure 5: Matlab representation of Neural Activity when there are target items for detection

In comparing these two graphic (figure 4 and 5) representations it is clear that when targets are initiated there is activity near the beginning of the 15 second segment and at the end.

In addition to this, in comparing the high performing detection group (figure 7) and the low performing detection group (figure 6) it is evident that spectral power breaches the positive region more often within the high performing group than the low performing group indicating that perhaps there is more neurological activity apparent within the high performing detection group in the same 15 second time period.

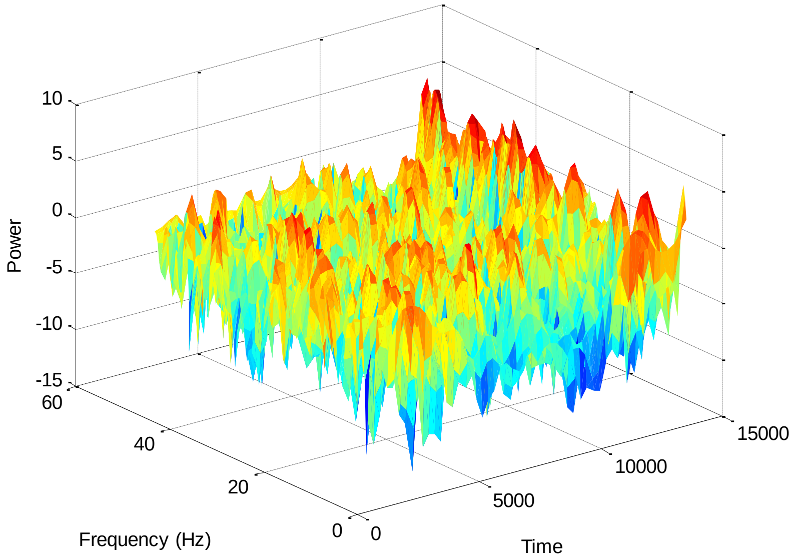


Figure 6: Matlab representation of Neural Activity for the low performing target detection group

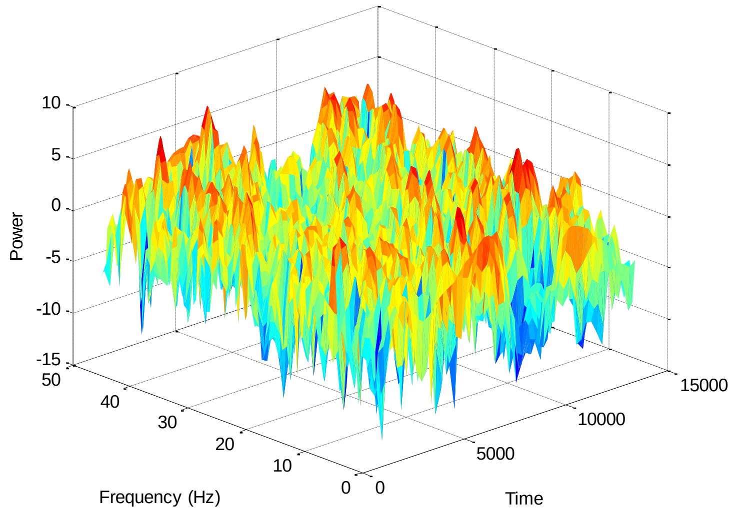


Figure 7: Matlab representation of Neural Activity for the high performing target detection group

However, this assertion requires further evidence in the form of statistical analysis. With regards to this a Mixed ANOVA was utilised (Huck, 2009). In order to utilise this statistical test it is necessary to meet certain parametric assumptions. There were no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box lengths from the edge of the box. In addition neural activity was for the most part normally distributed for all groups within all conditions, as assessed by Shapiro-Wilk's ($p \geq .05$).

Table 18: Descriptive Statistics of the Averaged ERSP Data for Items and Targets

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	**Statistic**	**df**	**Sig.**	**Statistic**	**Df**	**Sig.**
Theta items	High Performing	.29	4	.	.85	4	.212
	Low Performing	.25	4	.	.91	4	.489
Theta targets	High Performing	.29	4	.	.87	4	.295
	Low Performing	.14	4	.	1	4	.995
Alpha1 items	High Performing	.22	4	.	.98	4	.897
	Low Performing	.42	4	.	.69	4	.010*
Alpha 1 targets	High Performing	.24	4	.	.96	4	.773
	Low Performing	.41	4	.	.72	4	.021*
Alpha 2 Items	High Performing	.30	4	.	.89	4	.359
	Low Performing	.27	4	.	.85	4	.231
Alpha 2 Targets	High Performing	.34	4	.	.87	4	.306
	Low Performing	.28	4	.	.94	4	.641
Beta 1 items	High Performing	.30	4	.	.89	4	.359
	Low Performing	.27	4	.	.85	4	.231
Beta 1 targets	High Performing	.34	4	.	.87	4	.306
	Low Performing	.28	4	.	.94	4	.641
Beta 2 items	High Performing	.28	4	.	.83	4	.166
	Low Performing	.24	4	.	.87	4	.311
Beta 2 targets	High Performing	.26	4	.	.91	4	.466
	Low Performing	.40	4	.	.71	4	.014*

*not normally distributed

As the Mixed ANOVA is somewhat robust to deviations from normality (Huck, 2009), the decision was made to proceed.

Homogeneity of variances was assessed by Levene's test of homogeneity of variance ($p \geq .05$). Homogeneity of covariances was assessed by Box's test of equality of covariance matrices ($p \geq .001$). The following results were yielded.

Table 19: Descriptive Statistics of the Averaged ERSP Data

	Levene's Test – items	Levene's Test – targets	Box's Test	DF	F	Sig.	partial η^2
Theta	.02	.7	.11	1	3.23	.122	.35
Alpha 1	.54	.56	.77	1	25.51	.002*	.81
Alpha 2	.08	.16	.12	1	3.36	.117	.36
Beta 1	.08	.16	.12	1	3.36	.117	.36
Beta 2	.73	.19	.36	1	.09	.771	.02

*Statistically significant at the .05 significance level

Thus, this study cannot conclude that neural activity in areas traditionally linked with vigilance and visual processing is associated with increased detection.

The results indicate that detection is significantly associated with alpha 1 neural activity in this instance. Additionally, there is only a statistically significant difference between the high and low performing groups within the Alpha 1 band.

Hypothesis Two: *Detection is positively associated with the occurrence of beta activity*

In order to determine whether the increased neurological detection occurs predominately within the beta band. A 3D image was transposed to represent spectral power (amplitude) associated with frequency within a 2D representation (figure 8).

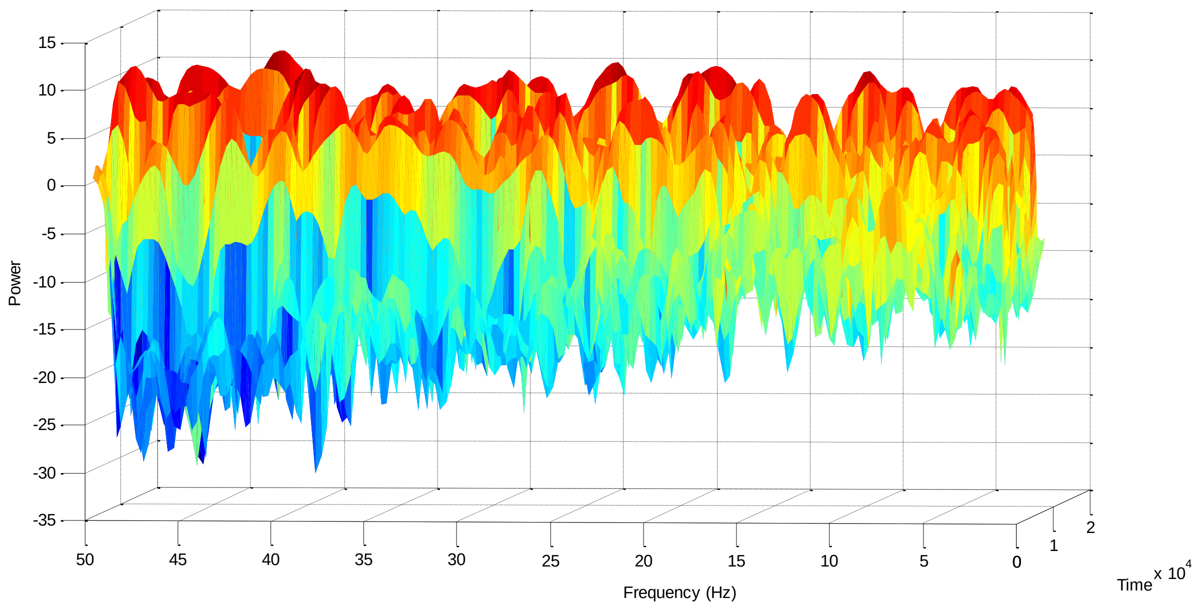


Figure 8: Matlab representation of power in relation to frequency (0-50 Hz)

Figure 8 represents a 15 second time frame in which a target item was presented. In examining these images it is evident that the power spectrum within the beta frequency band (Beta One – 13-21.5Hz; and Beta Two - 21.5-32Hz) is markedly more varied than the lower level frequencies, indicating fluctuations of greater magnitude occur within higher frequency bands. In addition to this, it appears that this variation continues to occur into the higher frequency spectrum of Gamma (32-100Hz) which is traditionally associated with short-term memory matching of recognisable objects, sounds, or tactile sensors (Kisley & Cornwell, 2006).

While the variance indicated graphically is interesting, statistical results determined above indicate that there is no statistically significant association between detection and the occurrence of beta activity within this study.

Hypothesis Three: *Levels of neural activity change during the time on task*

In analysing this hypothesis, the data set was divided into three time phases – beginning, middle and end – consisting of 10 minutes each.

Table 20: Descriptive Statistics of the Averaged ERSP Data in relation to Time on Task (Beginning (B), Middle(M), and End(E))

	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness	Kurtosis
Theta_B	2.66	3.43	3.04	.27	.07	.12	-1.30
Theta_M	2.66	4.25	3.26	.51	.26	1.07	1.39
Theta_E	2.73	4.17	3.27	.51	.26	.70	-.36
Alpha1_B	2.62	3.63	3.02	.42	.18	.69	-1.34
Alpha1_M	2.62	4.60	3.25	.671	.45	1.35	1.51
Alpha1_E	2.69	4.39	3.27	.69	.47	.80	-1.42
Alpha2_B	2.54	3.66	2.84	.36	.13	2.06	4.69
Alpha2_M	2.65	4.83	3.05	.73	.53	2.63	7.15
Alpha2_E	2.64	4.38	3.27	.67	.45	.79	-1.18
Beta1_B	2.53	3.54	2.81	.35	.12	1.57	2.02
Beta1_M	2.58	4.37	2.99	.58	.34	2.42	6.19
Beta1_E	2.60	4.83	3.27	.74	.55	1.48	2.38
Beta2_B	2.49	3.63	2.95	.48	.23	.47	-1.66
Beta2_M	2.56	4.48	3.21	.69	.47	1.22	.28
Beta2_E	2.57	5.97	3.38	1.11	1.22	2.27	5.70

The neurological activity (in terms of the ERSP results) was averaged over each of these periods with the intention of using a repeated measures ANOVA for each of the frequency bands to assess whether neural activity in each of the frequency bands changed during time on task. In order to utilise a repeated measures ANOVA it was necessary to assess whether the assumptions that allow for the use of a parametric test were adhered to.

With regards to this, the dependent variable (neurological activity) is at least an interval scale of measure; however conditions for normality – in terms of kurtosis and skewness (Huck, 2009) – were not met. Subsequently the non-parametric equivalent for a repeated measures ANOVA was used – the Friedman test (Huck, 2009). These analyses yielded the following results:

Table 21: Friedman Test comparing ERSP scores over time

Frequency Band	N	Chi-square	Df	Asump. Sig.
Theta	8	5.25	2	.072
Alpha 1	8	7.75	2	.021*
Alpha 2	8	7.75	2	.021*
Beta 1	8	7.75	2	.021*
Beta 2	8	3.25	2	.197

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

To examine where these differences actually occur, separate Wilcoxon signed-rank tests were run on the different combinations of related groups (Huck, 2009).

When examined more closely, Alpha 1 yielded the following results:

Table 22: Wilcoxon signed-rank test for Alpha 1

	Beginning and Middle	End and Middle	End and Beginning
Z	-1.960b	-.840b	-2.521b
Asymp. Sig. (2-tailed)	.050*	.401	.012*

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

Alpha 2 produced the following:

Table 23: Wilcoxon signed-rank test for Alpha 2

	Beginning and Middle	End and Middle	End and Beginning
Z	-1.820b	-.980b	-2.521b
Asymp. Sig. (2-tailed)	.069	.327	.012*

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

And, Beta 1 generated the following results:

Table 24: Wilcoxon signed-rank test for Beta 1

	Beginning and Middle	End and Middle	End and Beginning
Z	-1.400b	-.840b	-2.521b
Asymp. Sig. (2-tailed)	.161	.401	.012*

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

Therefore, levels of neural activity do change during time on task, specifically within the Alpha 1, Alpha 2, and Beta 1 frequency band. Additionally there is a marked difference between levels of neural activity at the beginning of the task and at the end of the task; and, within the Alpha 1 band, between the beginning of the task and the middle of the task.

Furthermore, it could be suggested that one can determine the direction of these changes by reviewing the means in Table 20, as such there is some indication that neural activity decreases with time on task, as ERSP results were negative and subsequently inverted.

Hypothesis Four: *High rates of false alarms are associated with lower levels of neural activity in the specified regions compared with low rates of false alarms*

With the purpose of investigating this hypotheses, overall neural activity was averaged over the duration of the task and subsequently compared to those participants that had several false alarms and those participants that had a few false alarms – Grouping B. In order to assess whether the group could be split in terms of this construct an independent t-test was utilised to determine whether there was a statistically significant difference between the means of these two groups – criteria for the use of this parametric method were met. A statistically significant difference was found between the two groups, t = 12.789, p = .012.

In order to compare the two groups an independent samples t-test was to be used, however in order to do so criteria for parametric testing needed to be met. The dependent variable was at least interval, the independent variable consisted of two categorical, independent groups, there were no significant outliers in the difference between the two groups, and normality was assessed in terms of skewness and kurtosis (Huck, 2009) – see Table 12 .

However, in terms of the results in Table 12, normality was not met in terms of kurtosis and it was necessary to use the non-parametric equivalent of the independent samples t-test – the Mann-Whitney U test – for all the frequency bands except Beta 1.

In addition to meeting the above assumptions, it was also necessary to have homogeneity of variance in order to complete the independent samples t-test, this was assessed with Levene's test for homogeneity of variance (Huck, 2009). Homogeneity of variance was found p = .307.

Table 25: Independent samples t-test for Beta 1 to Investigate False Alarms

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Beta 1	Equal variances assumed	1.24	.31	-2.07	6	.08	-.51	.24	-1.10	.09
	Equal variances not assumed			-2.07	5.19	.09	-.51	.24	-1.13	.12

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

These results indicate that there is no significant (p = .084) association between high rates of false alarms and levels of neural activity in the specified regions compared with low rates of false alarms within the Beta 1 band.

The remaining bands were assessed with the Mann-Whitney U test, and the results were as follows:

Table 26: Mann-Whitney U test for Theta, Alpha 1, Alpha 2, and Beta 2 to Investigate False Alarms

	Theta Average	**Alpha1 Average**	**Alpha2 Average**	**Beta2 Average**
Mann-Whitney U	2.00	5.00	3.00	2.000
Wilcoxon W	12.00	15.00	13.00	12.00
Z	-1.73	-.87	-1.44	-1.73
Asymp. Sig. (2-tailed)	.08	.39	.15	.08
Exact Sig. [2*(1-tailed Sig.)]	.11	.49	.20	.11

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

Thus, this study found no significant association between high rates of false alarms and levels of neural activity compared with low rates of false alarms within all of the frequency bands.

Hypothesis Five: *Misses are negatively associated with neural activity*

In a similar fashion to the previous hypothesis, overall neural activity was averaged over the duration of the task and subsequently compared to the high performing and low performing groups previously established in grouping A. In order to assess whether the group could be split in terms of this construct an independent t-test was utilised to determine whether there was a statistically significant difference between the means of these two groups – once again the criteria for the use of this parametric method were met. A statistically significant difference was found between the two groups, $t = 4.418$, $p = .002$ (as demonstrated in Table 6).

In order to compare the two groups an independent samples t-test was to be used, however in order to do so criteria for parametric testing needed to be met. The dependent variable was at least interval, the independent variable consisted of two categorical, independent groups, there were no significant outliers in the difference between the two groups, and normality was assessed in terms of skewness and kurtosis (Huck, 2009) – see Table 12.

The results indicated in Table 12 demonstrate that normality was not met in terms of kurtosis and as such it was necessary to use the non-parametric equivalent of the independent samples t-test – the Mann-Whitney U test – for all the frequency bands except Beta 1.

In addition to meeting the above assumptions, it was also necessary to have homogeneity of variance in order to complete the independent samples t-test, this was assessed with Levene's test for homogeneity of variance (Huck, 2009). Homogeneity of variance was apparent, p = .201)

Table 27: Independent samples t-test for Beta 1 to Investigate Misses

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Beta 1 Average	Equal variances assumed	2.07	.20	-3.12	6	.021**	-.62	.2	-1.1	-.13
	Equal variances not assumed			-3.12	4.15	.034**	-.62	.2	-1.16	-.08

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

Thus, this study found a statistically significant association between misses and neural activity in the Beta 1 band.

The remaining bands were assessed with the Mann-Whitney U test, and the results were as follows:

Table 28: Mann-Whitney U test for Theta, Alpha 1, Alpha 2, and Beta 2 to Investigate Misses

	Theta Average	**Alpha1 Average**	**Alpha2 Average**	**Beta2 Average**
Mann-Whitney U	.00	3.00	.00	.00
Wilcoxon W	10.00	13.00	10.00	10.00
Z	-2.31	-1.44	-2.31	-2.31
Asymp. Sig. (2-tailed)	.021**	.15	.021**	.021**
Exact Sig. [2*(1-tailed Sig.)]	.03	.20	.03	.03

*Statistically significant at the .05 significance level

**Statistically significant at the .01 significance level

This study determined there was a statistically significant association between misses and neural activity in the Theta, Alpha 2, and Beta 2 frequency bands.

However, there was no statistically significant relationship between misses and neural activity in the Alpha 1 frequency band.

Hypothesis Six: *Reaction time is positively associated with self-efficacy levels*

In order to determine whether there was a statistically significant relationship between self-efficacy levels and reaction time, the reaction time generated by ScanX was compared against the results of the self-efficacy scale utilised.

Table 29: Descriptive Statistics for Self-Efficacy and Reaction Time

	Range	**Min**	**Max**	**Mean**	**Std. Deviation**	**Variance**	**Skewness**	**Kurtosis**
Self-Efficacy	9	29	38	34.13	3.44	11.84	-.48	-1.54
Reaction Time	1.05	2.88	3.93	3.27	0.37	.13	.82	-.16

Since the parametric assumption of linearity and outliers was not met, in terms of the requirements for Pearson's correlation (Huck, 2009), it was necessary to run a Spearman's correlation. The results were as follows:

Table 30: Spearman's correlation between Self-Efficacy and Reaction Time

			Reaction Time	**Self-Efficacy**
Spearman's rho	Reaction Time	Correlation Coefficient	1.00	-.24
		Sig. (2-tailed)	.	.48
		N	11	11
	Self-Efficacy	Correlation Coefficient	-.24	1.00
		Sig. (2-tailed)	.48	.
		N	11	11

No significant association was found between reaction time and self-efficacy.

Conclusion

In summary the following results were established for each hypothesis:

Table 31: Summary of Results

Hypothesis	**Finding**
Detection is positively associated with increased neural activity in areas associated with vigilance and visual processing, specifically the anterior cingulate gyrus, the right frontal lobe, and the right parietal lobe.	The results of this study indicate that detection is only significantly associated with increased theta and alpha 1 neural activity; additionally there is only a statistically significant difference between the high and low performing groups within the Alpha 1 band.
Detection is positively associated with the occurrence of beta activity.	There is no statistical support for this hypothesis within this study.
Levels of neural activity change during the time on task	Results in this study indicate this to be the case within the Alpha 1, Alpha 2, and Beta 1 Frequency band.
High rates of false alarms are associated with lower levels of neural activity in the specified regions compared with low rates of false alarms.	There is no statistical support for this hypothesis within this study.
Misses are negatively associated with neural activity.	Results in this study indicate this to be the case within the Alpha 1, Beta 1, Beta 2 and Theta frequency band.
Reaction time is positively associated with self-efficacy levels.	There is no statistical support for this hypothesis within this study.

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A discussion of these results will follow in the next chapter of this research undertaking. The results will be discussed in light of the research questions and propositions set forth in the literature review. The limitations of the current study and the possible future research will also be examined in the ensuing chapter.

Chapter Five: Discussion

Introduction

The aim of this research was to assess the neurological processes involved in visual analysis tasks in terms of networks within the brain. It aimed to examine these processes while considering antecedents of visual analysis skills; specifically concentration spans, properties of the target, and signal detection characteristics such as the hit rate and reaction time. Additionally, it aimed to briefly consider how the decision processes, in terms of an individual's self-efficacy level, manifest themselves in neurological activity. In order to garner a deeper understanding of visual analysis processes an EEG machine was used. Neurological activity was compared in various visual analysis conditions. Specifically, each image cycle prompted a different reaction. Some image cycles were consistent with the standard image thus there was no target or trigger, other image cycles created a variation in form when compared to the standard image, and some image cycles altered mid-way through their presentation. These different conditions were compared in terms of neurological activity.

This comparison occurred within multiple frequency bands previously linked to detection, and was evaluated in terms of an array of conditions associated with visual analysis (hits, misses, false alarms, etc.). Additionally, it was compared with the time dimension which traditionally has a significant impact on vigilance and visual analysis tasks. Finally, the researcher examined the affect self-efficacy had on reaction times.

This chapter contextualises and discusses the significant results, examines their relation to previous research and their contribution to current research on visual analysis. Each of the hypotheses are discussed at length. This is followed by a discussion on the limitations of the study and possible future research.

Discussion of Results pertaining to the Hypotheses

Concerning the primary hypothesis – that detection is positively associated with increased neural activity in areas associated with vigilance and visual processing – and the subsequent hypotheses that elaborate on the dynamics of that interaction, the following results were found: while at a superficial level, graphic representations seem to indicate that neural activity increases at the beginning and at the end of a 15 second period when a candidate is presented with a target; there are few statistically significant indications of this occurrence (Table 13 through Table 17). There was a statistically significant association between visual analysis and neural activity within the Theta (4-7 Hz) (Table 13) and Alpha One (Table 14) frequency band (8-10 Hz), with neural activity decreasing in the theta band and increasing in the alpha band upon presentation of a target item. Additionally, it was deduced that in comparing high and low performing groups only Alpha One returned a statistically significant association between detection and increased neural activity. Yet, this study did not produce any other statistically significant associations with visual analysis activity and neural activity. Thus, hypothesis one was not supported for all frequency bands.

In considering this, it is important to note that independent visual analysis areas (the anterior cingulate gyrus, the right parietal lobe, and the right frontal lobe) were not considered in isolation within the results chapter as the anterior circulate gyrus and the right parietal lobe yielded insufficient numerical results and were thus unqualified to be utilised independently within statistical analyses. It would be worth exploring this anomaly further in future research endeavours, as research tends to highlight the significance of these areas in attention and vigilance (Kold & Whishaw, 2009; Posner and Rothbart, 2007; Codispoti, et al, 2006; and Posner, 2012).

In order to determine what importance lies in this research report, it is necessary to consider the factors that may account for these findings, while simultaneously acknowledging that further research may provide greater insight. Primarily, there are two inconsistencies between what was predicted in light of contemporary research and the results of this research endeavour. Firstly, effective detection is associated with sustained attention in a visual analysis task (Wickens & McCarley, 2008), and studies have indicated that sustained attention is associated with increased neural activity – specifically within the beta frequency band as it is traditionally associated with alertness (Bearden et al, 2004, Kamiński, Brzezicka, Gola, & Wróbel, 2012; Gola, Kamiński, Brzezicka, & Wróbel, 2012; Kolb & Whishaw, 2009). Yet, as described above, it is the alpha one band which yielded a statistically significant positive result, and the theta band which significantly decreased. Therefore, it is critical to understand the distinction between these bands.

It was predicted that fluctuations in Beta activity would be most prominent as they are considered to be the concomitant phenomena of mental activity (Niedermeyer, 2005; Teplan, 2002), while alpha activity was generally considered to be associated with “conditions of physical relaxation, and relative mental inactivity” (IFSECN, 1974, as cited in Niedermeyer, 2005, p. 168; Teplan, 2002). Additionally, Alpha activity was considered to be attenuated by attention, especially visual and mental effort (Niedermeyer, 2005; Teplan, 2002).

The significance of Alpha frequencies within this research study may subsequently be accounted for by the fact that participants within the study generally reported that during the task they felt significantly sleepy, and drowsiness was a common occurrence – one participant fell asleep during the duration of the task. Niedermeyer (2005) characterises Alpha 1 as “alpha dropout” which is traditionally associated with drowsiness. Fluctuations within this frequency band may therefore be indicative of the slight variations in drowsiness participants experienced throughout the duration of the task. The drowsiness that occurred could have multiple antecedents such a sleep deprivation, the characteristics of the sample (in that, as a student sample they are less familiar with visual analysis and vigilance intensive jobs), or the conditions of the environment (silence, darkness etc. are intrinsically associated with sleep).

However, what is interesting to observe is that despite the significance of Alpha activity as opposed to Beta activity, participants performed relatively well in the task. Some research (Ray & Cole, 1985, as cited in Roche & Dockree, 2011) suggests that Alpha occurs “during periods when individuals are alert and receptive, the alpha rhythm – a key attention-sensitive EEG signal – changes in power” (p. 22). Though this is generally the minority view presented in the research. That being said, Alpha activity – due to the restfulness associated with it – has been linked to meditative conditions (Sanei & Chambers, 2007); and previous research indicates that meditation improves psychomotor vigilance (a subset of vigilance research) (Kaul, Passafiume, Sargent, & O'Hara, 2010). Furthermore, Donald (2011) asserts that “an individual’s level of arousal is seen to impact on the motivational intensity and the individual’s level of alertness, but there is not always a simultaneous change in detection efficiency during reduces arousal” (p. 69). These factors may account for the findings of this research.

Additionally, the analyses conducted consider overall neurological activity, rather than neurological activity at specific intervals throughout the task. As a result the well documented phenomena which suggests that people’s attention seems to wane and wax within a visual analysis or vigilance task (Mackworth, 1969; Parasuraman, 1984, Wickens & Hollands, 2000) has not been accounted for in this initial analysis (it is considered at a later point). In considering neural activity in this holistic way, it is possible that these fluctuations that occur over time on task may serve to nullify each other, creating an average that does not generate a statistically significant distinction between neurological activity at the time of a target versus at times with no targets.

Further, the fact that results did not return the expected outcomes, may have arisen as a result of contextual factors associated with this study, specifically the fact that the sample size was smaller than perhaps necessary due to factors associated with ineffective measurement; as well as the fact that the study was limited by environmental factors associated with effective EEG recordings. These factors will be further explored within the limitations of the study.

Finally, of import is that, while Alpha and Beta activity did not reflect expectations, Theta activity did. Theta activity, associated with sleep and inactivity (Teplan, 2002) decreased as a result of detection. Indicating that detection resulted in some level of neural activity.

What is also interesting to consider is that the graphic representation of the data seem to indicate spikes in neurological activity on presentation of the stimulus as well as when the stimulus is leaving the screen. One possible explanation that accounts for this, would be that participants notice the trigger, consider it and then perhaps double check their decision. Additionally, graphic representations are inconsistent with the statistical findings, perhaps as a result of the fact that they represent a more holistic view which transcends the frequency bands and rather represent spectral power generally. Thus perhaps the statistically significant results associated with Alpha 1 are reflected in this representation, swaying the holistic picture.

The second inconsistency apparent between the posited theory within the literature review and the findings of the study, lies in the fact that not all of the regions of the brain traditionally associated with vigilance and visual attention are seen to be affected during a visual analysis task, determined by the fact that numerical data was not discernible when considering these regions independently. This suggests the possibility of several things: one, there may be additional areas of the brain neurologically associated with visual analysis; two, areas of the brain associated with vigilance might not necessarily be associated with the broader visual analysis construct. Subsequently it may be a requisite to further distinguish the two constructs, both theoretically, and in terms of the regions within the brain that influence effectiveness in such tasks. Lastly, perhaps a more intrusive means of assessing which regions of the brain come into play needs to be investigated as EEG reading are traditionally associated with surface level neurological energy (Niedermeyer, 2005; Roche & Dockree, 2011).

Results concerning hypothesis three (Table 21) were in line with the expectations established within the literature (Parasuraman, 1984; Wickens & Hollands, 2000). Levels of neural activity do change during time on task, specifically within the Alpha 1 (Table 22), Alpha 2 (Table 23), and Beta 1 (Table 24) frequency bands. All of the abovementioned frequency bands generate less spectral power as the task progresses, which is in line with theories that suggest vigilance or visual analysis skill decreases with time on task ((Mackworth, 1969; Parasuraman, 1984, Wickens & Hollands, 2000). What would be interesting with regards to future research is whether this decrement persists over a longer task.

In considering the frequency bands where changes occur over time it is curious to note that alpha 1 has a significant decrease in spectral power between the first 10 minutes and the middle 10 minutes (10-20 minutes) of the task this indicates that the occurrence of alpha 2 and beta 1 activity potentially served to quieten alpha 1 signals. This is in line with the idea that the candidates potentially became more alert between the beginning and middle segment of a visual analysis task (Niedermeyer, 2005). In hindsight, it seems clear that these frequency bands would be characteristic of this task as they are associated with restfulness and moderate concentration which is representative of the nature of this task. What is perhaps surprising, is the lack of differences over time within the beta 2 frequency band; indicating less overt mental activity associated with visual analysis than initially anticipated. This further lends itself to the previous assertion, that it is perhaps necessary to further investigate the level of neural energy expended in a visual analysis task.

Hypothesis four did not yield significant results (Table 25 and 26); high rates of false alarms had no association with lower levels of neural activity. This seemed to contradict logical assumptions regarding the occurrence of false alarms. However, this may be accounted for by one of two things, firstly the groups performed relatively well, limiting the range of false alarms (range = 6, mean = 3.125), so there was less of a foundation to establish the links of false alarms to neural activity. Secondly, it seems to indicate that there is a further construct associated with the occurrence of false alarms. Further analysis would need to look at the time frames wherein false alarms predominantly occur, rather than consider neurological activity holistically. Additionally, it may be useful to interview participants following their performance in a task of this nature, to determine if they always genuinely believed there to be a change apparent within the item presented, or to establish what they thought about during the duration of the task, in order to determine what other factors could potentially be acting on this event. False alarms could indicate overt mental activity was taking part that was not associated with the task at hand, and perhaps linked to extraneous thoughts or considerations. It would be necessary to investigate whether neural activity of this nature would occur within the areas analysed.

Concerning hypothesis five, the association of misses and neurological activity, a statistically significant association between misses and neural activity was apparent within the Theta, Alpha 2, Beta 1, and Beta 2 frequency bands (Table 25 and 26). With the spectral power increasing in the Theta band in the event of misses; and spectral power decreasing in the remaining bands upon the occurrence of misses. This hypothesis, thus generated results most in line with the expectations established within the literature review. Theta activity is traditionally associated with sleep (Niedermeyer, 2005; Roche & Dockree, 2011; Sanei & Chambers, 2007), and it stands to reason that in the event a participant is sleeping it is likely that he will miss targets presented. As aforementioned, the higher regions of the alpha band and the beta are associated with alertness and mental activity associated with visual attention, a decrease in these would indicate less overt attention, and subsequently less likelihood of detecting targets within the visual field.

The final hypothesis considered an addendum variable not directly associated with detection rates, yet with implications for potential inconsistencies between detection and neural activity. The logic behind this hypothesis lies in the fact that should inconsistencies between detection rates and neural activity arise there are other facets which may contribute to this – such as self-efficacy. However, no significant result was produced in comparing reaction times to self-efficacy. The implication of this is that, theoretically neural activity should not increase simultaneously to the occurrence of a miss (which in the instance of this research endeavour, does not occur). Thus this finding is in actuality congruent with the findings presented in the analyses of hypothesis five. However, once again it is critical to consider the means by which these constructs were assessed. The self-efficacy scale is a small scale (as it was included as an addendum consideration) used on a small sample (in terms of sample sizes associated with quantitative data) and thus there is significant room for error in this analyses. Replicating this study with a larger number of participants may provide greater insight. These are not physiological constructs and thus a small sample size would not necessarily produce significant results. Moreover, self-efficacy is a multi-faceted and complex idea, and there are thus various associations which may have been overlooked in the use of a scale that had a fairly one dimensional view of the paradigm.

Contextualising the Results

The sample drawn was predominantly a student sample, with candidates having little to no experience or training in working within visual analysis contexts or roles; still, it can be asserted that visual analysis is ubiquitous with everyday tasks, and thus this should not be a negative consideration. Of the 11 participants recorded three of the candidates data sets were corrupted due to flaws associated with the collection of the data. As a result this study made use of a smaller sample than initially intended, and this may have had several implications on the data generated. Considering such it is necessary to turn to the limitations of this study.

Limitations of the Study

There were several limitations to the current study. The primary being the sample size decreased the chance of finding significant results (Charter, 2003). This limitation in sample size also affects the degree to which these results are generalisable. Further participants were not recruited as studies within the EEG field for the most part make use of sample of between 8 and 24 participants, thus this study fell within the spectrum. The concern is that it falls in the lower end of the spectrum. Additionally, faults linked to shortages of the EEG machine continued to occur within further efforts to recruit more participants.

Moreover, EEGs using visual stimuli should be performed in a dark, sound-proofed, and electrically insulated room, in an attempt to avoid all possible interference to the results (Teplan, 2002). This research was conducted within an office in the Psychology building of the University of the Witwatersrand. Attempts were made to darken the office, but it was not entirely successful, as the office had a moderate amount of natural light which filtered through the blinds. Additionally the room was neither sound-proofed nor insulated. Therefore ambient noise from surrounding offices and lecture rooms was not completely removed, and may have served to distract participants. The lack of insulation would have resulted in electrical-noise artefacts appearing throughout the EEG data further impacting upon the results of this study. In some instances the degree of manual filtering or cleaning required to counteract this effect rendered datasets null in void – specifically in the instance of participant 9. Therefore a limitation of this research was lack of a proper EEG recording space, which may have resulted in some of the recordings not being as accurate and representative as they may have been. Furthermore, data was collected in mid-summer, thus participants tended to sweat which resulted in connectivity issues at some of the electrode points; and in some instances (participants 10 and 11) this caused the machine to short circuit meaning the data generated was unusable.

Finally, this research fails to account for extraneous variables that may act on the results presented – such as undiagnosed medical conditions, or life events which lend themselves to distraction in a task that is not particularly stimulating.

Implications of the Research

The importance of visual analysis in navigating effective detection in tasks associated with vigilance and attention has been demonstrated by the literature, and the precursors which indicate it neurologically have implications for understanding the characteristics of visual analysis tasks. This study serves to begin establishing a foundation of understanding of the neurological activity dynamics associated with the occurrence of effective detection within visual analysis tasks – that is to say, if we understand that visual analysis is predominantly associated with alpha activity, we understand that individuals engaged in visual analysis have the propensity to disengage as a result of their restful state. What factors lend themselves to candidates operating more within the beta frequency band associated with more effective detection?

This study thus has implications for the realm of ergonomics – as well as neuroergonomics, as it demonstrates the way in which objective information may counteract or reinforce previously established principals or theories, in order to garner a deeper understanding of effective detection in a visual analysis task.

All of the results from this study would benefit from having further research performed to confirm there applicability within the research field of visual analysis.

Directions for Future Research

Future research would benefit from a project with a broader scope - a larger sample, and more electrodes distributed on a participant – in order to ascertain whether there are other areas associated with visual analysis, that have previously not been considered. Additionally tasks of a longer duration may reaffirm the notion of attention waning and waxing over the duration of a visual analysis task. A more diverse sample in terms of age may also have implications for future research.

Additionally, as mentioned above, it would be interesting to alter facets of the study to see what factors generate spectral power with higher frequency bands (for example a more dynamic, didactic visual analysis task, or a real world task associated with visual analysis such as driving simulations), and what factors extenuate spectral power within the lower frequency bands. This would generate insight regarding ways in which mental fatigue may be combated within professions requiring visual analysis tasks.

Conclusion

Visual Analysis is a relatively new conceptualisation associated with tasks that involve signal detection skills; the search for and detection of visual stimuli is omnipresent within everyday tasks and functions and it pervades everyday behaviour; it is also largely associated with the field of ergonomics as it is involved in a number of occupational tasks – specifically within vigilance intensive jobs. Furthermore, as technology and automation progresses the frequency with which visual analysis skills are required in tasks is drastically increased, and as innovation progresses, visual analysis becomes markedly more complex.

As such it is important to gain a deeper understanding of the factors linked to effective detection within a visual analysis task: in order to pre-empt faults associated with visual analysis at the design level. That is to say, jobs and activities that require high levels of visual analysis skill need to be designed in a manner that facilitates effective interaction. The aspects of these designs linked to success can be determined by assessing current faults associated with effectiveness.

One of the ways, a heightened understanding can be generated with regards to the subtleties of effective detection in a visual analysis task, is by objectively examining the neurological dynamics that occur in conjunction with a visual analysis task.

This study analysed these two construct (detection and neurological activity) simultaneously in order to begin building the foundation of knowledge necessary to assist in the ergonomic design of visual analysis tasks in the future. Findings indicated that there exists a propensity to garner deeper insight into the multifaceted nature of visual analysis with the use of neurological measures; contributing to the body of knowledge collectively known as “neuroergonomics”.

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Appendices

Appendix A: Participant information sheet

Psychology

School of Human & Community Development
University of the Witwatersrand
Private Bag 3, WITS, 2050
Tel: (011) 717 4500 Fax: (011) 717 4559

11 July 2012

Good Day

My name is Ashleigh Fowler and I would like to invite you to participate in a research study that I am currently conducting for the purposes of obtaining a Masters degree in Organisational Psychology at the University of the Witwatersrand. I am looking at visual processes during an observation task.

Participation in this research will involve giving up approximately two hours of your time, in order for you to complete an observation exercise.

- **What do you have to do?**
  You will be required to complete an observation exercise while you are connected to an EEG machine.
- **What will an EEG machine tell me?**
  It will allow me to examine the neural activity occurring while you complete the observation task. That is to say, it will indicate the patterns of activity occurring in your brain while you undertake the observation exercise.
- **What does the EEG machine involve?**
  This is a non-invasive procedure, which means that it is neither uncomfortable nor harmful to you. It merely involves attaching several electrodes to your head during the duration of the observation exercises (see the attached EEG information sheet).
- **When will this happen?**
  This will occur during time periods arranged between you and myself at a time that suits you.

Participation in this research is completely voluntary, and you will not be advantaged or disadvantaged in anyway should you choose to participate or not. This research is not intended to investigate individuals but rather to establish general trends. As such, your responses will only be examined in relation to other responses. All responses will be kept strictly confidential and no information that could identify you as an individual would be included in the research report.

If you are willing to participate please complete the attached consent form and contact me on 0767779848. Should you have any queries, please do not hesitate to contact me or my supervisor, Fiona Donald.

Yours Sincerely

Ashleigh Fowler
Industrial Psychology Masters Student
0767779848/ashleigh.fowler@students.wits.ac.za

Dr Fiona Donald
Supervisor
Fiona.Donald@wits.ac.za

Appendix B: EEG information page

Psychology

School of Human & Community Development
University of the Witwatersrand
Private Bag 3, WITS, 2050
Tel: (011) 717 4500 Fax: (011) 717 4559

EEG information Page

- **What It Is?**
  An electroencephalogram (EEG) is a test that measures and records the electrical activity of your brain. Special sensors, known as electrodes, are attached to your head and hooked by wires to a computer. The computer records your brain's electrical activity on the screen or on paper as wavy lines.
- **Why am I using an EEG?**
  An EEG can be used to monitor alertness and cognitive engagement
- **The Equipment**
  Encephalographic measurements employ a recording system consisting of: *electrodes with conductive media* (which read the signal from the head surface), *amplifiers with filters* (which bring the microvolt signals into the range where they can be digitised accurately), *an A/D converter* (which changes the signals from analog to digital form) and a *recording device* (which stores and displays the data).
- **What are the Risks?**
  The EEG has been used for many years and is considered a safe procedure. The test causes no discomfort. The electrodes only record activity and do not produce any sensation. In addition, there is no risk of getting an electric shock. That being said, should you have any underlying medical conditions or are on any form of medication it is advised that you do not participate in this research.
- **If You Have Questions**
  Please feel free to contact either me or my supervisor should you have any questions about the procedure.

Appendix C: Consent Form for participation in research

Psychology

School of Human & Community Development
University of the Witwatersrand
Private Bag 3, WITS, 2050
Tel: (011) 717 4500 Fax: (011) 717 4559

I ____ consent to participate in the study by Ashleigh Fowler on concentration in an observation task.

I understand that:

- Participation is voluntary and I can choose whether to participate or not
- I have been advised not to participate if I have a pre-existing medical condition or am currently taking medication
- My name and personal details will not be included in the research reports
- My responses are confidential
- Individual results will not be distributed
- I will not be advantaged or disadvantaged in any way by participating in the study
- I may withdraw from the study at any stage while completing the observation task if I wish to do so
- I understand that data will be stored securely by Ashleigh Fowler or her supervisor on completion of the study.

Name: ______________________________
Phone number (w): ____________________ Cell: ____________________

Signed: __________________

Appendix D: Questionnaire

Please complete the following questionnaire by marking the responses that apply to you. Thank you for answering all the questions, your responses will be kept in absolute confidence.

1. Age

18-25	
26-35	
36-45	
46-55	
56-65	
Above 65	

2. Gender

Male	
Female	

3. Home Language

English	
Afrikaans	
IsiNdebele	
Sepedi	
IsiXhosa	
Tshivenda	
Setswana	
Sesotho	
IsiZulu	
SiSwati	
Xitsonga	

4. Highest Level of Education

Less than grade 12 or matric	
Matric or grade 12 Certificate	
Certificate	
Diploma	
Postgraduate Diploma	
Bachelors Degree	
Honours Degree	
Masters Degree	
Doctorate	
Other	

5. Frequency that you play video games

Never	
Seldom	
Sometimes	
Frequently	
Often	

6. Please state the extent to which you agree or disagree with each of the following statements:

	Statement	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly disagree**
1.	I will be able to achieve most of the goals that I have set for myself.	1	2	3	4	5
2.	When facing difficult tasks, I am certain that I will accomplish them.	1	2	3	4	5
3.	In general, I think that I can obtain outcomes that are important to me.	1	2	3	4	5
4.	I believe I can succeed at almost any endeavour to which I set my mind.	1	2	3	4	5
5.	I will be able to successfully overcome many challenges.	1	2	3	4	5
6.	I am confident that I can perform effectively on many different tasks.	1	2	3	4	5
7.	Compared to other people, I can do most tasks very well.	1	2	3	4	5
8.	Even when things are tough, I can perform quite well	1	2	3	4	5