Local-Global Feature Discrimination: How Configural Elements of Visual Stimuli Impact Sustained Attention

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"Books are useless! I only ever read one book, "To Kill a Mockingbird," and it gave me absolutely no insight on how to kill mockingbirds!" – H. J. Simpson

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Chapter 1

1.1. Introduction to Vigilance

Historically, the need to scan ones immediate environment for critical, unique, or rarely occurring stimuli has been a requirement for both humans and other animals. With the simple objective of survival, the requirement in the past has been to scan the immediate environment for two types of targets; threats and food. This behaviour can still be observed in the animal kingdom, with certain animals required to scan their immediate habitats for predators while simultaneously searching for edible foods. For modern day humans, the need to perform such tasks as a matter of survival is no longer a necessary requirement for the majority of the population. However, aspects of these types of tasks can be found elsewhere in everyday human life. Workplaces, for example, have experienced dramatic changes to their environments over the last 40 to 50 years due to technological advances. Workplaces which in the past may have required large amounts of manual, physical labour have shifted towards a more automated approach, using machines which are capable of lifting more, moving faster, and being more precise than humans. Due to these advances, individuals working in these environments have been required to transition to more observational roles where they are required to perform systems monitoring, ensuring that these systems are working correctly, and stepping in to manually control the system for short periods of time if an anomaly or critical failure is detected. Supervisory roles like this are not necessarily confined to formerly physical labour roles, and aspects of these types of tasks can be found in numerous workplaces. For example, an airport security officer will be presented with a large amount of information over an extended period of time. During this time, they will be required to quickly and accurately identify which objects are deemed to be safe, and which objects may pose a risk and require closer inspection.

There are also many non-workplace related, everyday activities in which people are required to perform this type of prolonged search behaviour. Driving a car for example requires the operator to constantly scan the environment for cues for potential hazards, whilst simultaneously performing a number of other cognitive and motor tasks. Sporting and recreational activities also possess aspects of this type of behaviour, given that they may require detection of specific movements or cues from the opposition. Indeed, when approached from a systems-based perspective, almost any human or animal activity could be reduced to terms of monitoring an environment for specific cues, and responding accordingly. This task of monitoring for rare, critical or unique stimuli while ignoring more frequently occurring and generic stimuli is referred to as either *vigilance* or a *sustained attention* task (Davies & Parasuraman, 1982; Helton & Warm, 2008; See, Howe, Warm & Dember, 1995).

1.2. A Brief History of Vigilance Research

While there is some evidence of sustained attention tasks being investigated previously (Head, 1923; Wyatt & Langdon, 1932), the first scientific research dedicated solely to the area of vigilance is commonly attributed to Mackworth (1948). Mackworth was commissioned by the Royal Air Force (RAF) to investigate why cadets working as radar operators would experience a gradual decline in performance over time. As part of the role requirements, cadets were to observe their radar screen and detect small blips (enemy submarines) over an extended period of time. Over the course of these periods of watch, cadets showed an observable decrease in task performance in which they displayed an impaired ability to correctly detect targets. Mackworth simulated this radar-detection environment in the laboratory, with the aim of determining when performance would reach a critical level where cadets would either fail to detect targets, or were taking too long to respond to the critical signal. Mackworth designed a clock-face task (now known as a Mackworth clock), which required participants to respond whenever a clock hand jumped forward two spaces instead of the usual one space. Moreover, this two-jump event occurred relatively infrequently compared to the one-jump event, mimicking the event rate found in the more real world example of radar detection. It was found that participants' performance (measured in terms of missed signals) decreased with time on task in a somewhat linear fashion, modelling the phenomenon observed in the RAF cadets. This effect of performance decline over time has come to be labelled as the *vigilance decrement* by future researchers, and is a central point to most research focussed on sustained attention tasks.

The Mackworth clock task was intended to capture the relevant features of the radar detection environment of the RAF cadets during their everyday tasks. Subsequently, similar findings have also been observed in experiments which have modelled their paradigms on different environments. Experimental paradigms involving airport luggage scanning, medical monitoring, car driving, airplane operating, and other generic system monitoring tasks have been found to show the same vigilance decrement effect which was observed in the Mackworth clock tasks (Ballard, 1996; Damos & Parker, 1994; Davies & Parasuraman, 1982; Hancock & Hart, 2002). The common aspect to these situations being that the operator or operators are required to sustain a vigilant state for an extended period of time, while responding to a unique and rarely occurring signal amongst a series of distracter signals. As vigilance research has advanced from the initial investigations, it has become clear that rather than being domain-specific, the processes which govern vigilance performance are somewhat general in their functioning, given the large range of environments that vigilance tasks have been used in and the similarity of findings despite ecological differences.

1.3. Competing Theories on Vigilance Decrement

Despite a wide range of research in the area of sustained attention, there is still extensive debate amongst vigilance researchers and theorists regarding the underlying causes of the vigilance decrement. Two main competing types of theories have emerged from this, which can be broadly categorized by the umbrella terms of over-load theories or under-load theories; however, they are more commonly referred to as resource-depletion theories and boredom-mindlessness theories respectively (Brache, Scialfa, & Hudson, 2010; Helton & Warm, 2008; MacLean et al., 2009; Manly et al, 1997; Roberston et al., 1997). While determining the exact underlying cause of vigilance decrement is not a main investigative aim of this thesis, these theories inevitably must be considered when approaching any sustained attention research.

Under-load theories suggest that the vigilance decrement is due to receiving insufficient stimulation from the task, be it the nature of the stimuli, or general task paradigm properties. In other words, they are under-loaded by the task requirements, which results in a lack of interest in the task itself. Due to this, combined with vigilance tasks typically being of a subjectively boring, uninteresting or repetitive nature, people become disengaged from the task and their attention drifts away from the task requirements as time increases. Therefore, participants lose focus on the task as well as motivation to perform the task, which results in a decline in performance over time; the vigilance decrement (Manly et al., 1999; Manly et al, 2004; Robertson et al., 1997; Scerbo, 1998). This is generally characterized by an increase in task-unrelated-thoughts throughout the duration of the task (Giambra, 1995; Smallwood et al., 2004), as well as the associated decrease in performance over time. Under-load models suggest that in the time that lapses between critical signals, there is too little external support provided by the stimuli or task properties to maintain an individual's attention. From this perspective if task monotony is eliminated, then lapses in attention will similarly be eliminated. This idea has been investigated by using content-free auditory cues during vigilance tasks to draw the participants attention back to the task and out of their 'mindless' state. Findings from such investigations, however, yield inconsistent results (Helton, Head & Russell, 2011; Helton & Russell, 2012; Manly et al., 2004; Seli, Cheyne & Smilek, 2012).

Over-load theories, or resource theories, offer an alternative view; that the vigilance decrement is a result of the brains' inability to maintain the high levels of workload, attention, information processing and response generation that are required during a vigil over an extended period of time. This is due to a limited amount of cognitive resources which are available to be expended (Broadbent, 1958; Kahneman, 1973). The brain reaches a critical point at which it is over-loaded by the task requirements and unable to match the cognitive demands of the task, resulting in a decline in performance. While task monotony and task features do play significant roles in vigilance performance, under-load theories place them as a central component of sustained attention tasks. In contrast, overload theories view them as smaller components which can interact with the central component; resource allocation. A common model used to explain resource theory refers to a 'resource reservoir', a finite pool of cognitive resources which can be allocated towards various components of a task. As time on task increases, this pool of resources is depleted, resulting in fewer resources that are able to be allocated towards the task. Vigilance tasks require that an individual monitors an environment for an extended period of time in search for critical signals. This in turn means that participants do not receive an opportunity for breaks or a rest period to replenish their used cognitive resources, as these tasks are continuously using resources even while no targets are present (this is shown in the typical resource-based model of sustained attention which is presented in Figure 1.1). Resource theories state that this gradual drain of cognitive resources is the cause of the vigilance decrement typically observed in sustained attention tasks (Davies & Parasuraman, 1982; Matthews et al., 2000; Matthews, Davies & Holley, 1993; Smit, Eling & Coenen, 2004; Temple et al., 2000; Warm, 1993; Warm, Parasuraman & Matthews, 2008).

Evidence appears to be more consistent with resource-based theories of vigilance decrement rather than mindlessness-based theories. First, investigations using non-repetitive stimuli, interesting or novel stimuli importantly have been shown to result in significant vigilance decrement with time on task, despite predictions from mindlessness models which state that this should not be the case (Head & Helton, 2015; Helton, Head & Russell, 2011; Helton & Russell, 2012). Second, vigilance decrement is also accompanied by changes in blood flow velocity over the course of the task, a finding which provides a potential physiological indicator of resource use (Hitchcock et al., 2003; Lim et al., 2010; Schnittger et al., 1997; Shaw et al., 2009). Third, self-report findings show that feelings of mental fatigue, stress, and perceived mental workload are positively associated with vigilance decrement (Helton et al., 2000; Helton et al., 2005; Warm et al., 2008), suggesting that these seemingly straightforward tasks are subjectively hard work.. Finally, vigilance decrement effects have been found in a wide range of environments; including aviation, power control, motor vehicle operation and other novel environments (Ballard, 1996; Davies & Parasuraman, 1982; Hancock & Hart, 2002; Wickens, 1992; Wickens et al., 2009; Wiggins, 2011). This supports the idea that vigilance performance may be governed by something other than specific stimuli or task properties.

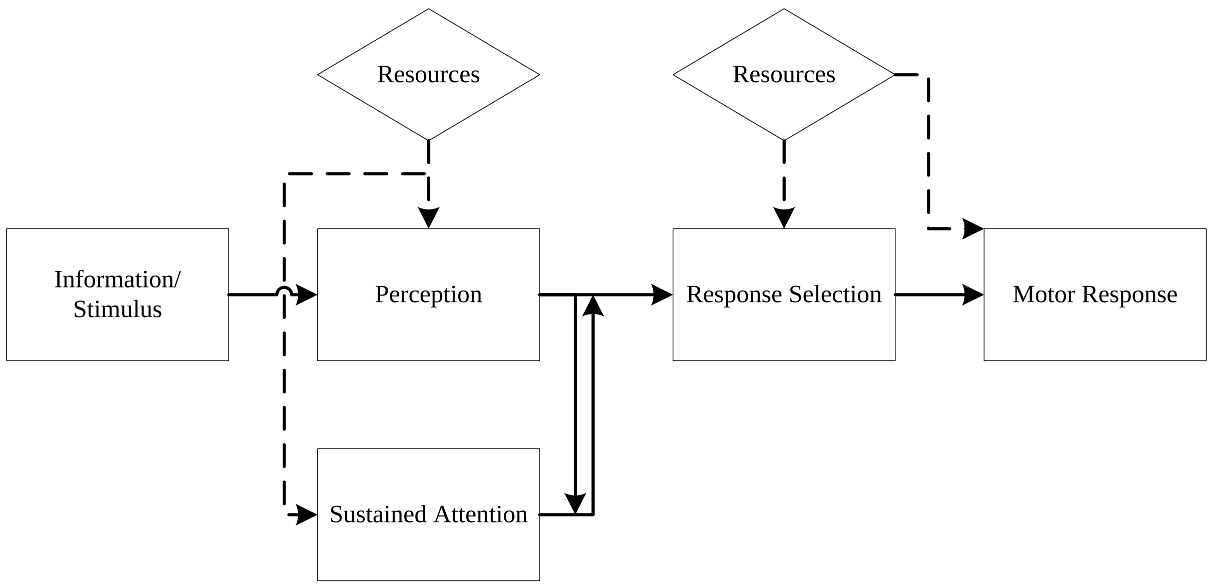


Figure 1.1. Example of a resource-based model for vigilance tasks.

While resource theory is the more supported of the two core theories, within resource theory itself is debate over the exact nature of the resource pool. More specifically, the debate is focussed on whether there is a singular resource pool which governs vigilance performance, or whether multiple resource pools exist. Single resource theories suggest that the brain has access to a single, central pool of resources which are ‘tapped’ into when required to perform a task (Kahneman, 1973). When an individual is required to perform two tasks at once, the available capacity of the resource pool is exceeded, thus creating cognitive demand. As the number of tasks increases so too does the difficulty of the tasks, potentially due to somewhat of a procedural bottleneck effect (Pashler, 1994). Once the cognitive resources available are exceeded and unable to accommodate both tasks, performance degradation is observed. Central to this view is that there is a system-wide resource which all actions access in order to be performed.

Multiple resource theory (MRT) is an alternative model of resource theory which states that there are multiple pools or networks of cognitive resources (Wickens, 1984; Wickens, 2000; Wickens, 2002). This theory has found extensive real world use, especially in the design of multi-modal systems involving human input. These include vehicle interfaces (Kramer, Cassavaugh, Horrey, Becic & Mayhugh, 2007; Santos et al., 2005), patient monitoring processes (Seagull, Wickens & Loeb, 2001) and flight decks (Van Erp, Jansen, Dobbins & van Veen, 2004). A central point to MRT is that cognitive resource pools are somewhat specialized in their function; for example, the resources which are recruited for spatial processing are separate from those which are recruited for auditory processing. Similarly, resource pools which are activated for perceptual processes are separate from those which are activated during cognitive processes, response selection, or motor control. This model suggests that tasks which are performed in parallel to each other should not experience large performance impaired if those tasks draw from separate resource pools. Similarly, those which use the same resources should experience impairment above and beyond that which would occur when only performing the single task. For example, an operator who was required to perform two spatial monitoring tasks in parallel should experience greater difficulty performing this than they would experience if they were required to perform a spatial monitoring task and a verbal monitoring task in parallel. This is supported by Caggiano and Parasuraman (2004), who found a decline in performance of a visuospatial task over time when participants performed a concurrent visuospatial task, while no such decline was found when participants were required to perform a concurrent visual verbal task. Similar results have been observed by Brill and colleagues (2007; 2008; 2009), where visual-visual dual tasking performance is found to be more impaired comparative to visual-tactile and visual-auditory dual tasking, findings which are in support of multiple resource theory.

There is also the possibility that resources may operate as somewhat of an amalgamation of unitary and multiple resource theories. There is evidence that the level of interference may be a function of the combination of the tasks involved. For example, steeper vigilance decrement patterns are found during visuospatial memory tasks compared to verbal memory tasks regardless of the modality of the concurrent task (Helton & Russell, 2011; Helton & Russell, 2012). This research also found increased impairment when a visuospatial memory task was partnered with a visuospatial vigilance task, comparative to when the memory task was paired with a verbal vigilance task. These findings are in support of multiple resource theory, however they also support the notion that there is an underlying, central resource pool from which resources are recruited for a number of tasks. As stated previously the debate regarding the underlying theories of vigilance is not a central theme to this thesis. However, sustained attention and the vigilance decrement will predominantly be approached from a MRT perspective for the remainder of this thesis.

1.4. Neural Processes of Vigilance

Sustained attention is commonly thought to be predominantly representative of 'top-down' processes, given that such tasks require utilization of some of the 'higher' aspects of attention such as divided or selective attention, however there is evidence of integration with "bottom-up" processes also (Sarter, Givens & Bruno, 2001). Top-down processes are those in which an individual's processing is aided by knowledge-driven mechanisms which assist with the discrimination between critical targets and distracter targets. Such mechanisms may also help the individual learn specific stimuli properties, task properties, or response rules which can then assist (or impede) response to certain aspects of the task. For example, upon initially beginning a vigil, individuals are immediately presented with a number of new and unique stimuli, throughout which they must search for the particular target. Individuals are also required to learn about particular characteristics of the task, such as signal modality, location of stimuli, signal speed and signal probabilities. From this, particular strategies may be developed by each operator for signal search and for target response. These variables all have some influence on vigilance performance, and are based on a number of underlying mechanisms including attentive filtering, signal processing, and passive perceptual learning (Hancock & Warm, 1989; Egner, Monti, Trittschuh et al., 2008; Head & Helton, 2015; Pessoa, Kastner & Ungerleider, 2003; Posner, 1994).

'Bottom-up' perspectives in contrast are those which describe sustained attention as a function of the stimuli characteristics and the context in which the stimuli are presented. From a bottom-up perspective, vigilance performance is driven by a number of aspects from the stimulus itself, and activation of the higher cortical levels is a result of the base-level processing which comes from this. In the context of these models, an individual is required to initially process the stimulus visually, which would activate the visual cortex, this would then activate regions associated with identification, location, decision-making and response generation (Cave & Wolfe, 1990; Treisman & Gelade, 1980; Treisman & Schmidt, 1982). It is important to note that top-down and bottom-up processing are not mutually exclusive, and most often interact and integrate with each other to find an optimal performance level during sustained attention tasks (Egeth & Yantis, 1997; Shallice et al, 2008; Stuss et al, 1995).

1.5. Cerebral Activation during Vigilance

As stated earlier, vigilance decrement is traditionally accompanied with reductions in blood flow velocity with time on task (Hitchcock et al., 2003; Lim et al., 2010; Schnittger et al., 1997; Shaw et al., 2009). Blood flow velocity changes, or cerebral hemodynamics, are closely linked to neural activity during sustained attention tasks (Moore & Cao, 2007; Raichle, 1998), and it has been proposed that these changes could provide researchers with an objective measurement of cognitive workload during tasks (Parasuraman & Caggiano, 2005; Shaw et al., 2013). There are a number of trends which have emerged throughout the literature investigating vigilance and cerebral activation. Perhaps the most consistent finding in this field is that sustained attention is right-hemisphere lateralized. In other words, the right hemisphere displays elevated levels of blood flow and metabolic activity comparative to the left hemisphere during vigilance tasks. This finding has been consistent across a number of studies using a wide range of brain imaging techniques including functional magnetic resonance imaging (fMRI), positron emission tomography (PET), transcranial Doppler sonography (TCD), and functional near-infrared spectroscopy (fNIRS; Berman & Weinberger, 1990; Buchsbaum et al., 1990; Cohen et al., 1988; Helton et al., 2007; Hitchcock et al., 2003; Lewin et al., 1996; Parasuraman, Warm & See, 1998; Shaw et al., 2009; Stroobant & Vingerhoets, 2000; Warm, Matthews, & Parasuraman, 2009; see Helton et al., 2010 for overview). This is also supported by research with commissurotomized (split-brain) patients, which demonstrates improved performance in vigilance tasks when signals are presented to the right hemisphere as opposed to the left hemisphere (Diamond, 1979a; 1979b;

Ellenberg & Sperry, 1979). Additionally, studies have revealed this hemodynamic response occurs in a number of areas, with greatest activation being found in the anterior cingulate cortex, the right inferior parietal regions, the basal ganglia, the right intralaminar region of the thalamus, the reticular formation, and the inferior prefrontal cortex (Kinomura, Larsson, Gulyas, & Roland, 1996; Langner & Eickhoff, 2013; Ogg et al., 2008; Parasuraman, Warm, & See, 1998).

However, a number of other factors have been identified as influencing cerebral activation, which may also influence the right-hemisphere lateralization effect. These findings suggest that right-hemisphere lateralization observed during sustained attention tasks may not be solely due to vigilance requirements alone. First, right-hemisphere lateralization has also been found to be a function of task difficulty (Helton et al., 2010; Kenett, Anaki & Faust, 2015; Klingberg, O'Sullivan, & Roland, 1997; Passarotti, Banich, Sood, & Wang, 2002; Yoshizaki, Weissman, & Banich, 2007). A finding which may be accounted for by the hemispheric division of labour theory, which suggests that when lateralized processes place unequal amounts of resource demands on which ever hemispheric system it is specialized in, the processing is transferred to the other, less utilized hemisphere. Second, right hemisphere lateralization has also been observed to be a function of certain types of emotional or arousing stimuli (Doi et al., 2013; Hancock, 2015; Herrmann et al., 2008; Hoshi, 2009; Ossowski, Malinen & Helton, 2011). Finally, it appears that certain stimuli properties result in increased bilateral activation, suggesting that configural or stimulus properties could result in more processing demands being placed on particular a hemisphere. For example, the requirement to process local or global information has been found to affect cerebral lateralization (de Joux, Russell & Helton, 2013; Helton, Hayrynen & Schaeffer, 2009).

1.6. Local-Global Feature Discrimination and Configural Properties of Stimuli

All visual shapes and objects are organized in a hierarchical fashion, in such a way that an overall shape is composed from smaller shapes and features. For example, a simple square could be considered to be a composition of four single straight lines, which have been ordered in a particular formation to represent what we interpret as box shape or square. These squares may in turn combine with other shapes and objects to form an even larger shape, a process which can then occur on multiple levels until a much larger and complex shape or object is formed. This may be analogous to the hierarchical structure of a sentence, where letters may combine to form words, which are then combined to form a coherent sentence. When discussing visual stimuli in terms of these objects, the smaller components are referred to as local objects, while the overall or fully formed component is referred to as the global object (Navon, 1977). Local-global feature discrimination then, is when an individual is required to attend to a certain aspect of a shape during a task (i.e., attending to the forest or attending to the trees).

Local-global feature discrimination itself has received a large amount of investigation, predominantly from the perception field of psychology rather than vigilance or sustained attention fields (Kimchi, 1992; Lamb & Roberston, 1990; Navon, 1977). During these tasks, both global and local precedence effects have been observed under specific circumstances. However, a global precedence effect, in which global features are more readily perceived, is arguably more common (Navon, 1977). These types of investigations have used experimental designs in which external prompts are provided prior to the presentation of the target stimuli; in some cases this cue may indicate that the stimulus is about to be presented, while in other cases this cue may serve as a point of comparison where the participant must compare the target stimuli against the cue. This acts as both a memory aid and an arousal aid to the participant throughout the task. These types of task paradigms remove the requirement to maintain a constant visual search for the unique target, which is a central characteristic of sustained attention tasks. A number of previous studies have investigated local-global feature discrimination without the use of external prompting. Flevaris, Bentin and Robertson (2010; 2011a; 2011b) for example, utilized a vigilance-type block trial method in which participants were required to continuously respond to the target stimuli with no memory or arousal aid, however sustained performance was not the main point of focus for the research and as such, time on task effects were not examined. The effects that local-global feature discrimination, and by extension the configurative aspects of stimuli used in vigilance tasks, may have on sustained attention performance has been relatively under examined.

1.7. Local-Global Feature Discrimination during Vigilance: Performance and Cerebral Activation.

Helton, Hayrynen, and Schaeffer (2009) suggested a number of reasons to suspect that vigilance performance may be influenced when participants are required to attend to either local or global elements of stimuli during sustained attention tasks. Specifically, they suspected that global feature discrimination should result in greater impairment in vigilance tasks compared to local feature discrimination. First, as stated above in regards to cerebral activation during vigilance tasks, the right hemisphere displays elevated levels of blood flow and metabolic activity comparative to the left hemisphere (Buchsbaum et al., 1990; Helton et al., 2007; Hitchcock et al., 2003; Parasuraman, Warm, & See, 1998; Shaw, Satterfield, Ramirez & Finomore, 2013; Warm, Matthews & Parasuraman, 2009; for an overview, see Helton et al., 2010). Second, research investigating cerebral activation during local-global feature discrimination reveals hemispheric differences between discrimination types. Lux et al. (2004) and Yamaguchi, Yamagata, and Kobayashi (2000) found the right hemisphere to be more dominant when an individual is required to perform global-feature discrimination, while the left hemisphere shows dominance when local feature discrimination is required. Additional support for this idea is found in research by Fink et al. (1997a, 1997b), which suggests that local and global feature discrimination possess some degree of hemispheric specialization during processing. Finally, Posner and Peterson (1990) propose a number of models of attention which suggest that, although systems for pattern recognition and maintenance of attention are connected via neural pathways, their functioning in the brain is divided. It is a requirement that these pathways are integrated during sustained attention tasks, which may result in performance differences in relation to the type of stimuli that is used. The implication of this is that global stimuli discrimination during sustained attention tasks may place higher resource demands on the right cerebral hemisphere, due to both sustained attention tasks and global feature discrimination tasks being more right hemisphere intensive. In contrast, local feature discrimination during sustained attention should result in more bilateral cerebral activity.

Two key studies have investigated local-global feature discrimination during vigilance tasks; the aforementioned Helton et al. (2009) investigation, and de Joux et al. (2013). Helton et al. (2009) used simple Navon objects (shapes that are composed of a number of smaller shapes; Navon, 1977) to investigate the effects that local-global feature discrimination had on vigilance performance. This investigation found that under vigilance conditions a local precedence effect may occur, as evidenced by significantly faster reaction times in the local condition compared to global. This investigation also used tympanic membrane temperature (TMT) as a measurement of cerebral activation before and after the task. TMT change scores revealed higher right hemisphere activation compared to left hemisphere activation when global feature discrimination was required. In contrast, local discrimination resulted in elevated left hemisphere activation relative to right hemisphere, as well as elevated bilateral activation compared to the global feature discrimination condition.

De Joux et al. (2013) extended this paradigm, with an increased vigil length and an alternative measurement of cerebral activation; functional near-infrared spectroscopy (fNIRS). This form of measurement allowed for the continual monitoring of hemodynamic activity in the prefrontal cortex, rather than pre-task versus post-task changes. Similar to the Helton and colleagues' investigation, local feature discrimination resulted in faster reaction times when compared to global feature discrimination, again suggesting a local precedence effect under vigilance conditions. Measurements obtained from the fNIRS also revealed differences in trends of cerebral activation over time. In the global feature discrimination condition, the traditionally observed right hemisphere bias was found, in that the right hemisphere had elevated levels of activity compared to the left hemisphere. Additionally, a linear trend in the right hemisphere was observed in the global feature discrimination task, with rSO_2 change scores increasing with time on task in the right hemisphere, compared to the left hemisphere remaining relatively stable. In comparison, the local discrimination task elicited significant bilateral activation. Although the right hemisphere was elevated in comparison to the left, both hemispheres followed the same trends over activation over time.

In long duration tasks, bilateral activation may be advantageous due to the increased total amount of cognitive resources that are able to be recruited for the task. Due to this, it is proposed that this bilateral activation may be in some part responsible for the superior performance found in the local feature discrimination condition. Additionally, evidence from previous research suggests an increase in interference during tasks that require the use of the same cerebral territory during functioning (Kinsbourne, 1982). This may further explain the differences found in Helton et al. (2009) and de Joux et al. (2013), as the brain functions required during the local discrimination task would not have the need to compete with each other to the same degree as those functions required during global discrimination.

One of the overarching goals of the current research is to extend this previous research investigating local-global feature discrimination during sustained attention tasks. While the first experiment in this series may be seen to be an extension of the de Joux et al. (2013) investigation, the following experiments begin to explore how much more complex stimuli with varying local and global components may influence vigilance performance. The intention is for this research to assist future research that involves more novel, complex, or even real-world stimuli that possess varying local-global elements.

1.8. Structure of thesis

The format of this dissertation may vary slightly from conventional formats, due to each chapter being based on self-contained journal articles which are focussed on the over-arching theme of configurative processing during vigilance. These are in various stages of publication; chapters 2 and 3 have been published, chapter 4 having received initial feedback from reviewers, and chapters 5 and 6 scheduled to be submitted for publication shortly. As such, each chapter contains its own literature reviews, complete methodological information, analysis and conclusions. Unfortunately as a result, some repetition was unavoidable during the writing process. Effort has been made, however, to improve readability and avoid unnecessary repetition wherever possible. Each chapter has been tailored to place increased emphasis on the specific goal or aim the particular experiment is investigating.

Chapter 2 builds on my previous local-global feature discrimination investigation, and further investigates interactions between vigilance and local-global processing using simple objects. This experiment also measured hemodynamic response during the task, which acted as a measure of cerebral activation. Chapter 3 is designed to investigate how local-global processing may be affected when using more complex or novel stimuli. Chapter 4 extends the previous paradigm, with a core focus on how motion processing may influence vigilance performance and feature processing during the task. Chapter 5 extends this paradigm, and combines it with aspects of Chapter 2, by investigating task transition demands during a task with complex and novel stimuli. Finally, Chapter 6 serves as a platform to tie together the previous chapters. Cerebral hemodynamic response is recorded during this complex stimuli paradigm, with comparisons being made between this and the research on simple local-global features. Chapter 7 provides a brief conclusion of each experiment, and a general discussion of the results found in the experiment chapters. This discussion, however, explores links between the studies and suggestions for future research, rather than specific elements of the results obtained.

Chapter 2

The Effects of a Transition between Local and Global Processing on Vigilance Performance

2.1. Abstract

Sixty participants performed a sustained attention task during which they were required to perform either local or global feature discrimination. Two groups were required to complete just one type of discrimination, while the remaining two groups were required to start with one type of discrimination before performing a transition to the other discrimination type half-way through. Results revealed that a transition resulted in a lessening of the vigilance decrement when comparative to the no transition conditions. It was also found that the local discrimination groups showed improved performance over time compared to the global discrimination groups, a finding which further strengthens the argument that a local precedence effect exists in feature discrimination during sustained attention tasks. Functional near-infrared spectroscopy (fNIRS) was used to measure cerebral blood oxygenation during the task, and was used as an index of cerebral hemodynamic activity in the prefrontal cortex. Total oxygenation was found to increase more in global discrimination tasks. It was also found that the left prefrontal cortex showed little change over time in the non-transition tasks; while in transition tasks the left prefrontal cortex followed the same trend as the right prefrontal cortex, indicating increased bilateral activation. Combined with the corresponding performance data, the results further support the theory that an increased utilization of bilateral resources may in some cases provide performance benefits over time.

2.2. Introduction

Every day, humans are presented with a large amount of stimuli and information. The range of these stimuli can be quite vast, encompassing visual, auditory and haptic senses, as well as varying significantly in terms of duration, strength, and speed of presentation. As these stimuli are presented, we are required to quickly determine the importance of that information, before producing an appropriate response. Often these stimuli are innocuous and do not require an immediate or specific response. However, occasionally there will be a critical stimulus presented to us that requires a very specific response or set of responses. For early humans, this type of activity was a necessity for survival, with the need to identify prey and avoid predators. While no longer a necessity for survival for the majority of the population, the need to detect rarely occurring critical stimuli amongst a series of non-critical stimuli can be found in many modern occupations, including air-traffic control, search and rescue personnel and hospital workers. The task of responding to these rare and critical stimuli is more commonly referred to as sustained attention or vigilance (Davies & Parasuraman, 1982; Warm, 1984).

An extensive body of literature exists on the subject of vigilance and the various factors that may impact performance during vigilance tasks. These may include stimuli event rate, target signal probability, signal salience and method of response (Ballard, 1996; See et al., 1995). An area that has not received a large amount of focus, however, is the effect that local-global object or feature discrimination may have on vigilance performance (Helton, Hayrynen & Schaeffer, 2009). Visual objects are organized in a hierarchical fashion, with small shapes combining with other small shapes to create a larger object. This process can occur at multiple levels in order to create a much larger and more complex visual image. This could be considered to be somewhat analogous to the structure of a written sentence, where letters are combined to form words, and those words are combined to form meaningful sentences. In regards to visual shapes or objects, the larger completed object is commonly referred to as the global object, while the smaller compositional shapes are commonly referred to as local objects (Navon, 1977).

Local-global feature discrimination has been approached extensively in psychological literature, albeit predominantly from a perception perspective rather than a sustained attention approach (Kimchi, 1992; Lamb & Robertson, 1990). Studies of this nature have tended to adopt experimental designs in which an external prompt is presented before the target stimulus is presented to the participant; in some cases to act as a cue to indicate oncoming stimulus presentation, while in other cases the cue may be presented concurrently and act as a point of comparison for the target stimulus. Paradigms of this nature remove the requirement to maintain the target stimuli in memory, which is a key characteristic of sustained attention paradigms. There are a number of studies which have approached local-global feature discrimination without using these external prompts (Flevaris, Bentin & Robertson, 2010; 2011), however vigilance performance does not appear to be the primary focus of these investigations. It is important to investigate the role that local and global feature discrimination may have during vigilance tasks, as it may have implications in regards to performance on various tasks in the workplace, particularly those in which a large amount of visual information may be received.

Helton, Hayrynen, and Schaeffer (2009) approached local-global feature discrimination from a more vigilance-based perspective using Navon objects. Navon objects are objects in which smaller, local shapes are arranged to form larger, global shapes (Navon, 1977). The particular shapes used in Helton et al. (2009) were large letters which were made up of an arrangement of smaller letters. Participants were required to respond to either the global or the local feature of the target object amongst a series of similar distracter targets. For example if the target feature was a large “T” letter that was composed from a series of small “E’ letters, the local discrimination group would be required to respond to the “E” shape, while the global discrimination group would be required to respond to the “T” shape. The results revealed that participants in the global feature discrimination condition showed slower reaction times compared to participants in the local feature discrimination condition, despite accuracy being similar across conditions. Tympanic membrane temperature (TMT), a method which involves measuring inner-ear temperature differences at pre- and post-test states, was also used in the study in order to assess cortical activation. From TMT, changes in hemispheric activation can be inferred. TMT measurements revealed differences in temperature changes between the left and right ear, with the right ear being more elevated in the global discrimination condition while the left ear temperature was more elevated in the local discrimination condition. Additionally, the local discrimination condition revealed more bilateral activation, in that both the right and left ear displayed increases in TMT. The combination of both performance trends and TMT changes suggested that the global feature discrimination condition produced elevated levels of cognitive fatigue compared to the local feature discrimination condition. They also suggest that global feature discrimination during vigilance tasks may place higher levels of cognitive demand on the right hemisphere, while local feature discrimination may elicit more bilateral activation.

Helton et al. (2009) proposed a number of reasons to suspect that performance on vigilance tasks may be disrupted more during tasks which require global feature discrimination compared to local feature discrimination. First, it has been found in previous investigations that the right hemisphere displays a greater level of metabolic activity compared to the left hemisphere during sustained attention tasks; a trend that has been found when using a variety of brain imaging techniques including functional near-infrared spectroscopy (fNIRS), functional magnetic resonance imaging (fMRI), positron emission tomography (PET) and transcranial Doppler sonography (TCD; Buchsbaum, et al., 1990;

Helton et al., 2007; Hitchcock et al., 2003; Parasuraman, Warm & See, 1998; Warm, Matthews & Parasuraman, 2009; Shaw, Satterfield, Ramirez & Finomore, 2013; for an overview, see Helton et al., 2010). Additionally, research investigating sustained attention performance using split-brain patients, the right hemisphere appears to be dominant during vigilance tasks (Diamond, 1979a, 1979b). A second important point is the apparent right hemisphere dominance during global feature discrimination and left hemisphere dominance during local feature discrimination (Lux et al., 2004; Yamaguchi, Yamagata & Kobayashi, 2000). Third, Posner and Peterson (1990) propose a number of models of attention where a division of labour exists among separate neural systems for both pattern recognition and attention maintenance. In prolonged tasks, these separately operating systems are required to integrate their activity.

Helton and colleagues perspective was primarily based on multiple resource theory (MRT; Wickens, 1984). Proponents of MRT propose that there are a number of cognitive resource pools which are utilized during perception, processing and performance. Originally, however, some resource theorists proposed a unitary model of resources (Kahneman, 1973). Vigilance researchers have explained the vigilance decrement as a result of the depletion of these cognitive resources. As time increases, the brain is unable to match the cognitive demands of the vigilance task. Expanding on the original unitary resource theory, MRT advocates propose specialized resource pools, matching some of the system modularity discovered in both functional brain imaging studies and behavioural studies using dual-task methods. For example, the resource pool for spatial processing has been found to be separate from the pool utilized during verbal processing (Pritchard & Hendrickson, 1985). The left and right hemispheres contain resource pools that are to some degree independent of the other hemisphere (Herdman & Friedman, 1985; Friedman, Polson, Dafoe & Gaskill, 1982; Friedman & Polson, 1981). The current study approaches the issue of local-global feature discrimination during vigilance tasks from a multiple resource theory perspective, as this provides a better framework to explain the differences found in both cerebral activation and performance during these tasks (de Joux et al., 2013; Helton et al., 2009).

Due to the reasons proposed by Helton et al. (2009) to suspect differences in performance during local-global discrimination based vigilance tasks, there are a number of possible outcomes that could occur during tasks of this nature. First, global feature discrimination during vigilance tasks should place higher demands on the right hemisphere, given both vigilance tasks and global pattern recognition are right hemisphere lateralized. Second, local feature discrimination during vigilance tasks should result in greater bilateral activation. Increased bilateral activation can in some cases be advantageous, as it increases the total amount of cerebral resources available to be devoted towards a task, as well as reducing structural interference (Friedman & Polson, 1981; Kinsbourne, 1982). Global feature discrimination, however, could possibly be advantaged due to increased intra-hemisphere co-ordination (Helton et al., 2009), where the right hemisphere may become more efficient at processing information with time on task.

De Joux, Helton and Russell (2013) investigated these possibilities using similar local-global Navon shapes (Figure 2.1). In this study, reaction times during the local feature discrimination task revealed a quadratic trend, where reaction times initially increased before improving and returning back to original starting levels. In the global feature discrimination task however, a linear trend occurred, with reaction times continuing to get slower over time (i.e. a stereotypical linear vigilance decrement trend). The study also used functional near-infrared spectroscopy (fNIRS) as a measure of cerebral hemodynamic response in the right and left prefrontal cortex. Cerebral hemodynamic response has been found to be closely linked with neural activity during sustained attention tasks (Moore & Cao, 2007; Raichle, 1998). Hemodynamic response during sustained attention tasks occur in multiple neural areas, particularly in the anterior cingulate cortex, the right inferior parietal regions, the basal ganglia, the right intralaminar region of the thalamus, the reticular formation, and the inferior prefrontal cortex (Kinomura, Larsson, Gulyas & Roland, 1996; Langner et al., 2012; Langner & Eickhoff, 2013; Ogg et al., 2008; Parasuraman, Warm & See, 1998). Due to the link between hemodynamic response and neural activity, measurement of changes in these areas of the brain can be used as a quantitative measure of mental workload (Parasuraman & Caggiano, 2005; Shaw et al., 2013). Results from the de Joux et al. (2013) investigation showed an overall greater level of oxygenation in the right hemisphere compared to the left. Right hemisphere oxygenation also increased over time, which was in line with previous studies suggesting right hemisphere dominance during sustained attention tasks (Duschek & Schandry, 2003; Helton et al., 2007; Parasuraman et al., 1998). Of note, an increasing linear trend in oxygenation across both hemispheres was observed in the local discrimination condition, while the global condition displayed no significant change. These findings were interpreted as an increase in bilateral activation in the local task. When combined with the performance data, these findings provide further support for the argument made by Helton et al. (2009) that local feature discrimination results in greater levels of bilateral cerebral activation compared to global feature discrimination, and that this bilateral activation may provide some form of performance benefits over time.

The differences between local and global vigilance performance, as well as the differences in vigilance decrement trends, found in Helton et al. (2009) and de Joux et al. (2013) indicate that vigilance tasks that require elevated levels of local or global discrimination may recruit separate cognitive resources. The current study is an extension of the de Joux et al. (2013) research, and looks to further examine the effects that differing types of discrimination have during sustained attention. While the previous study provided support for bilateral activation during local-feature discrimination tasks, it was felt that more research was needed to investigate this hypothesis given that bilateral activation could be influenced by a number of task parameters. Due to the nature of the objects used, it was possible to have participants perform a transition in the experiment from either local-to-global or global-to-local feature discrimination without changing the actual target stimuli. In doing so, it was possible to further examine the effects of local versus global feature discrimination.

Transitions in task demands have been identified as a crucial area in human factors research (Wickens & Huey, 1993). It has been found in previous investigations that sudden changes in task demand can impair performance across a number of modalities (Cumming & Croft, 1973; Cox-Fuenzalida, 2007; Cox-Fuenzalida & Angie, 2005; Helton et al., 2008). Both increases and decreases in task demand impaired performance, although typically decreases in task demand result in more extreme performance impairments (Bowers, 2013; Cox-Fuenzalida, Beeler & Sohl, 2006; Ungar, 2008). This suggests that task-transitions themselves may have an element of difficulty, regardless of the switch type. The demand costs associated with transitioning may have an impact on the current research. If local and global feature discrimination requires the recruitment of different neural resources, and therefore evoke different levels of cognitive demand, then a transition between local and global feature discrimination may yield changes in performance. Ward (1982) investigated a similar proposition to the current research, where participants were required to respond to targets at a particular level of feature discrimination. Of particular interest to the current research, it was found that a switch between local and global processing in a unitary attention task (required to only make responses to one type of discrimination) produced slower reaction times in both conditions. This is in line with the suggestion that any transition may have associated demand costs. However, it is unclear whether these results will be replicated in the current experiment, as a key issue with the current paradigm is that the unique target remains the same for both local and global discrimination while the distracter targets are manipulated. The transition only requires a change in feature discrimination, not a change in the target stimulus itself.

If local feature discrimination recruits bilateral resources (as opposed to the typical right hemisphere dominance) then it is hypothesized that a transition from global-to-local discrimination will result in improved performance post-transition. The cognitive resources from the left hemisphere will provide additional resourcing when the task transitions to local feature discrimination. This should result in an improvement in performance. Conversely, a transition from local-to-global discrimination will not display an improvement in performance, and performance levels will continue to decline. This would be due to no additional resources becoming available during the post-transition phase of the task, as no new source of resources would be actively recruited. A transition to global discrimination would place demands on an already activated resource pool. A non-transition local and non-transition global group performed a task identical to the de Joux et al (2013) study, both in order to assess whether de Joux et al.'s results replicated and to act as control groups for comparison with the transition conditions. It was expected that the transition groups would show a degree of impaired performance initially after the transition in comparison to the non-transition groups, due to the aforementioned research suggesting that task transition places additional demands themselves on participants, (i.e. switch costs).

Right and left hemisphere prefrontal cortex oxygenation was also measured throughout the vigil using fNIRS. It was expected that percentage rSO_2 change would increase over time. This hypothesis was based on findings from previous studies using fNIRS, which suggest that tissue oxygenation increases as processing demands increase (Helton et al., 2007; Stevenson et al., 2011). De Joux et al. (2013) found significant hemispheric differences over time between local and global (non-transition) conditions. It was expected that similar differences will be found in the current study. Transitions have been found to impair performance (Ungar, 2005; Bowers, 2013) and increase distress (Helton et al., 2008), which suggests that there is a degree of difficulty associated to the act of transitioning itself. As difficulty has been shown to increase bilateral activity (Helton et al., 2010), it was expected that the transition groups would display increased bilateral activity compared to non-transition groups.

2.3. Method

2.3.1. Participants

Sixty participants (29 males, 31 females) comprised of students from the University of Canterbury in Christchurch, New Zealand completed the study. The ages ranged from 18 to 46 years (*M* = 23.7 years, *SD* = 4.3). All participants were right handed, which was indicated by the participant and confirmed through observation of hand use while signing the consent form, completion of questionnaires and key responses during the vigilance task. All participants had normal or corrected-to-normal vision.

2.3.2. Materials and Procedure

The 60 participants were assigned at random to either a global, local, global-to-local or local-to-global vigil. Participants were tested individually in a windowless laboratory room. Participants were seated approximately 40cm from a 270mm x 340mm video terminal display, which was positioned at the eye level of the participant. While the participants were unrestrained, they were instructed to minimize unnecessary movements which could displace the fNIRS sensors or increase fNIRS noise. All participants were briefed regarding the task, and informed of the fNIRS and its function.

Prior to the beginning of the task participants were fitted with the fNIRS instrumentation, which was the Nonin Near-Infrared Cerebral Oximeter using Equanox sensors. The sensors were placed at the Fp1 and Fp2 positions (using standard 10/20 configuration for EEG placement) on each participant's forehead, and secured using a customized headset. The Fp1 and Fp2 positions were specifically chosen due to this being the most commonly used method during clinical use of fNIRS (Kim et al., 2000; Scheeren, Schober & Schwarte, 2012). Additionally, placement in these positions aligns with previous investigations involving vigilance tasks (Helton et al., 2007; Punwani et al., 1998; de Joux et al., 2013). Before the main task was started, a five minute baseline was recorded where participants were instructed to maintain a state of "relaxed wakefulness" while seated in front of a blank display. During this period they were to remain silent, minimize body movement, and maintain regular breathing patterns. Cerebral oxygenation during the final minute of this baseline period was used as a baseline index (Aaslid, 1986).

The Nonin Near-Infrared Cerebral Oximeter measures cerebral oxygen saturation (rSO_2). This is calculated by determining the relative amounts of oxyhemoglobin (O_2HB) and deoxyhemoglobin (HHb) in each hemisphere. The Nonin Near-Infrared Cerebral Oximeter requires two sensor pads (specifically the Equanox Advance Model 8004CA pads) to be attached to the forehead of the participant throughout the entirety of the task. The Equanox pads consist of two light emitters and two light detectors, with each detector receiving light from each light emitter. The emitters to detector distances are 20mm and 40mm. Four different wavelengths of light are used (725nm, 755nm, 805nm and 875nm). Readings were obtained at 3-second intervals.

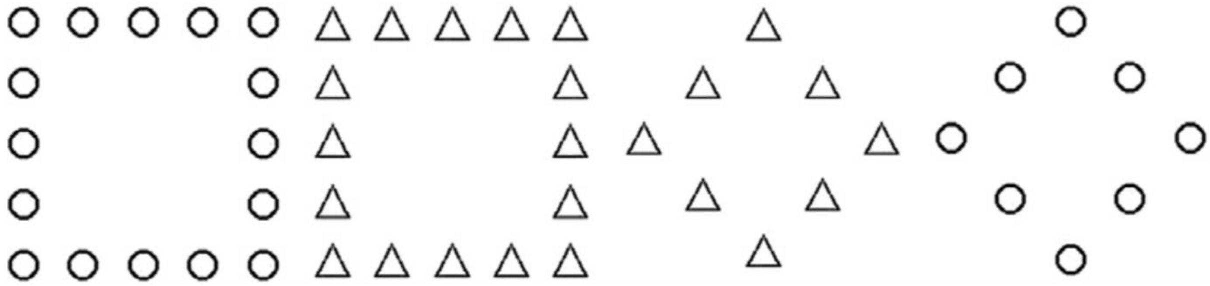


Figure 2.1. Examples of the local-global stimuli.

Participants performed a detection task using global-local shapes (see Figure 2.1), which are larger shapes formed by much smaller shapes (Navon, 1977; Helton, Hayrynen & Schaeffer, 2009; de Joux et al., 2013). In all response conditions participants were required to respond to the same unique target shape, however the distracter stimuli in each condition were changed which resulted in one condition requiring local target discrimination and one condition requiring global target discrimination. The target shape in all conditions was a square comprised of small circles. Whenever the target stimulus was displayed participants were required to respond by pressing the ‘response’ key on a keyboard (the spacebar). If the shape displayed was a distracter stimulus the participant was required to abstain from pressing the key. These shapes were presented in the centre of the screen. The distracter stimuli in the local target discrimination task were a large square and a large diamond both made of smaller triangles, while the distracter stimuli in the global target discrimination task were a large diamond made of smaller circles and a large diamond made of smaller triangles. This meant that the unique component of the target in the local discrimination condition was the small circles (the local shape), while in the global discrimination condition the unique component was the larger square (the global shape). Both distracter and target shapes were presented in a random order with a target shape probability of $p = 0.33$ and distracter shape probability of $p = 0.66$. During each trial participants were presented with a fixation cross that was displayed for 1000ms. The stimulus was then displayed for 100ms and then masked with an 85mm x 110mm black rectangle for 900ms, during which the participants' responses were recorded. Only responses made within this 900ms period were logged. Each trial was 2000ms in duration from fixation cross to stimuli presentation and response, resulting in 30 trials per minute and 120 trials per period.

All participants were given a 30-second trial period in order to familiarise themselves with the task. Target and distracter shape probabilities for this trial period were set to the same levels as for the experimental periods. The short practice period was simply for participants to familiarise themselves with the task requirements. Participants were also provided with appropriate feedback during this practice session. The decision for a shorter practice period than that of previous experiments (de Joux et al., 2013; Helton et al., 2009) was made so that this period did not cause undue influence on fNIRS readings, and that initial experimental readings would closer approximate true resting levels. Following this trial period participants completed eight continuous four-minute periods. In the local and global conditions, all eight periods involved the one form of discrimination task. In the transition conditions (i.e. local-to-global) the first four four-minute periods involved one form of discrimination (i.e. local discrimination), before switching between the 4th and 5th periods to the previously unused discrimination group (i.e. global discrimination) for the rest of the task. This resulted in four periods of each discrimination task for the transition conditions. Participants in the transition conditions were not informed that that transition would occur during the experiment, and were provided with the same instructions as the non-transition groups (i.e. only respond to a square comprised of small circles). The decision for this was to reduce any potential impact that foreknowledge may have on switch-costs (de Jong, 2000; Sohn, Ursu, Anderson, Stenger & Carter, 2000; Sohn & Anderson, 2003). Immediately following completion of vigil task, the fNIRS was removed from the participants' forehead.

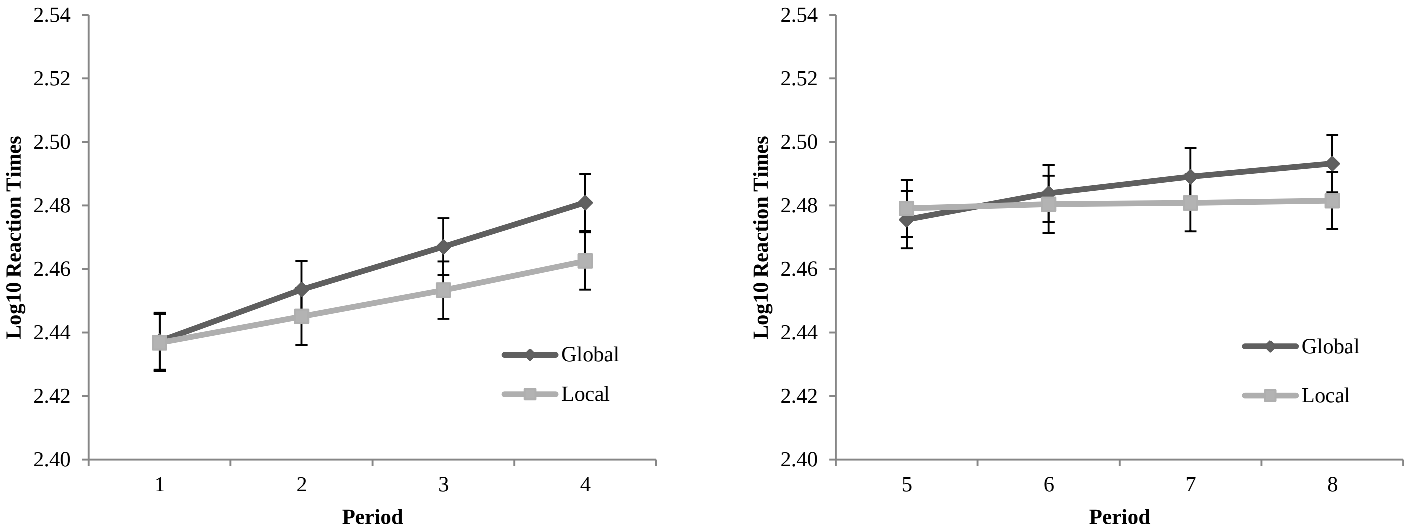
2.4. Results

2.4.1. Performance

Practice session performance was analysed with an independent groups ANOVA. No statistically significant differences were found between groups in terms hits, false alarms or reaction times. Due to the high percentage of hits (M = 98.03%) and low percentage of false alarms (M = 1.02%), reaction time was chosen as the more appropriate performance metric for the experiment. Reaction times were subjected to a $\log_{10}$ transformation, as recommended by Maxwell and Delaney (2004). For assessments of changes with periods of watch (changes over time) we employed orthogonal polynomial contrasts to assess for linear trends as hypothesized. These contrasts were employed because they are orthogonal 1 degree of freedom contrasts, hence, are not subject to concerns regarding the sphericity assumption. They are also the most direct and powerful tests of our hypothesized changes with time on task (Rosenthal & Rosnow, 1985; Rosenthal, Rosnow & Rubin, 2000; Rosnow & Rosenthal, 1996; Ross, Russell & Helton, 2014). Given that repeated measures ANOVA is the more commonly used analysis in vigilance research however, the omnibus analysis of variance results are included in addition to the orthogonal polynomial contrast results. In these analyses the Huynh-Feldt correction for failures to meet the sphericity assumption were only reported if both the Mauchly's test was significant and the correction resulted in a substantive change in the statistical test. In those cases the Huynh-Feldt were reported. For ease of analysis, as well as allowing us to more closely examine the effects of the transition itself, the pre-transition (first four periods) and post-transition (last four periods) scores were analysed separately.

The pre-transition transformed values were analysed with a 2 (discrimination task: global versus local) x 2 (change versus no-change) x 4 (period of watch) mixed between-within repeated measures ANOVA with orthogonal polynomial contrasts. In the pre-transition stage there was a significant linear trend for period of watch, $F(1, 56) = 22.58$, $p = .001$, $\eta p^2 = .287$, with reaction times increasing over the four periods. For the omnibus test, there was a significant period main effect, $F(3, 168) = 19.59$, $p = .01$, $\eta_p^2 = .259$. No other effects or interactions were statistically significant, nor were any other linear or quadratic trends.

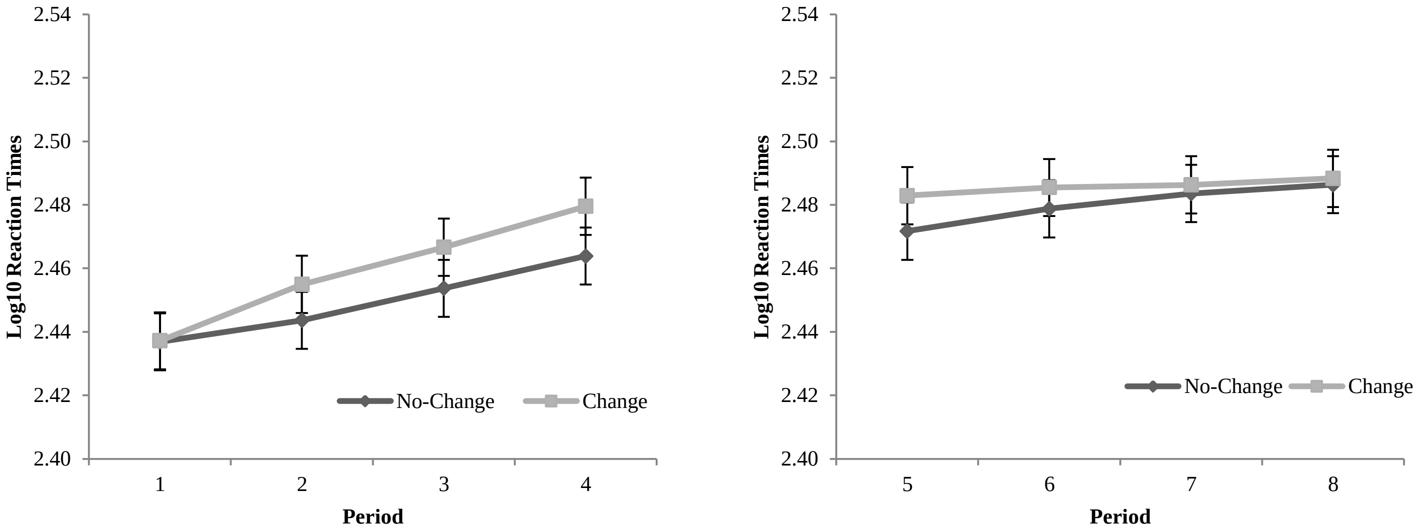
The post-transition transformed values were analysed with a 2 (discrimination task: global versus local) x 2 (change versus no-change) x 4 (period of watch) mixed between-within repeated measures ANOVA with orthogonal polynomial contrasts. A significant linear trend for period of watch was observed, $F(1, 56) = 13.58$, $p = .001$, $\eta p^2 = .195$. Again, reaction times over the four periods increased over with time on task. There was also a significant interaction linear trend for period by discrimination, $F(1, 56) = 7.95$, $p = .007$, $\eta p^2 = .124$, where the global and local discrimination conditions show different linear trends over time. The global condition shows a linear increase, while the local condition does not show the same increase over time. For the omnibus test there were two statistically significant effects: a period effect, $F(3,168) = 12.59$, $p = .000$, $\eta_p^2 = .184$, and a period by discrimination task interaction, $F(3,168) = 7.35$, $p = .000$, $\eta_p^2 = .116$ (see Figure 2.2). The period by change interaction, $F(3,168) = 3.04$, $p = .031$, $\eta_p^2 = .05$, was significant uncorrected, however with a Hunyh-Fedlt correction was non-significant, $p = .076$. No other effects or interactions were statistically significant. Due to the significant period by discrimination task interaction in the post-transition periods, we analysed each discrimination task separately with one way repeated measure ANOVAs with orthogonal polynomial contrasts to assess the period effect for each group. For the global task the periods effect was statistically significant, $F(3,87) = 14.30$, $p = .001$, $\eta_p^2 = .330$. For the local task the periods effect did not reach significance, $F(3,87) = .48$, $p = .694$, $\eta_p^2 = .016$. The pre- and post-transition reaction times for type of discrimination task can be observed in Figure 2.2, while reaction times for change versus no-change conditions can be observed in Figure 2.3.



Pre-Transition

Post-Transition

Figure 2.2. Mean reaction times (ms) for local and global conditions during pre-transition (left) and post-transition (right) periods of watch. Error bars depict standard error.



Pre-Transition

Post-Transition

Figure 2.3. Mean reaction times (ms) for transition and no-transition conditions during pre-transition (left) and post-transition (right) periods of watch. Error bars depict standard error.

2.4.2. Physiology

In line with previous studies that have used fNIRS, a relative measure of regional oxygen saturation (rSO_2) was used for analyses (Helton et al., 2007; Yoshitani, Kawaguchi, Tatsumi, Kitaguchi & Furuya, 2002; de Joux et al., 2013). These rSO_2 scores are based on the percentage change relative to the individuals' resting baseline. A score of 0 indicates zero change from the baseline. In line with performance data analysis, the pre- and post-transition scores were analysed separately. Therefore, pre-transition the rSO_2 change scores were examined using a 2 (discrimination task: global versus local) x 2 (hemisphere) x 4 (period of watch) mixed between-within repeated measures ANOVA with orthogonal polynomial contrasts. During the pre-transition stage there was a significant linear trend for periods of watch, $F(1, 56) = 15.37$, $p = .001$, $\eta_p^2 = .215$, with rSO_2 scores decreasing with time on task. This was also the result of the omnibus test, where a significant period effect was revealed, $F(3, 168) = 11.95$, $p = .001$, $\eta_p^2 = .176$. There were no other statistically significant effects or interactions pre-transition in either the polynomial contrasts or omnibus test results.

Post-transition, the rSO_2 change scores were examined using a 2 (discrimination task: global versus local) x 2 (change versus no-change) x 2 (hemisphere) x 4 (period of watch) mixed between-within repeated measures ANOVA with orthogonal polynomial contrasts. There was a significant linear trend for periods of watch, $F(1, 56) = 7.36$, $p = .009$, $\eta_p^2 = .116$, with rSO_2 change scores increasing over time. There was also a significant linear trend for the period by discrimination task interaction, $F(1, 56) = 6.98$, $p = .011$, $\eta_p^2 = .111$, where rSO_2 change scores in the local conditions show little change over time, while an increase over time is observed in the global condition. This is shown in Figure 2.4. Finally, there was a significant period of watch by hemisphere by change 3-way interaction linear trend, $F(1, 56) = 9.70$, $p = .003$, $\eta_p^2 = .148$. For the change groups both the right and left hemispheres show an increasing linear trend over time. The no-change groups in comparison reveal an increase in right hemisphere rSO_2 change scores, while the left hemisphere in the no-change groups do not show this increase. This is shown in Figure 2.5. For the omnibus ANOVA test, there was a significant period effect, $F(3, 168) = 3.915$, $p = .001$, $\eta_p^2 = .065$, a significant period by post-transition discrimination task interaction, $F(3, 168) = 4.284$, $p = .006$, $\eta_p^2 = .071$, and a significant hemisphere by period by change interaction, $F(3, 168) = 5.352$, $p = .002$, $\eta_p^2 = .087$.

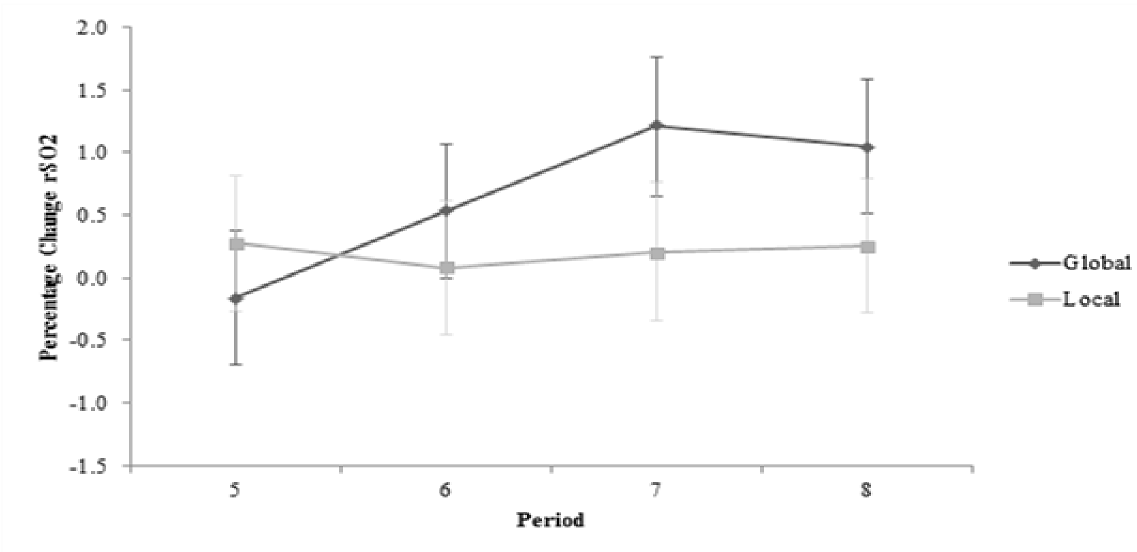


Figure 2.4. Mean percentage rSO2 change scores for local and global conditions during the last four periods of watch. Error bars depict standard error.

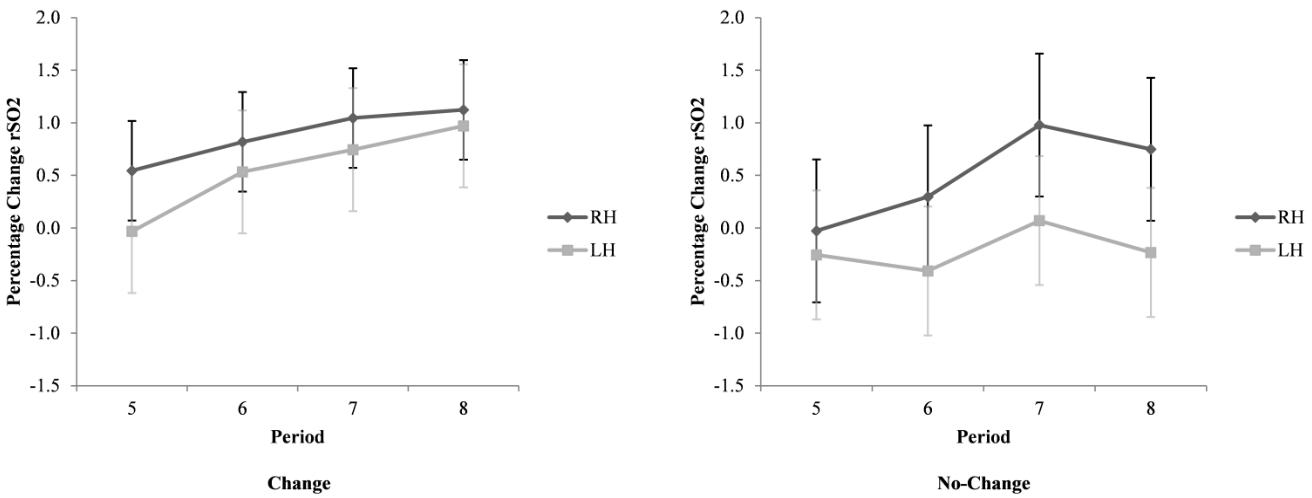


Figure 2.5. Mean percentage rSO2 change scores across each hemisphere in both the change (left) and no-change (right) conditions during the last four periods of watch. Error bars depict standard error.

In order to further explore the 3-way interaction, two separate hemisphere by period of watch repeated measures ANOVAs were conducted for the change and no-change groups separately. In the case of the change group, there was only a significant period effect, $F(3, 87) = 3.08$, $p = .032$, $\eta_p^2 = .096$ [with a Huynh-Feldt correction, $p = .050$], indicating that no differences exist between the right and left hemispheres in these conditions. In the case of the no-change group there was a significant hemisphere by period interaction, $F(3, 87) = 3.11$, $p = .031$, $\eta_p^2 = .097$, further supporting the previous interpretation that hemispheric differences were present in these groups.

2.5. Discussion

Log10 transformed reaction times during the pre-transition periods were characterized by a linear trend where reaction times across all groups increased over the four periods. This finding is not of great importance to the overall research question; however it did demonstrate that there was a significant vigilance decrement, and that there were no statistically significant differences between the groups at this stage. This is consistent with trends found in previous similar experiments (de Joux et al., 2013, Helton et al., 2009).

The post-transition reaction times were characterized by an overall period effect, a period by change interaction (although not statistically significant with a correction for a violation of the sphericity assumption), and a period by discrimination task interaction. The overall period trend indicates a vigilance decrement in the final periods of the vigil, continuing the pattern of decrement found in the pre-transition periods. Of more importance to the research aims however were the change versus no-change interaction and the discrimination task effects observed in the post-transition periods. As shown in Figure 2.2, the global condition exhibits a much larger increase in reaction times over the final four periods, while the local condition does not change significantly with time on task. This is in agreement with de Joux et al. (2013), where reaction times for local participants displayed a quadratic trend over a similar time frame. This finding is in line with our expectations in regards to the advantages that local feature discrimination tasks may have compared to global discrimination tasks during vigilance tasks, and the associated patterns of vigilance decrement.

The mean reaction times for the change versus no-change conditions are shown in Figure 2.3. These findings provide some support to the suggestion that transitioning from one condition to another (regardless of what the transition is to or from) has an effect on the overall reaction times; a finding only partially in line with expected results. While reaction times are increasing over time in both conditions (the significant period effect), the trends found here suggest that changing between discrimination types may slow initial reaction times (e.g. the change causes a slower than expected response time). This finding does not match expectations that a change may be overall beneficial to performance due to an increase in bilateral activation. Instead the change appears to, if anything, result in an initial relative slowing in the post-transition periods. This finding appears to be more in line with previous work regarding switch-costs (Ross et al., 2014) and transitions in task demands (Cox-Fuenzalida, 2007; Cox-Fuenzalida & Angie, 2005; Helton et al., 2008), which suggest that any type of change in task demands impairs performance. It is also more in line with Ward (1982), in that a change between discrimination types initially impairs performance.

The rSO_2 change scores obtained from the fNIRS were characterized by four main effects. The first was a significant period effect in the first four periods of watch, where rSO_2 scores decreased over the periods. This indicates a decrease in cerebral activation in the first four periods. As previous studies using fNIRS have shown that tissue oxygenation increases along with information processing demands (Helton et al., 2007; Stevenson, Russell & Helton, 2011, Toronov et al., 2001), it may be interpreted that participants experienced a decrease in information processing requirements from their baseline levels. One explanation for this finding is that the present task, while demonstrating a significant slowing of response times over time (i.e. a vigilance decrement), was not a particularly challenging vigilance task, as is evidenced by the near-perfect accuracy throughout the task across all conditions. This would result in a decrease in processing demands from whatever previous task each participant was undertaking. Future research may require more demanding local and global discrimination vigilance tasks in order to more closely examine this initial decrease. In the post-transition phase, there was a significant period effect for time on task, an overall upward trend in rSO_2 change scores is observed. This may be an indication that participants are experiencing an increase in information processing requirements in the final four periods.

There was a significant period by post-transition discrimination task effect (Figure 2.4) in which rSO_2 change scores increased in the global condition, while those ending in the local condition did not show any significant changes over time. This is contradictory to findings from the de Joux et al. (2013) study in which both local and global conditions increased over time in the same general trend. This may be due to the global task becoming more demanding late in the vigil, potentially due to increased task demands placed on the right hemisphere, and appears to match with the decreased performance noted in the global condition relative to that found in the local discrimination task.

Finally, there was a significant change by period by hemisphere 3-way interaction (Figure 2.5). In the change group there was an increase in rSO_2 change scores over time. While the right hemisphere was slightly higher than the left in this group, both hemispheres show the same increasing trends over time. We expected that the change in task demands and change in associated cognitive resource requirements would result in increased bilateral oxygenation; however it was expected that this bilateral activation was to be evident only in conditions requiring local discrimination in the post-transition periods. In the no-change condition however, the right hemisphere exhibited a much greater increase in rSO_2 change scores over time when compared to the left hemisphere change scores, which stayed relatively stable in this group for the duration of the post-transition phase. This finding is similar to that of de Joux and colleagues' (2013), during which the right hemisphere showed a large, increasing trend over time while the left hemisphere showed a minimal increase with time on task. That this trend is only found in the no–change groups suggests that, over time, vigilance tasks may become more taxing on the right hemisphere (as mentioned previously, vigilance tasks are typically right hemisphere dominant). The increase of both right and left hemisphere activation in the change group suggests that a change between discrimination types may increase bilateral activation. This relative increase, however, does not appear to result in any particular performance benefits, and may instead simply reflect compensatory expenditure due to the new challenge presented by the change.

Increased bilateral activation has also been found to be a function of task difficulty in previous investigations (Helton et al., 2010). This raises the issue of whether the increased bilateral activity observed in the change group is a function of transitions themselves being more difficult; a function of the requirement to perform a new type of discrimination; or perhaps an interaction between these. Research by Ungar (2005) and Helton et al. (2004; 2008) found transitions in task demands to increase subjective ratings of distress. Any switch may increase challenge and this may result in increased bilateral recruitment. Unfortunately, due to the relatively simplistic nature of the stimuli used in the current task, accuracy data is not appropriate to determine difficulty effects here. Future research is needed to separate out overall task difficulty effects from the issue of the specific resources utilized as a result of specific task requirements. This may require brain imaging with increased topographic resolution.

While these results are not entirely in line with expectations, they provide support the position that the local and global properties of stimuli used during vigilance tasks may be an important dimension of sustained attention that was previously overlooked (Helton et al., 2009; de Joux et al., 2013). These results warrant further research investigating the effects of local-global stimuli and configurative properties of stimuli during sustained attention tasks.

Chapter 3

The Configural Properties of Task Stimuli do Influence Vigilance Performance

3.1. Abstract

Sixty-one participants performed a sustained attention task during which they responded to a critical signal that required feature discrimination. Three separate groups performed the task, with different global display configurations given to each group. The local feature elements (directional arrow shapes) were displayed either on a circle, a circle which was broken apart and reversed, or a reconnected figure which bore a degree of resemblance to the broken object, however had extended spatial information. For two of the groups the entire display consisted of a clear and complete global shape (circle and reconnected), while for one of the groups the display had no discernible global element (broken circle). The critical signal, however, remained the same for all conditions. Analyses of hit rate and *A'* scores revealed that performance of the broken group was impaired compared to the circle and reconnected groups. It is suggested that these results are due to a configural superiority effect, where performance is improved by having a completed global shape property to the entire display. The results provide validation for further research using this paradigm in conjunction with a measurement of cerebral activation, given that cerebral activity during vigilance tasks is dependent on a number of factors, including both task difficulty and hierarchical aspects of the display. The configurable or hierarchical aspects of vigilance displays may be critical in understanding sustained attention performance and its hemispheric lateralization.

3.2. Introduction

People regularly need to monitor their immediate environments during extended temporal searches for rare or infrequently occurring stimuli. Psychologists refer to this process as vigilance or sustained attention (Davies & Parasuraman, 1982; Warm, 1984). A consistent finding in the scientific literature is that sustained attention appears to elicit right-hemisphere cerebrally lateralization. In other words, blood flow and metabolic activity are elevated in the right hemisphere compared to the left hemisphere during such tasks, a finding which has been determined by employing a variety of imaging techniques including; functional magnetic resonance imaging (fMRI), positron emission tomography (PET), transcranial Doppler sonography (TCD), and functional near-infrared spectroscopy (fNIRS; Berman & Weinberger, 1990; Buchsbaum et al., 1990; Cohen et al., 1988; Helton et al., 2007; Hitchcock et al., 2003; Lewin et al., 1996; Parasuraman, Warm & See, 1998; Shaw et al., 2009; Stroobant & Vingerhoets, 2000; Warm, Matthews & Parasuraman, 2009; for a more concise perspective however see Helton et al., 2010). Additionally, research involving commissurotomized (split-brain) patients has demonstrated improved performance when signals are presented to the right as opposed to the left hemisphere (Diamond, 1979a; 1979b). Recent investigations have also shown an association between reductions in right hemisphere cerebral blood flow with declines in vigilance task performance (Shaw et al., 2013), suggesting that the right hemisphere plays an integral role in vigilance performance and sustained attention maintenance.

Nevertheless, the right lateralization of vigilance may require some caveats. For example, this cerebral lateralization resulting from vigilance tasks appears to be, at least in part, a function of task characteristics other than prolonged temporal search. Helton and colleagues (2010) found evidence that suggest the laterality profile may be a function of task difficulty, where vigilance tasks of a higher difficulty elicit more bilateral cerebral activity.

This finding is in agreement with findings of literature on tasks other than vigilance which show an increased bilateral activiation with increased task challenge (Ferrari et al., 2013; Gur et al., 2000). In addition to overall task difficulty, it is also a possibility that the compositional or hierarchical features of the stimuli may be influential on bilateral activation.

Visual objects, for example, are ordered in a hierarchical fashion, where larger objects are composed from a number of smaller features or shapes. These smaller features themselves may be composed from even smaller elements, and so on. The smaller features of an overall object are referred to as local shapes or features, while the overall object itself is commonly referred to as the global shape or feature. Local-global feature discrimination, and cognitive processing of such features, has been thoroughly investigated from a perceptual standpoint (Kimchi, 1988; Kimchi, 1992; Kimchi & Palmer, 1982; Lamb & Robertson, 1990; Navon, 1977; Pomerantz, 1983). The discrimination of local and global visual objects during sustained attention tasks, however, has received relatively little investigation. Research that has been performed in this area has found that the processing of local and global visual objects produce differing effects on both objective measures of vigilance performance as well as measures of cerebral activity (de Joux, Russell & Helton, 2013; Helton, Hayrynen & Schaeffer, 2009). Vigilance tasks where local feature or shape discrimination is required appear to elicit more bilateral activity compared to tasks that require more global shape or feature discrimination.

The differences found between local and global feature discrimination during vigilance tasks may be the result of each type of feature discrimination requiring the use of separate cognitive resources across hemispheres. This raises the issue of whether feature discrimination during sustained attention tasks is governed by a unitary resource, or whether multiple resource pools contribute towards performance. Given that local and global feature discrimination results in differing response and cerebral activation trends, previous findings may be more in support of multiple resource theory (MRT; Wickens, 1980; Wickens, 1984; Wickens, 2008; Wickens & Hollands, 2000). Studies investigating local-global discrimination using a range brain imaging techniques indicate a right hemisphere bias for global discrimination and left hemisphere bias for local discrimination (Lux et al., 2004; Van Kleeck, 1989; Yamaguchi, Yamagata & Kobayashi, 2000). Evidence from a number of studies also suggests that the left and right hemispheres could be considered to contain their own cognitive resource pools (Friedman & Polson, 1981; Friedman, Polson, Dafoe & Gaskill, 1982; Herdman & Friedman, 1985). From a MRT perspective, the differences between local and global discrimination during sustained attention tasks that have been found in previous research occur because local discrimination tasks with bilateral involvement recruit a greater total amount of cognitive resources that are available for allocation towards vigilance performance. This may also account for differences in local and global precedence found between local-global perception research and local-global vigilance research. De Joux et al (2013; 2015a/Chapter 2) found that global feature discrimination display linear trends (a traditional vigilance decrement). In contrast, local feature discrimination displayed a quadratic trend in performance, with accuracy and reaction times initially showing a decrement before improving in the final periods of the vigil. From a unitary resource perspective, it could be argued that global feature discrimination is more taxing, therefore creating a more immediate decline in performance. However this explanation may not quite match relating literature to local-global discrimination which finds that global features are more readily distinguishable, as well as subjectively easier to attend to, compared to local features (Martin, 1979; Miller, 1981; Navon, 1977; Paquet & Merikle, 1984). These performance differences also correspond with differences in cerebral laterality profiles, with global discrimination resulting in elevated right hemisphere activation over time, while local discrimination resulted in increased bilateral activation. These findings provide further support for the notion that local discrimination may benefit from overall total amount of resources available for recruitment.

Although vigilance or sustained attention may often be right lateralized, this may reflect object feature hierarchy processes as well, where vigilance tasks may employ stimuli that evoke local-global feature discrimination processes. This raises the issue of how the configural elements of stimuli used in vigilance tasks may influence task performance and cerebral activation. Funke and colleagues (2010) in a recent study, for example, employed a task in which participants were required to monitor four arrows (simulating aircraft) that were orientated in the same direction, with the rare target stimuli represented by one of the arrows being orientated in the opposite direction to the other arrows. In Funke's experiment, the four arrows were placed on a ring shape (see first image in Figure 1 for an example). Funke and colleagues, using TCD and fNIRS, failed to detect the right lateralization patterns that are typically associated with vigilance tasks. This trend has also been noted in other more recent studies using similar stimulus arrangements (Funke et al., 2012; Nelson et al., 2014). In the context of local-global feature processing, these four arrows could be considered as local features of the global circle shape, a point that has been raised by Funke and his associates. Therefore, one possible explanation of the deviant laterality profiles found with this task is that it evokes, at least in some part, local feature processing. This means that participants are required to recruit greater left hemisphere resources, resulting in increased bilateral activity. Indeed the compositional properties of stimuli used during vigilance tasks, as well as how the brain processes these features over time, may be an issue which has been previously overlooked. Pomerantz and associates (1977; 1986; 1989) have previously noted the *configural superiority effect*, in which stimuli that form a full gestalt, or a complete configuration, are processed more efficiently than stimuli which do not (see also Bennett & Flach, 2011). By further investigating the configural superiority effect, and the possible impacts that this effect may have on vigilance performance, the deviant results found in investigations using the Funke et al., (2010) paradigm could be explained

The present study was therefore designed to explore the importance that configural or hierarchical elements of stimuli may have on vigilance performance. In addition to this, the current study seeks to expand on previous research investigating local-global discrimination tasks, which have used relatively simple stimuli. By using more complex stimuli, a clearer indication of how local and global discrimination may interact during vigilance tasks may be sought. The configural nature of the Funke and associates experiments may be revealed by manipulating the global shape while maintaining the local target features across conditions, and examining the impact that these alterations in global shape (or configuration) may have on task performance. Three global shapes were designed for use in the current experiment: a circle, a reversed broken circle and a reconnected shape (see Figure 3.1 for examples). The circle global shape was chosen as it provided a similar configuration to the Funke et al., (2010) experiment. In terms of local and global configuration, this display may be considered as local target features (arrows) on a global background shape (the circle). The reversed broken circle shape consists of the same overall level of spatial information provided in the completed circle condition; however by splitting the circle and reversing it, the overall global shape itself no longer forms a full gestalt or single bounded object. Additionally, this condition no longer bares any resemblance of a circle shape. The broken circle condition may therefore be considered to consist of local target features (arrows) on separate objects. The reconnected shape is the reversed broken circle shape which has been reconnected in order to again form a full global shape or single bounded object. This condition does share some aspects of the broken condition, in regards to the disjointed and reversed nature, however it may also be considered to be somewhat similar to the circle shape, in that it forms a configurative whole and consists of local features on a global shape. It does, however, possess more total spatial information compared to the circle and broken conditions.

Funke et al., (2010) found a decrease in hit rate over time: which represents the traditional vigilance decrement. As the circle condition is highly similar to the stimuli used in the previous experiment, it is expected that there will be a decline in the mean proportion of hits over time for this condition. By extension, it is also expected that the two remaining groups will display this decrease in hit proportion over time. The broken circle shape, however, should exhibit a lower level of performance than the circle and reconnected shapes, as it lacks the same completed configurative properties as the other conditions (configural superiority effect). The broken circle shape should force participants to search for a deviation among four completely separate features or objects, not local features on a global shape as would be found in the circle and reconnected conditions, and therefore should not be as likely to recruit the same neural processing resources as the intact shapes should.

Proctor et al., (2004) also noted that signals are more accurately detected when target objects were presented on a meaningful background. It is suggested that the underlying mechanism for this is that different visual processing systems are utilized in the processing of background and foreground visual information (Julesz, 1978). While we do expect that the circle and reconnected conditions will display higher accuracy compared to the broken condition due to both shapes forming a fully bounded figure, we did expect that the circle shape would show a higher level of accuracy when compared to the reconnected condition, as it is considered to be a more common or more “meaningful” background object.

It should be noted that the current research only examines performance effects across these groups, as the potentially important role of the configurative properties or feature hierarchy on vigilance performance needs to be established using these configural stimulus sets before more in-depth brain imaging research using them can be undertaken. If, as we suspect, configurative properties influence vigilance performance, then this investigation may provide behavioural evidence to spur further research and theorizing on the underlying brain mechanisms for these effects.

3.3. Method

3.3.1. Participants

Sixty-seven participants (27 men, 40 women) from the University of Canterbury completed the study. All participants had normal or corrected-to-normal vision. Ages ranged from 18 to 49 years (*M* = 21.48 years, *SD* = 4.28).

3.3.2. Materials

The visual stimuli consisted of four black arrows on a white shape, which was centred on a solid red circle. The black arrows act as the local component of the overall object, while the white shapes are considered the global component. The solid red circle acted as a point of central fixation, similar to a fixation cross which is common in vigilance tasks. The screen position and size of the black arrows (75 mm x 80 mm) was uniform across all three conditions, while the white global shape was manipulated between the conditions. Three manipulations of the white global shape were presented: a complete enclosed circle (circle); a disconnected "broken" circle (broken), where the components of the circle shape had been broken apart and reversed; and reconnected "broken" circle (reconnected; see Figure 3.1 for examples), which had elements of the broken object but had been extended in certain points to reconnect it. There were also clockwise and anti-clockwise versions of the local arrow shapes, which served as both counter-balancing measures as well as to determine whether arrow direction had any significant effects. The width of the white line was kept the same across all conditions (120 mm), while the overall size of the global objects differed slightly (circle = 10 cm x 10 cm; broken = 9.5 cm x 9.5 cm; reconnected = 15cm x 15cm).

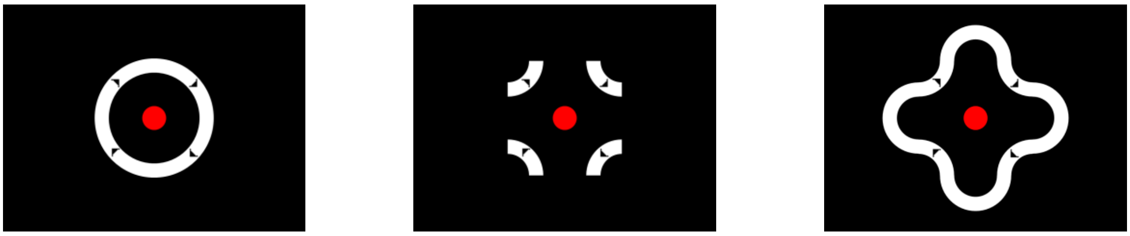


Figure 3.1. Examples of the visual stimuli.

3.3.3. Procedure

The experiment was performed by participants in groups of between 5 and 10 people in a computer laboratory setting where each participant was assigned to a separate cubicle workstation. Each participant was randomly assigned into one of the three shape groups, and into either the clockwise or anti-clockwise arrow.

Participants were shown a brief instructional screen, before completing a short, thirty-second practice period of the task. During the task, participants were required to monitor brief displays of the stimuli, and respond whenever one of the four black arrows was orientated in an opposite direction to the other three black arrows. The opposite arrow could occur on any of the four positions shown in Figure 1. Responses were made using the central space bar on a computer keyboard. Each trial began with the red central circle alone displayed for 500ms. Following this, the global shape was presented for 500ms, followed by the red central circle displayed alone for another 1000ms. It was during the 1500ms period between stimulus onset to end of the final red circle being shown that participant responses were recorded. There were 120 trials per period, and each period had a duration of 4 minutes. Target stimuli (one opposite pointing arrow) occurred on 6.6% of trials, while neutral stimuli (all arrows in uniform direction) occurred on the remaining 93.4% of trials. This was consistent across all practice trial and main trial blocks. Participants completed 5 periods in total over the course of the vigil. There was no rest break between periods, as is typical for vigilance tasks. The overall time including all periods and practice trials was 20.5 minutes. Immediately following the experiment each participant was debriefed regarding the task before leaving.

3.4. Results

For each subject over each period of watch, the proportion of correct detections (hits), the proportion of false alarms and the signal detection theory metric *A′* were calculated. *A′* is a metric used in signal detection theory to measure perceptual sensitivity (Stanislaw & Todorov, 1999). Preliminary analysis found no reaction time differences between groups; therefore these are not included here. Reaction time differences will, however, be explored in Chapter 6. Six participants who failed to detect any targets during the practice trials were excluded from analysis. This resulted in two groups of twenty participants and one group of twenty-one participants. Preliminary analysis revealed that there were no significant differences between shape groups at the practice stage in regards to either hits, false alarms or *A'*. Additionally, there were no significant differences between clockwise and anti-clockwise presentations of the stimuli. Therefore, each version of the shape was combined to form one factor based on shape. A 3 (shape: circle, broken, or reconnected) x 5 (periods of watch) repeated-measures ANOVA with pre-planned orthogonal polynomial contrasts was performed for each metric (see Keppel & Zedeck, 2001; Ross et al., 2014; Ruxton & Beauchamp, 2008). While repeated-measures ANOVA is more commonly used in vigilance research, orthogonal contrasts provide more powerful statistical tests (Rosenthal & Rosnow, 1985; Rosnow & Rosenthal, 1996; Rosenthal, Rosnow & Rubin, 2000). Such tests avoid problems related to the assumption of sphericity and are direct tests of trend differences (changes over periods of watch) between the shape groups. Similar to other experiments within this thesis, the omnibus test results are reported here, however the orthogonal contrast results are used as the main source for inference. For the pre-planned orthogonal contrasts we limited the contrasts to the linear and quadratic trends.

In the case of hit proportions, there was a significant quadratic effect for periods of watch, $F(1, 58) = 18.06$, $p = .001$, $\eta_p^2 = .237$, with overall hit proportions initially decreasing before increasing in the final periods. Of more importance, however, was the significant linear trend found for the shape by period of watch interaction, $F(2, 58) = 3.24$, $p = .046$, $\eta_p^2 = .100$. The circle and reconnected conditions decrease over time, while the broken condition shows an increase in hits over the five periods of watch. The circle and reconnected conditions also show an overall higher level of hits compared to the broken condition, as is evidenced by the significant main effect for shape, $F(2, 58) = 3.72$, $p = .030$, $\eta_p^2 = .114$. A comparison between the combined circle and reconnected conditions versus the broken condition revealed a significant difference, $F(1, 58) = 7.44$, $p = .008$, $\eta_p^2 = .113$, while no significant difference was found between the circle and reconnected conditions. The circle and reconnected conditions also show a significant linear trend, $F(1, 43) = 8.24$, $p = .006$, $\eta_p^2 = .161$, as well as a significant quadratic trend, $F(1, 43) = 10.96$, $p = .002$, $\eta_p^2 = .203$, for period of watch. The broken condition alone, however, did not show any significant linear or quadratic trend. Mean hit proportions are presented in Figure 3.2.

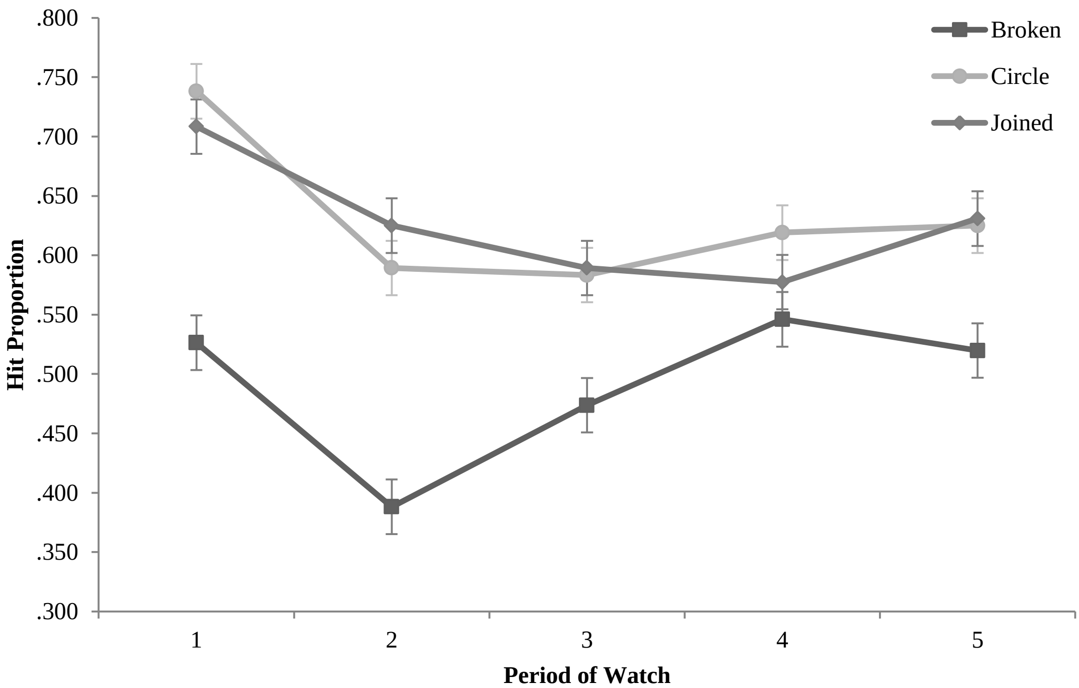


Figure 3.2. Mean proportions of hits over 5 periods of watch. Error bars depict standard error.

In the case of false alarm proportions, there was a significant linear trend, $F(1, 58) = 42.61$, $p = .001$, $\eta_p^2 = .424$, as well as a significant quadratic trend, $F(1,58) = 8.71$, $p = .005$, $\eta_p^2 = .131$, for periods of watch. All conditions show a decrease with time on task. The quadratic trend appears to be the result of a floor effect, given that overall false alarm rate is very low across all conditions. For the periods of watch by shape interaction there was no significant linear trend, $F(2, 58) = 0.50$, $p = .607$, $\eta_p^2 = .017$, nor was there a significant quadratic trend, $F(2, 58) = 2.76$, $p = .071$, $\eta_p^2 = .087$. This indicates that all conditions show the same trends over time. This was also evidenced by the omnibus repeated-measures ANOVA result, which revealed no significant main effect for shape, $F(2, 58) = 0.25$, $p = .776$, $\eta_p^2 = .009$. Mean false alarm proportions are presented in Figure 3.3.

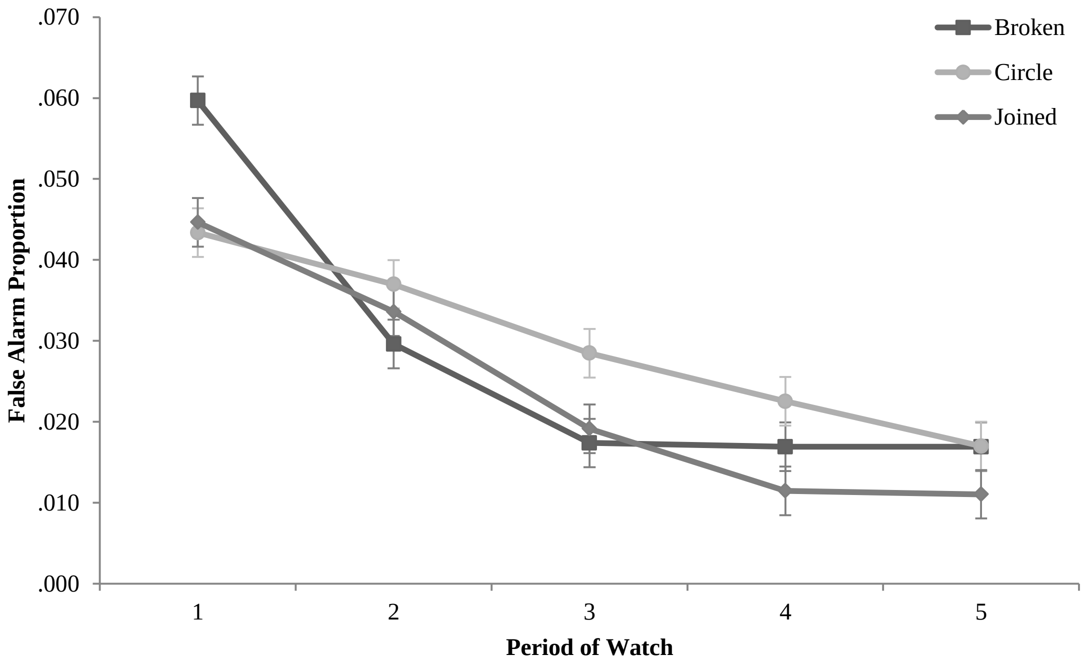


Figure 3.3. Mean proportion of false alarms over 5 periods of watch. Error bars depict standard error.

In the case of *A'* scores, there was a significant quadratic effect for periods of watch, $F(2, 58) = 3.32$, $p = .043$, $\eta_p^2 = .103$, with overall accuracy initially decreasing before increasing in the final periods. There was also a significant linear trend found for the shape by period of watch interaction, $F(2, 58) = 5.26$, $p = .008$, $\eta_p^2 = .153$. The circle and reconnected conditions decrease slightly over time, while the broken condition shows an increase in hits over the five periods of watch. The circle and reconnected conditions also show higher mean *A'* scores compared to the broken condition, as is evidenced by the significant main effect for shape, $F(2, 58) = 3.32$, $p = .043$, $\eta_p^2 = .103$. A comparison between the combined circle and reconnected conditions versus the broken condition revealed a significant difference, $F(1, 58) = 6.52$, $p = .013$, $\eta_p^2 = .101$, while no significant difference was found between the circle and reconnected conditions. The circle and reconnected conditions also showed a significant quadratic trend, $F(1, 43) = 13.31$, $p = .001$, $\eta_p^2 = .236$, for period of watch, with *A'* scores initially decreasing before improving over the final periods of watch. The broken condition in comparison revealed a significant linear trend, $F(1, 18) = 11.25$, $p = .004$, $\eta_p^2 = .385$, with *A'* scores increasing with time on task. No significant quadratic trend was found in the broken condition however, $F(1, 18) = .141$, $p = .712$, $\eta_p^2 = .008$. Mean *A'* scores are presented in Figure 3.4.

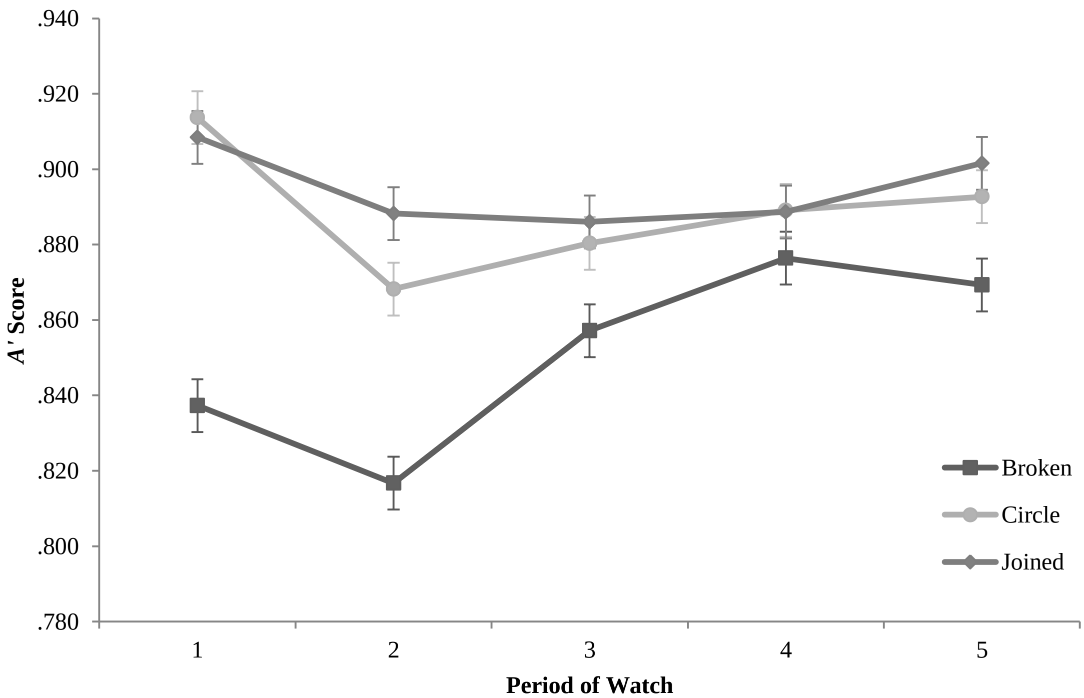


Figure 3.4. Mean A' scores over 5 periods of watch. Error bars depict standard error.

3.5. Discussion

As hypothesised, the broken condition displayed impaired performance compared to the circle and reconnected conditions, with hit proportions and *A′* scores at lower levels throughout the task. Additionally, trend differences between the shape groups over time were found, with the broken group *A'* scores increased linearly over time, while the circle and reconnected groups initially decreased in the first periods of watch before increasing over the remaining periods; a quadratic trend over time. These results support the claim that overall shape configuration may be influential on sustained attention performance over time.

The period by shape interaction of hit rate proportions indicates differences between shape groups over time, with visual inspection suggesting a vigilance decrement observed in the circle and reconnected conditions, while no observable decrement was found in the broken condition. It was expected that hit rates would follow a similar pattern to that observed by Funke and colleagues (2010). They report a decrease in hit rates over time in a task that is extremely similar to the circle condition in the current experiment. In the present experiment a decreasing linear trend indicative of a vigilance decrement was found in the groups which formed a configurative whole (circle and reconnected groups). The broken condition however does not display this trend. Hit proportions and *A'* scores start at a much lower level in the broken condition, and remain at a lower level over the five periods (despite generally improving over time. It is possible that this may be, at least in some part, a function of overall task difficulty in this condition. It is assumed that the broken group is more difficult compared to the circle and reconnected groups, as it requires objects to be processed on four separate objects rather than one. Task difficulty has been found to have effects on both blood flow lateralization and task performance, where higher levels of task difficulty are result in an increase in bilateral activation (Helton et al., 2010). This increased bilateral activation may in turn have mitigating effects on vigilance decrement trends, as increased bilateral activity may result in a higher total amount of cognitive resources becoming available for recruitment during the task. An alternative explanation to the broken condition trend may be that this task may have been at a level of difficulty that has induced an effect akin to a floor effect, given that hit proportion rates could be considered to be around chance. While performance could have in theory been lower than that which is found in hit rates and A' scores, most vigilance tasks eventually see performance declining to a stable asymptote (Parasuraman & Giambra, 1992). Vigilance theorists have proposed that this performance asymptote may be the point at which the resource requirements of the task to maintain the performance level achieved are matched by the ability of the nervous system to replenish those required resources. Therefore, the alternative explanation for the trend observed in the broken condition is that participants in this condition may have reached that asymptote very quickly, perhaps due to its inherent difficulty creating something similar to a floor effect.

The significant linear trend for the period by shape interaction that was found in mean A' scores again indicates that shape configuration affects task accuracy. All three groups show an initial decrease in performance before improving over the remaining periods. The circle and reconnected conditions do not rise above their initial A' scores, and overall display a decreasing level of performance over the five periods of watch. The broken condition mean A' scores increase overall from initial mean scores, indicating an improvement in performance with time on task. Despite this observed improvement over time, the broken condition still performs worse than the remaining two conditions throughout the five periods. Again, the performance improvement observed in this condition could be, in part, attributed to a hypothetical increase in bilateral activation with higher task difficulty. As suggested above, increased bilateral activity may increase the overall resource capacity for participants in this group, resulting in a lack of a clear decrement pattern. Indeed this may have resulted in

A' increase noted for this group. Increased cerebral activation has also been found to predict improvements in task performance during perceptual learning experiments (Ong, Russell & Helton, 2013), while other researchers have noted concerns regarding the impact that passive perceptual learning may have on vigilance task performance (Head & Helton, 2015; Szalma et al., 2004). There is the potential that perceptual learning may be impacting the trends observed in the current experiment, where participants may passively learn search strategies as the vigil length increases, which improves performance. Moreover, this improvement is greater in conditions that initially show lower levels of performance (Head & Helton, 2015). Further investigations, perhaps with extended vigil length, may be needed to more fully explore this possibility.

It was expected that the circle condition would show the highest level of accuracy out of the three conditions, followed by the reconnected condition, with the broken condition expected to show the lowest level of performance. The results revealed that the broken condition was indeed the worst performing of the three conditions, while the circle and reconnected conditions exhibited similar levels and trends of performance over time. The comparatively poorer performance in the broken condition is attributed to the split or breaks between the separate components of the overall shape, which in turn may cause the object to be processed as four separate local objects as opposed to a singular overall global object like those which are found in the circle and reconnected conditions. Of particular interest however is the finding of the reconnected condition performing at a similar level to the circle condition, as well as showing extremely similar trends throughout the task. The expectation that the circle condition would display improved performance when compared to the reconnected condition was due to the increase spatial extension that the reconnected group displayed (possibility broadening the focus of attention), as well as the circle condition having a more common or “meaningful” shape (Proctor et al., 2004). Additionally, Julesz (1978) suggests that different processing mechanisms are used in the processing of background and foreground information. With more spatial information to process, the reconnected condition was expected to be adversely affected. The reconnected shape was also extremely similar to the reversed broken circle shape in regards to the positioning of the breaks in the overall global object. While the current findings are not necessarily what was hypothesised, they do somewhat fit with the aforementioned research, given that these two conditions clearly display higher accuracy compared to the broken condition. Perhaps though, instead of separate background and foreground processing mechanisms being utilized, another mechanism more accurately explains the results found in the current experiment. The lack of a significant difference between the circle and reconnected conditions, does support Pomerantz and associates' (1977; 1986; 1989) *configural superiority effect*, in which objects which form a whole are easier to process than those which do not. As a result of this configural superiority effect, the broken circle task without a clear global aspect was more difficult for participants to perform compared to the global aspect tasks (circle and reconnected groups). This would also explain the similarity of performance between the circle and reconnected groups, which were expected show performance differences.

Based on these interpretations, a number of extensions to the current research paradigm should be undertaken. First, measures of hemispheric activation (brain imaging) could be taken to allow researchers to examine whether the behavioural patterns found here correspond with patterns of cerebral activation. The current investigations' findings suggest that there may be differences between conditions regarding in activation during the task; specifically, increased bilateral activation and potentially hemisphere differences between groups. A measure such as fNIRS (de Joux et al., 2013; Helton et al., 2007; Hitchcock et al., 2003; Ong et al., 2013; Parasuraman, Warm & See, 1998), which has been used during similar vigilance studies in the past, would be appropriate for such an investigation. This may also assist with determining why deviant laterality profiles have been found in previous similar experiments (Funke et al., 2010; Funke et al., 2012; Jeroski et al., 2014). Second, the effects of task difficulty should be more fully explored. This could be achieved in experiments where the configuration changes during the experiment. If task difficulty increases bilateral activation, a transition from or to a more difficult condition should in theory yield a number of performance changes. A transition effect between local and global processing has been examined using simple Navon objects (de Joux et al, 2015a) with findings suggesting performance differences between local and global processing. This task, however, used stimuli which were of a relatively simplistic nature or low difficulty. The use of a transition with much more complex stimuli, as seen in with the current experiment, has not been examined. In addition, investigations of the relationship between local-global configuration and task difficulty could be explored. Previous research suggests that local and global feature discrimination do not significantly differ in subjective difficulty (de Joux et al., 2013), again however the stimuli in the current experiment appears to be more complex comparatively, which may influence perceived workload, stress, and difficulty. Further self-report measures of perceived workload and effort should be included along with objective measurements, which would allow researchers to more fully explore these potential relationships.

The research aim was to investigate whether global shape configuration resulted in performance differences during a vigilance task where the target object was found at a local level, with the intent of establishing whether any behavioural differences found warranted further investigation using measures of cerebral activation. The results found here suggest that global shape configuration does indeed impact vigilance task performance. The configural superiority effect observed here indicates that the hierarchical or configurative properties of vigilance tasks may be important aspects of understanding both vigilance performance and its cerebral activation patterns. The results found also suggest that overall task difficulty may potentially be influencing patterns of response over time, a finding that is in line with previous research involving measures of cerebral activation. The results of the current research seem to suggest that the disparity between conditions is due to; differences in local-global object processing demands, differences in task difficulty, and the processing demands that are typical of sustained attention tasks. Previous research investigations that have used a paradigm from which the current experiment is based on did not find the typical right-lateralization effect in cerebral activation. The current research provides a basis to believe that this may be due to the more complex stimuli that have been used in these studies, which evoke the requirement for local-global processing. More research investigating the effects that hierarchical properties of objects used during vigilance tasks and their impact on both performance and cerebral activity is warranted.

Chapter 4

Motion Processing Influences Configural Property Processing During Sustained Attention

4.1. Abstract

Ninety-three participants performed a sustained attention task during which they were required to respond to a critical signal requiring feature discrimination. Three separate groups performed the task, each with a different global display configuration. The local feature elements (arrow shapes) acted as target shapes, and were displayed either on a circle, a circle that had been broken apart and reversed, or a reconnected figure. This meant that for two of the groups the entire display consisted of a completed global shape (circle and reconnected), while for one of the groups the display had no discernible or complete global element (broken circle). The critical signals, however, remained the same for all three groups. In addition to this, the stimuli were rotating for the duration of each trial. This required participants to engage in motion processing throughout the vigil. Analyses of hit rate and *A'* scores revealed that the circle figure group had superior performance compared to the other groups. Additionally, the reconnected group performed worst overall, and broken condition performed better; a reversal of the group differences found in Chapter 3. This result may lend support to the idea of "motion streaks", in which moving objects leave residual neural activity that aids motion processing under certain conditions. The results also suggest that motion processing aids with the perception of a coherent global form when some degree of separation is present in the global object.

4.2. Introduction

Vigilance, or sustained attention, is the task of maintaining focus on certain stimuli over an extended period of time, and responding appropriately and efficiently when a rare and critical target object is presented. There are two characteristics which are commonly observed during tasks that require sustained attention. First, performance typically declines with time on task; where a participants' ability to respond accurately to those critical stimuli decreases over time, or a participants' ability to respond in a timely manner increases over time. This decline in performance is commonly referred to as the vigilance decrement (Davies & Parasuraman, 1982; Warm, 1984). Second, vigilance tasks typically induce greater levels of cerebral activity in the right hemisphere compared to the left hemisphere (Berman & Weinberger, 1990; Buchsbaum et al., 1990; Davies & Parasuraman, 1982; Helton et al,. 2007; Hitchcock et al., 2003; Langner & Eickhoff, 2013; Langner et al., 2012; Shaw et al., 2009; Warm, Matthews & Parasuraman, 2009; see Helton et al., 2010 for an overview). That is, blood flow is commonly observed to be elevated in the right hemisphere during vigilance tasks. This is not always the case however, with a number of studies having failed to demonstrate the commonly observed right hemisphere dominance during tasks requiring sustained attention (de Joux et al., 2013; Funke et al., 2010; Helton et al., 2010; Jeroski et al., 2014; Shultz et al., 2009). Two potential factors that may account for this lack of right hemisphere lateralization are overall task difficulty and the configurative or hierarchical aspects of the stimuli themselves.

Task difficulty, for example, has been found to be influential on cerebral lateralization, with tasks of a higher level of difficulty resulting in increased bilateral activation (Helton et al., 2010; Sunaert et al., 2000). This has potential implications for sustained attention tasks, given the right hemisphere dominance typically found. For example, if increased activation of both hemispheres does aid performance by increasing the total amount of cognitive resources available for allocation to a task, then tasks that have an elevated level of difficulty may show some form of performance benefits over time by increasing the spread of neural recruitment. It is possible that these challenging tasks may, under some conditions, be more resistant to performance decrement trends over time as the central nervous system allocates more total resources to these tasks. This may explain the findings of previous research in which cognitive vigilance tasks (i.e. tasks requiring more information processing) are less prone to decrements than simpler sensory vigilance tasks (Funke et al., 2010; Funke et al., 2012; Head & Helton, 2015; Nelson et al., 2014).

In addition to potential impacts from task difficulty, the discrimination of local and global feature objects in sustained attention tasks has been found to have differing effects on both objective measures of performance and on physiological measurements of cerebral activity (de Joux, Russell & Helton, 2013; Helton, Hayrynen & Schaeffer, 2009). Visual objects are ordered in a hierarchical fashion with larger objects composed of a number of smaller elements. These smaller elements themselves may be composed from even smaller elements, and so on, to a level where basic shapes and features are found. These smaller elements of an overall object are referred to as local shapes, while the overall object itself is referred to as the global shape. Local-global feature discrimination has been thoroughly investigated from a perceptual standpoint, in which both global precedence effects and local precedence effects can be found under particular experimental conditions (Kimchi 1982; 1988; 1992; Lamb & Robertson, 1990; Navon, 1977; Pomerantz, 1983). Evidence from recent investigations suggests that differences in both performance as well as cerebral activation found during vigilance tasks may also be, in part, dependent on the configural properties of the stimuli used and at which hierarchical level the critical target object is determined. Performance is, for example, superior during tasks that require local feature discrimination rather than global feature discrimination (de Joux et al., 2013; Chapter 3;

Helton et al., 2009). This superior performance is also accompanied by increased bilateral cerebral activation. Extending from simple local-global objects, experiments using more complex stimuli have found that performance is improved when local features appear on a coherent global configuration (de Joux et al., 2015b). Similar experiments have found increased left-hemisphere activity, beyond that which is typical of vigilance tasks (Funke et al., 2010; Jeroski et al., 2014). This suggests that configurative properties of stimuli may be influential on cerebral activation in a much similar way to local-global features.

The current experiment extends on research presented in Chapter 3, and investigates whether motion processing may have an effect on, or an interaction with, the configural superiority effect of stimuli used during a sustained attention task. Recent research has raised questions as to how dynamic vigilance tasks, in which the stimuli used is presented with movement, may alter the character of the vigilance decrement (Szalma et al., 2004). In Chapter 3, participants were required to monitor four arrows which were orientated in the same direction, and were to respond whenever one of the arrows was orientated in an opposite direction (see Appendix A, far right). These arrows were placed on one of three background shapes: a circle, a broken reversed circle, and a reconnected figure (see Chapter 3, Figure 3.1 for examples). In terms of local-global configuration, the circle and reconnected figures were considered as an overall global object with local feature elements, while the broken shape was considered to be local shapes on separate local objects. The circle and reconnected shapes formed full and complete figures, while the broken shape did not. Results revealed the broken condition to have impaired performance compared to both the circle and reconnected conditions. In addition to overall performance differences, the broken condition showed an improvement over time, while in comparison the circle and reconnected conditions did not. One possible explanation for this finding is that passive perceptual learning occurs in the more difficult task; a phenomenon which has been noted in previous vigilance tasks (Head & Helton, 2015; Ong et al., 2013). When examined alone, the circle and reconnected conditions revealed identical levels of performance across all metrics, as well as identical trends of the periods of watch. The superior performance with stimuli that form full or complete global forms provide another example of configural superiority effects (Pomerantz & Kubovy, 1986; Pomerantz & Pristach, 1989; Pomerantz, Sager & Stoever, 1977).

The main goal of the Chapter 3 investigation was to establish whether global shape properties had a significant impact on responses made to changes at a local level, as well as whether this shape configuration had a significant effect on performance over time. While the study appears to establish that the configural properties do indeed have an impact on performance, most likely through a configural superiority effect, more research is needed using this paradigm to explore the configuration effects. To extend the findings of the research presented in Chapter 3, the current experiment includes the additional element of motion processing.

The sequential presentation of stimuli has been found to induce the perception of coherent motion (Burr & Ross, 2002; Krekelberg, Vatakis & Kourtzi, 2005; Ross, Badcock & Hayes, 2000). This type of dynamic presentation of stimuli has been found to activate mechanisms that are associated with motion perception, whereas static or stationary presentation of stimuli is more closely associated with the mechanisms that are associated with form perception. Evidence from previous research suggests that these mechanisms can be considered to be largely separate from each other in their functioning, as well as activating different neural pathways in the brain (Gazzaniga, Ivry & Mangun, 2002; Goodale & Milner, 1992; Goodale, Milner, Jakobson & Carey, 1991). With differences in cerebral activation between motion perception and form perception, the addition of motion perception to the experiment presented in Chapter 3 may yield different results from experiments using the stationary presentation of stimuli. It is assumed that processing of objects in the Chapter 3 experiment are not affected by motion processing due to the stimuli giving no indication of movement.

Moreover, there is potential for some performance improvements in specific cases where motion processing is required. For example, using Glass patterns (moiré patterns made from random dot configuration; Glass, 1969) it has been found that separation between dots result in a diminished sensitivity to global form when displayed statically (Kurki et al., 2003; Palomares et al., 2010). In contrast, however, increased dot separation with these same stimuli increases sensitivity to global form when the patterns are displayed dynamically (Burr & Ross, 2006; Day & Palomares, 2014). This suggests that the dynamic presentation of an object may aid with the perception of global form when the configurative components that make up the global object retain stable separation and distance. In addition to this, there is also neural evidence that global shape perception is influenced by motion perception. Investigations reveal that motion activates fields in the superior temporal sulcus (Braddick & Qian, 2001; Duffy & Wurtz, 1991a; Duffy & Wurtz, 1991b), while the integration of pattern signals activates the V4 visual field area (Gallant, Braun & Van Essen, 1993; Gallant, Connor, Rakshit, Lewis & Van Essen, 1996). The suggestion is that information from these systems must be integrated in late stages of perception, thus interacting with each other and influencing performance (Ross, 2004; Van Essen, Anderson & Felleman, 1992). Some caution should be exhibited when proposing this link between Glass patterns and the current stimuli, given the difference between the objects from a purely perceptual standpoint. However, the underlying mechanism may be influential in both paradigms due to the local-global configurations presented. If the dynamic presentation of stimuli can assist with the perception of a more coherent global form, then the addition of a requirement to perform motion processing may yield contrasting results to those found in Chapter 3, specifically in the broken condition given the distance between objects in that condition.

The current experiment uses the same three shapes as found in the Chapter 3 experiment: a circle, a reversed broken circle and a reconnected shape (see Figure 1 for examples). Whereas in the previous study these objects were presented in stationary positions, the objects will be rotated through 60 degrees in the current investigation. This addition of motion processing will allow for further examination and understanding of how more complex stimuli which possess multiple levels of configural elements are processed during a vigilance task.

A number of specific outcomes are to be expected. First, it is hypothesized that the circle object will display the highest overall level of accuracy, regardless of trends, due to this object being a more easily recognizable shape, as well as forming a full and complete gestalt figure. Additionally, this global shape does not show a large amount of perceptual change when it is rotated compared to the remaining conditions, which should result in improved performance.

Second, it is hypothesized that the broken condition would show an improved level of accuracy in comparison to its' stationary counterpart in Chapter 3, due to the additional element of motion processing. Although the previous experiment showed that the broken condition had impaired performance in comparison to the circle and reconnected groups, as stated above, motion processing has been shown to aid with perception of global forms or configurations when the local components of an object are separated (Burr & Ross, 2006; Day & Palomares, 2014; Ross, 2004). The separations between the objects in the broken condition are expected to assist with the perception of a more coherent structure or object when the entire image is rotating, and this more readily perceived coherent structure will assist with performance over time. This group is not expected to perform to the level of the circle condition however, given that the circle condition does not require such processing, and maintains a uniform shape throughout rotation.

It is also predicted that the reconnected condition will show impaired performance in comparison to its' stationary counterpart in the previous experiment, as the rotation of this object may actually disrupt global form perception. As this object moves through its rotation, it essentially goes through two distinctly different looking full gestalts (see Appendix A). Additionally, motion processing should not aid in the perception of global form with the reconnected shape, as despite showing some similarities to the broken condition, the object still maintains a complete global figure.

In terms of performance trends found in the task, it is expected that the circle condition will show a decrease with time-on-task, perhaps similar to the quadratic trend found in the previous experiment. In comparison the reconnected and broken conditions are expected to show an increase over time, perhaps due to passive perceptual learning, due to the development of search strategies over time with more difficult tasks (Head & Helton, 2015; Ong et al., 2013). The broken and reconnected conditions are expected to be more difficult initially compared to the circle condition, due to a circle's invariant appearance during rotation. Despite these trends, it is expected that the broken and reconnected conditions should still exhibit an overall lower level of performance compared to the circle condition.

4.3. Method

4.3.1. Participants

Ninety-three participants (31 men, 62 women) from the University of Canterbury completed the study. All participants had normal or corrected-to-normal vision. Ages ranged from 17 to 50 years (*M* = 20.46 years, *SD* = 6.31).

4.3.2. Materials

The visual stimuli consisted of 4 black arrows on a white shape, which was centred on a solid red circle. The black arrows act as the local component of the overall object, while the white shapes are considered the global component. The solid red circle acted as a point of central fixation, similar to a fixation cross which is common in vigilance tasks. The screen position and size of the black arrows (75mm x 80mm) was uniform across all conditions, while the white global shape was manipulated between the conditions. Three manipulations of the white global shape were presented; a complete enclosed circle (circle), a disconnected "broken" circle (broken), where the components of the circle shape had been broken apart and reversed; and reconnected circle (re-joined; see Appendix A for examples), which had elements of the broken object but had been extended in certain points to reconnect it. There were also clockwise and anti-clockwise versions of these shapes, which served as counter-balancing measures and to determine whether the direction of the rotation had any significant influence. The width of the white line was kept the same across all conditions (120mm), while the overall size of the global objects differed slightly (circle = 10cm x 10cm, broken = 9.5cm x 9.5cm, re-joined = 15cm x 15cm).

4.3.3. Procedure

The experiment was performed by participants in groups of between 3 and 5 people in a windowless computer laboratory setting. Each participant was blocked from viewing any other monitors during testing. Each participant was assigned to one of the three groups, and into either the clockwise or anti-clockwise version of that group.

Participants were shown a brief instructional screen, before completing a 30-second practice period of the task. Each trial of the task consisted of a series of 8 images which were presented in succession to induce the perception of coherent motion. The first and last images in the succession were the red central circle alone, which were both displayed for 1000ms. Starting from the 2^{nd} image in the series, both the local and global components of the shape were rotated 10 degrees each image in either a clockwise or anti-clockwise direction, dependent on condition. This resulted in the entire image being rotated through 60 degrees per trial. The rotation of both the local and global objects was relative, meaning that all object components moved at the same proportion and in the same direction as each other. Each image in the succession was presented for 1000ms, resulting in each trial taking 8000ms to complete. In the neutral trials, the four black arrows remained in the same orientation for each of the six images. In the target trials, one of the four black arrows reversed during one of the image representations, before returning to the appropriate orientation on the next image in that succession. The participants were instructed to respond to the target by pressing the space bar. This was a traditional response task, with a target probability of 0.135 and a neutral stimulus probability of 0.865. This target probability was consistent between practice trials and main trials. There were 30 trials per block (4 minutes per block) with 4 blocks being performed, resulting in a 16-minute total task time. Immediately following the experiment participants were debriefed before leaving.

4.4. Results

Proportion of correct detections (hit rate), proportion of false alarms, and *A'* scores were calculated for each participant over each period of watch. A' is a metric used in signal detection theory to measure perceptual sensitivity (Stanislaw & Todorov, 1999). Similar to

Chapter 3, preliminary analysis found no reaction time differences between groups; therefore these are not included here. No significant differences were found between the clockwise and anti-clockwise versions of each shape, therefore direction of movement was discounted as having any effect. Direction of movement was not included as a factor in the treatment of results. Five participants who failed to detect any targets during the practice trials or first period of watch were removed from further analysis. There were no significant differences between groups at the practice stage. A 3 (shape: circle, broken, or reconnected) by 4 (periods of watch) repeated-measures ANOVA with pre-planned orthogonal polynomial contrasts, or "trend analyses" (Keppel & Zedeck, 2001; Ross et al., 2014; Ruxton & Beauchamp, 2008), was performed for each performance metric. While repeated-measures ANOVA omnibus tests are more commonly used in the analysis of sustained attention tasks, we have opted to use orthogonal polynomial contrasts, which are more powerful and robust statistical tests (Rosenthal & Rosnow, 1985; Rosnow & Rosenthal, 1996; Rosenthal Rosnow & Rubin, 2000). Specifically, such tests avoid issues related to the assumption of sphericity as they are one degree of freedom contrasts and allow us to directly test trend differences (changes over periods of watch) between conditions. In order to maintain conformity to other experiments and analyses found within this thesis, the omnibus test results are reported here. However, the orthogonal contrast results are used as the main source for inference. For orthogonal contrasts we limited the contrasts to the linear and quadratic trends.

In the case of hit proportions, there were no significant linear trends, $F(1, 90) = 3.10$, $p = .082$, $\eta_p^2 = .033$, or quadratic trends, $F(1, 90) = 1.41$, $p = .238$, $\eta_p^2 = .015$, for periods of watch. Additionally, there were no significant period by shape linear trends, $F(1, 90) = .117$, $p = .889$, $\eta_p^2 = .003$, or quadratic trends, $F(1, 90) = .840$, $p = .435$, $\eta_p^2 = .018$. There was, however, a significant main effect for shape found in the omnibus test, $F(2, 90) = 6.08$, $p = .003$, $\eta_p^2 = .119$, which indicates that groups differ in their overall hit rates. The orthogonal contrast comparing the circle condition with the combined reconnected and broken conditions revealed a significant difference, $F(1, 90) = 10.39$, $p = .002$, $\eta_p^2 = .103$, with the circle condition showing an elevated level of performance in comparison to the combined broken and reconnected conditions. While it does appear that the broken condition shows a slightly elevated level of performance in comparison to the reconnected condition, the contrast analysis does not reach significance, $F(1, 90) = 1.77$, $p = .187$, $\eta_p^2 = .019$. Mean proportion of hits are presented in Figure 4.2.

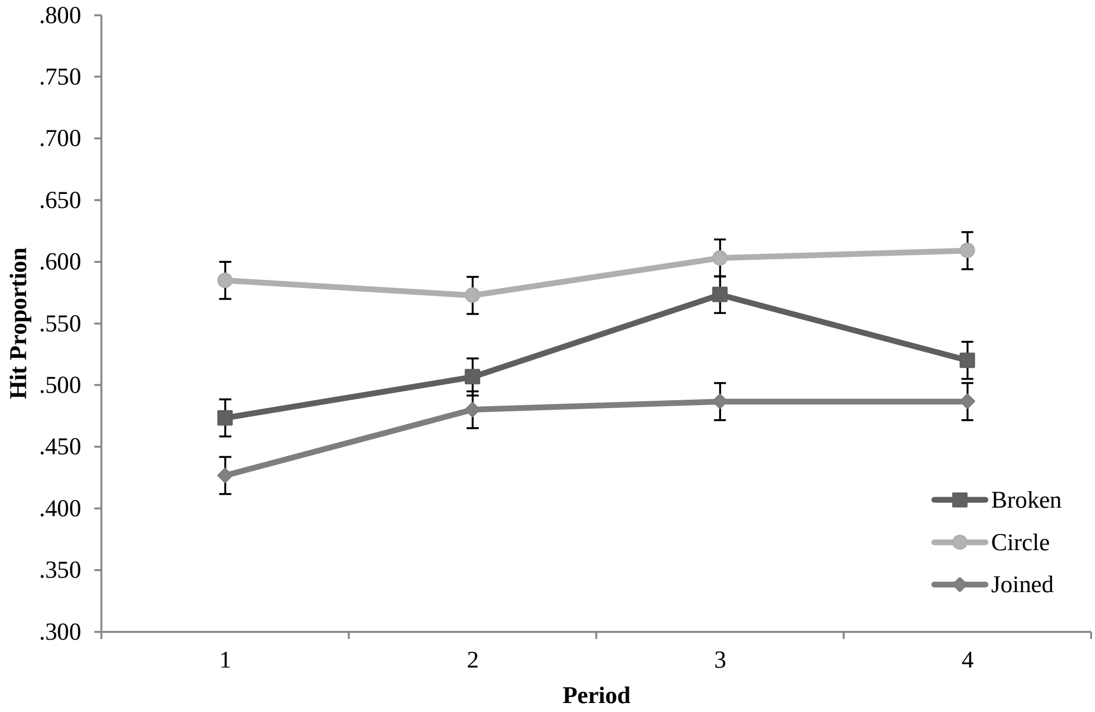


Figure 4.1. Mean proportions of hits over 4 periods of watch. Error bars depict standard error.

In the case of false alarm proportions, there was a significant linear trend for periods of watch, $F(1, 90) = 18.94$, $p = .000$, $\eta_p^2 = .174$, with false alarms decreasing over time. There was no significant period by shape linear trend found, $F(2, 90) = .362$, $p = .697$, $\eta_p^2 = .008$, indicating that there were no significant differences between the groups over time. This was further evidenced by the omnibus test results, which found a significant main effect for periods of watch, $F(3, 270) = 9.24$, $p = .000$, $\eta_p^2 = .093$, as well as no significant group main effect, $F(2, 90) = .07$, $p = .935$, $\eta_p^2 = .001$. It is important to note that similar to the findings of other experiments presented in this thesis, the overall false alarm rates were at very low levels (Mean probability = .05). Mean proportion of false alarms are presented in Figure 4.3.

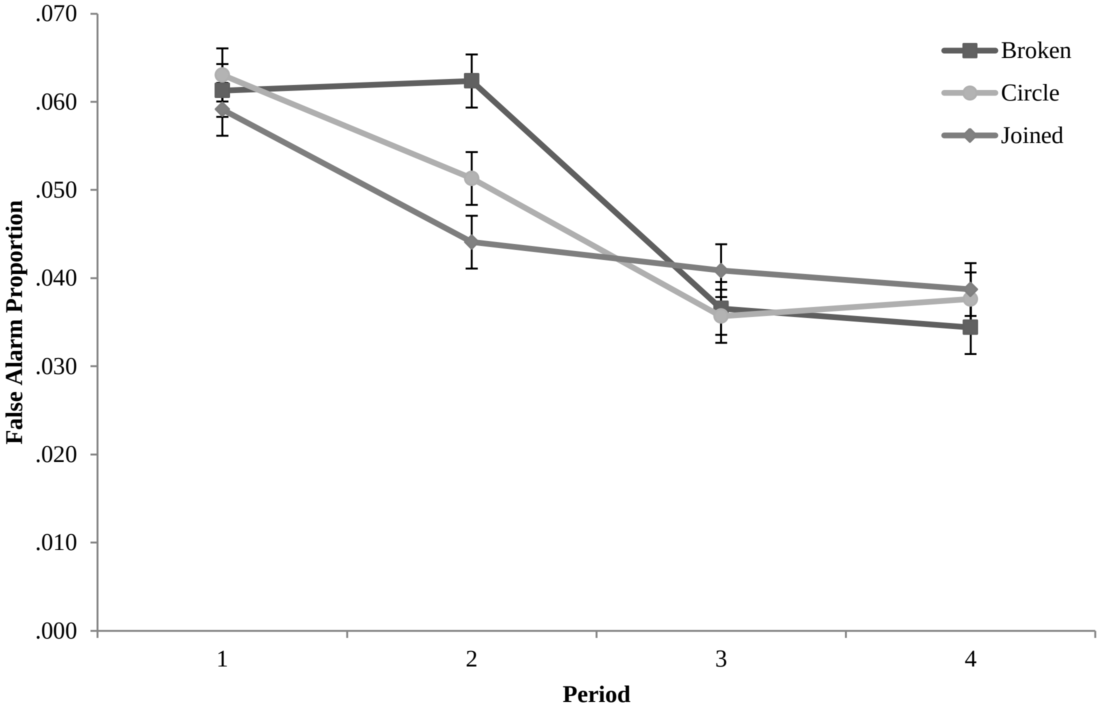


Figure 4.2. Mean proportion of false alarms over 4 periods of watch. Error bars depict standard error.

In the case of mean *A'* scores, there was a significant linear trend for periods of watch, $F(1, 90) = 7.40$, $p = .008$, $\eta_p^2 = .076$, with *A'* scores overall increasing over time. There was no significant quadratic trend for time on task however, $F(1, 90) = 3.49$, $p = .065$, $\eta_p^2 = .037$. Similar to hit proportions, there were no significant period by shape linear trends, $F(2, 90) = .97$, $p = .384$, $\eta_p^2 = .021$, or quadratic trends, $F(2, 90) = .27$, $p = .762$, $\eta_p^2 = .006$. There was, however, a significant main effect for shape found in the omnibus test, $F(2, 90) = 4.67$, $p = .012$, $\eta_p^2 = .094$. Similar to the case of hit proportions, a series of pre-planned contrasts were performed comparing the performance of individual conditions against the others. A comparison of the circle condition versus the combined broken and reconnected conditions was significant, $F(1, 90) = 8.40$, $p = .005$, $\eta_p^2 = .085$, while no significant differences were found between the reconnected and broken conditions, $F(1, 90) = 0.93$, $p = .337$, $\eta_p^2 = .010$. The broken condition again exhibits an increase during the second half of the vigil, and again shows an overall higher level of performance compared to the reconnected condition, however this does not appear to be a significant difference. Mean *A′* scores are presented in Figure 4.4.

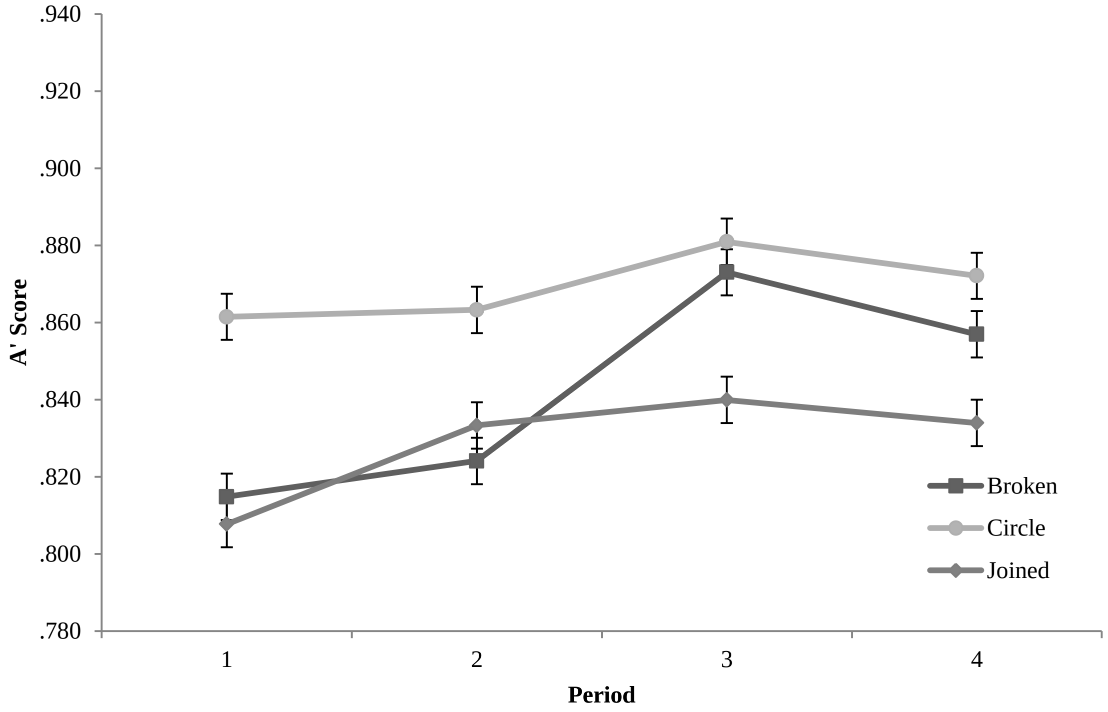


Figure 4.3. Mean A’ scores over 4 periods of watch. Error bars depict standard error.

4.5. Discussion

Traditional vigilance decrement patterns were not observed in hit rates or *A’* scores for any of the conditions. This is evidenced by the significant increasing linear trends over time for both hit proportions and *A’* scores. There were no significant reaction time trends or differences to report, meaning that this metric cannot be used to determine a decrement function. There was also a significant decreasing linear trend for false alarm proportions. This was in line with expected results, given previous findings in Chapter 3, as well as the expected practice effects. These findings partially support the hypothesis that traditional vigilance decrement patterns would not be observable in the broken and reconnected conditions; however it was also hypothesised that the circle condition would reveal a traditional vigilance decrement trend over time. These findings suggest that increased task difficulty may potentially provide some performance benefits over time in vigilance tasks, given the increased total amount of available resources in these tasks due to increased bilateral activation over time (Helton et al., 2010). This would appear to be at the cost of overall accuracy however. This finding is similar to those found in Chapter 3, where performance in the more difficult condition showed improvement over time. It is a possibility that all of the conditions in the current experiment possess some additional degree of task difficulty compared those found in Chapter 3, potentially due to the dynamic presentation of the objects in the current investigation. It could also be the case that the gradual improvement here indicates participants reaching a stable performance asymptote, which is common in vigilance tasks. Resource theorists suggest that performance asymptotes may be the point at which the resource requirements to complete the task for the performance level achieved are matched by the ability of the nervous system to replenish those required resources; something akin to an equilibrium state (Parasuraman & Giambra, 1992). It is more common, however, for performance to decrease from initial levels before reaching this asymptote, rather than the increase that has been found here. This could again be linked to the increased level of difficulty associated with the current task. It is important to note that the current experiment showed lower initial *A'* scores when compared to scores obtained in Chapter 3. This may provide an objective indication that the task used in the current experiment is, as a whole, more difficult than the previous study. This again could account for the differing performance trends and decrement patterns found, as each task condition is, in theory, more difficult to complete than the comparative conditions in Chapter 3.

Another possible explanation of the improvement over time could be that participants passively learn procedures and search strategies throughout the task, which enhance the ability to identify targets (passive perceptual learning; Poggio et al., 1992). This point was raised as a possible explanation of the results found in Chapter 3. This process has been found to result in performance improvements over time, particularly in conditions that initially show lower performance due to greater difficulty (Head & Helton, 2015; Seitz & Dinse, 2007). If this is the case in the current experiment, participants may be learning certain mechanisms or strategies for target search throughout the duration of the task here, which has resulted in the increase in accuracy before the asymptote is reached.

Further research is needed to more clearly separate out reasons for the lack of traditional vigilance decrement patterns over time. The task difficulty explanation hinges on the notion that more total cognitive resources are being made available for recruitment during the task. In order to determine whether passive perceptual learning is influencing the patterns found, a longer vigil may be needed. If a longer vigil was employed, it may be possible to determine which explanation best describes the processes being used here. For example, if passive perceptual learning was the case, it would be reasonable to suspect that an asymptote state would be reached earlier, before a decrement in performance occurred. In other words, an inverted “U” function is predicted for a longer vigil. In contrast, if the difficulty-resource explanation held true, it would be reasonable to expect that a more stable or slower trend would be observed in reaching an asymptote, before a slower decrement trend was observed. Again, further research with a longer vigil is needed to investigate these possibilities and determine why a lack of a vigilance decrement occurs with use of this stimulus set.

One issue with the current experiment is that the position of the potential target features (four black arrows) was uniform across groups in terms of direction, speed, and placement. It is possible that participants were able to, at least in part, predict the location of the next stimuli placement in the sequence of the rotation. Performance has been shown to improve in similar types of tasks by providing participants with foreknowledge of where the next phase in rotation will occur (Hodsoll & Humphreys, 2001; Hodsoll & Humphreys, 2005; Kristjánsson, Wang & Nakayama, 2002). While this may not necessarily have an impact on group differences (as all groups should experience a similar effect), it may provide further explanation as to the lack of traditional decrement patterns found. Again, further research may be needed to investigate this, perhaps by utilizing less predictable patterns of target placement.

There was a significant group difference in both hit rates and *A'* scores, with the circle condition displaying the highest level of accuracy, followed by the broken and reconnected conditions. This was in line with the hypothesized accuracy results, given previous research has shown dynamic presentation of stimuli can improve the perception of global form when there is separation between the local components (Burr & Ross, 2006; Day & Palomares, 2014). In these investigations, when presented at low speeds (or in a stationary form) an increased separation between local components of the object resulted in the detection of a coherent global structure becoming more difficult compared to when those same stimuli were presented at in a dynamic or moving nature. It was suggested that this supported the idea of "motion streaks"; in that moving objects leave residual neural activity, which in turn aids motion processing (Geislers, 1999). As mentioned previously, some caution should be exhibited when making comparisons between the current paradigm and those which use Glass patterns. However, it is possible that a similar mechanism or effect is influencing the results obtained in the current investigation. The separation between objects in the broken condition assists with detection of the targets by creating motion streaks as the shape rotates, therefore allowing the broken object to be viewed as a more coherent global object. This may also provide an explanation for the poorer performance of the reconnected condition relative to the stationary counterpart in Chapter 3. As the reconnected condition moves through its rotation, any motion streaks make the perception of a coherent global object more difficult. This is because despite similar separations in the reconnected object, there is added spatial extension compared to the broken condition. Any residual neural activity with this moving reconnected object makes the object as a whole much more convoluted and therefore difficult to process, as the previously blank space between the object is quickly occupied by the rest of the shape moving through or near that space. The circle condition does not result in this, as it maintained a coherent and uniform global shape throughout each trial. Without the need for assistance from motion streaks to aid processing of a coherent global structure, the circle group therefore performs at an improved level comparative to the remaining conditions. Another possibility is that the circle shape is not perceived to be moving as a whole object in the same way that the reconnected and broken objects are. Only the local components (black arrows) appear to be moving throughout each trial, while in the reconnected and broken groups both the local and global components are perceived to be rotating. This does not necessarily mean motion streaks would not be affecting the local components in the circle group, however it may explain why the circle condition could be considered to be relatively easier task to perform, and therefore displaying superior performance.

The motion streaks explanation is also consistent with the configural superiority effect, which was the proposed mechanism behind the findings in Chapter 3. If the rotation of stimuli creates a more easily recognizable or coherent global structure which in turn aids with response to targets, then it would stand that the improved accuracy in the broken condition is due to this more readily perceived coherent global structure, regardless of whether the object forms a full and complete global figure when statically displayed. The configural superiority effect states that stimuli which form a full gestalt figure are more easily processed, which could also be interpreted as “objects which a more coherently organized”. If the configural superiority effect is interpreted as such then it fits with the motion streaks theory; where motion streaks cause the broken condition to have a more coherent global form, which in turn creates a configural superiority effect. This in turn results in higher accuracy over time in this condition. These results further support the findings of the Chapter 3 research regarding configurative properties.

The aim of this chapter was to investigate whether motion processing had a significant influence on the perception of a coherent global object, thus assisting with performance. Due to the result of the broken condition, which showed improved performance when compared to the statically presented counterpart found in Chapter 3, it can be suggested that motion processing does influence participants' perception of a coherent global object under certain conditions. These results are considered to be due to neuronal processes, where objects leave residual neural activity when they are rotated from a previous position which aids in the processing of a more coherent global structure. This residual neural activity is suggested to be the mechanism that causes both the improved performance in the broken object condition, and potentially for the decreased level of performance in the reconnected object condition. The circle object does not require such a mechanism to aid with the perception of a more coherent global structure, as it maintains a coherent global object regardless of the rotation phase. It is also interpreted from the results that either passive perceptual learning or increased task difficulty may be influencing performance patterns over time. These explanations may require further investigation using cerebral activation imaging techniques, as well as a longer vigil length, in order to more fully determine the cause of a lack of traditional vigilance decrement trends. Another potential issue is the lack of direct statistical analysis between the dynamically presented stimuli found in the current experiment and the stationary counterparts used in Chapter 3. This was due to methodological differences which would make such analysis inappropriate. Future research may need to address this flaw, and allow for a more direct comparison. The results provide further evidence to the explanations presented in Chapter 3, that the configural properties of stimuli can have an effect on vigilance performance. This may be of use for future researchers, who may not observe expected vigilance decrement patterns when using complex or uncommon stimuli in vigilance tasks.

Chapter 5
The Effects of a Transition between Objects with Varying Configurative Properties on Vigilance Performance

5.1. Abstract

The current study combines elements of two previous experiments presented in this thesis; specifically, a transition between discrimination requirements (Chapter 2), and the use of objects which consist of varying configurative properties (Chapter 3). One of the main investigative aims is to explore potential behaviour similarities between these two experiments, as they vary in terms of stimuli complexity. Sixty participants performed a sustained attention task during which they were required to respond to a critical signal requiring feature discrimination. The local feature elements (arrow shapes) were displayed either on a circle (circle condition) or a circle which had been broken apart and reversed (broken condition). Four separate groups performed the task with different global display configurations. For the circle condition, the entire display consisted of a completed global shape which formed a full shape. In contrast, the broken condition no discernible global element. For two of the groups, the global display remained the same for the entire duration of the task (either circle or broken). For the remaining two groups, the global display configuration was changed halfway through the vigil (circle-to-broken or broken-to-circle). Analyses of hit rate and *A'* scores revealed group differences between the circle and broken conditions, similar to findings from Chapters 3 and 4. This result provides further support to the previous interpretation that a configural superiority effect influences task performance with this stimulus set. It was also found that, despite some transition effects in reaction times, most of the effects can be attributed to differences in global configuration rather than difficulty of performing a transition. Behavioural patterns are similar to those of Chapter 2, suggesting similarities in local-global processing despite an increase in object complexity.

5.2. Introduction

Sustained attention is the task of maintaining focus to regularly occurring stimuli for an extended period of time, while providing an appropriate response when rare or critical stimuli are presented. In typical vigilance tasks, a decline in performance is observed with time on task. This decline in performance typically manifests itself through a reduction of hits, and slower reaction times. This decline in performance over time is commonly referred to as the *vigilance decrement* (Davies & Parasuraman, 1982; Warm, 1984). Vigilance tasks are also found to evoke greater levels of hemodynamic activity in the right compared to the left hemisphere (Berman & Weinberger, 1990; Buchsbaum et al., 1990; Helton et al., 2007; Hitchcock et al., 2003; Parasuraman, Warm & See, 1998; Shaw et al., 2009; Stroobant & Vingerhoets, 2000; Warm, Matthews & Parasuraman, 2009; see Helton et al., 2010 for a more in depth overview). There are a number of factors, however, which appear to influence this cerebral lateralization of blood flow during vigilance tasks. For example, task difficulty, transition demand, and configural properties of stimuli have been found to impact hemisphere lateralization. By eliciting more bilateral activation these factors may in turn create performance differences or changes to the decrement profile found in vigilance tasks, given that bilateral activation may allow for more total amount of cognitive resources to be made available for the task (Friedman & Polson, 1981; Friedman, Polson, Dafoe & Gaskill, 1982).

A series of sustained attention studies have failed to demonstrate the right hemisphere dominance that is typical of sustained attention tasks (de Joux et al., 2013; Chapter 2; Funke et al., 2010; Helton et al., 2010; Jeroski et al., 2014; Shultz et al., 2009). It is possible that this could in part be due to the difficulty of the tasks themselves, given that hemisphere lateralization has been found to be a function of task difficulty in previous research (Helton et al., 2010; Sunaert et al., 2000). It is also possible that the observed increase in bilateral activation may be influenced by the requirement to engage in local-global processing throughout the task due to the configurative makeup of the stimuli used. Recent investigations have revealed that differences in performance and cerebral activation during vigilance tasks may be dependent on the configural properties of displays (de Joux, Russell & Helton, 2013; Helton et al., 2009). Performance is, for example, improved by the object having a coherent global configuration (Chapter 3 and 4). This global configuration of stimuli has also been found to elicit different patterns of cerebral activation; having target objects on a coherent, global configuration results in more bilateral activation compared to target objects that do not (presented in Chapter 6, Funke et al., 2010; Funke et al., 2012). To further extend investigations in this area, the effects of a transition between these objects are examined during the current experiment.

Transitions in task demands have previously been identified as a crucial area in human factors research due to practical implications for workplaces, given that workers are rarely required to perform just one task for an extended period of time (Wickens & Huey, 1993). A consistent finding in task transition literature is that changes in task demands result in impaired performance (Cox-Fuenzalida & Angie, 2005; Cumming & Croft, 1973; Helton et al., 2008), regardless of whether the demand is high-to-low, or low-to-high. Impairment is, however, more extreme when task demand decreases (Bowers, 2013; Cox-Fuenzalida, Beeler & Sohl, 2006; Ungar, 2005). This suggests that in addition to task demands, the act of a transition itself also has a level of difficulty associated with it, which in turn contributes to impaired performance. Resource theorists may explain this as a result of resources being exhausted during the high demanding task, thus depleting the total available resources that can be recruited once a lower demand task is transitioned into. Additionally, people performing a transition are required to adjust to the new task parameters, an action which itself may require more cognitive resources to perform as well as increase task related stress (Davies & Parasuraman, 1982; Kahneman, 1973; Matthews et al., 2000; Wickens, 1984).

The current experiment builds on previous research from Chapter 2 and Chapter 3, and examines a transition between shapes with differing configural properties (see Figure 5.1 for examples). Chapter 3 investigated the effects that configural properties of stimuli have on vigilance performance. Participant's monitored four arrows which were placed on one of three background shapes. Two of the background shapes formed a full and completed object, while one shape did not. The two shapes that formed a configurative whole did not show any significant group differences or trend differences, despite being distinctly different shapes. These two groups also displayed improved performance over the group that did not form a configurative whole. It is suggested that these results were due to a configural superiority effect (see; Pomerantz & Kubovy, 1986; Pomerantz & Pristach, 1989; Pomerantz, Sager & Stoever, 1977), where objects that form a full gestalt, or a more coherent object, are more readily processed.

Chapter 2 investigated the effects of a transition between local and global feature discrimination using simple Navon objects (shapes that are composed from a number of smaller shapes; Navon, 1977). Performance differences were found between the types of discrimination tasks, but not for transition versus non-transition groups (there were, however, prefrontal cortex activation differences between the transition versus non-transition groups). This suggests that performance differences when transitioning between these types of processing are due more to the task type itself, rather than difficulties associated with transitions. As stated above, this investigation used very simple Navon stimuli, and specifically focussed on local versus global transitioning. Much more complex stimuli, as found in the Chapters 3 and 4, are composed of multiple levels of local and global information. A transition between objects with greater configural differences may yield different results compared to a transition between more simple objects, due the presumed increased task difficulty found with the more complex stimuli. In addition to this, one potential cause for concern to the overall aims of this thesis was the distinct difference between the stimuli used in the Chapter 2 experiment and the later investigations. It may be that these more complex stimuli require engaging mechanisms beyond that of local-global processing alone. By investigating the effects of the transition between these objects, and examining the similarities or differences to results found in Chapter 2, the argument that these objects are indeed evoking local-global feature discrimination processing may be strengthened.

The current investigation explores the effects of a transition between an object with a full configurative property (i.e. forms a complete object) and an object which does not. Additionally, two groups, which will not experience any transition, will serve as control groups. In previous experiments using these objects, no significant vigilance decrement patterns have been found. This is expected to be replicated in the current experiment when comparing the non-transition groups. It is also expected that the completed object will show superior performance.

In regards to the transition groups, there are a number of possible outcomes. First, a transition between these objects may result in similar patterns to those found in Chapter 2, where post-transition period of watch differences were not significantly different between transition and no-transition groups. If this was the case, we would expect the main source of performance differences in the post-transition periods of watch to be associated to the type of task being undertaken (broken or circle group), rather than associated to the requirement to perform a transition. Contrastingly, it is also possible that a transition from the higher-demand object (broken) to the lower-demand object (circle form) will result in a performance decrement above and beyond that of which could be explained by group differences (Bowers, 2013; Cox-Fuenzalida, Beeler, & Sohl, 2006; Ungar, 2005).

5.3. Method

5.3.1. Participants

Sixty participants (32 men, 28 women) completed the study. Ages ranged from 17 to 66 (*M* = 22.25 years, *SD* = 7.81 years). All participants were right handed, which was indicated by the participant and confirmed through observation of hand used while signing the consent form and key responses during the vigilance task. All participants had normal or corrected-to-normal vision.

5.3.2. Materials

The visual stimuli consisted of 4 black arrows on a white shape, which was centred on a solid red circle. The black arrows act as the local component of the overall object, while the white shapes are considered the global component. The screen position and size (75mm x 80mm) of the black arrows was uniform across all conditions, meaning that their screen positioning, size, and direction did not change between global shapes, while the white global shape was manipulated. Two manipulations of the white global shape were presented; enclosed circle (circle) and reversed broken circle (broken; see Figure 5.1 for examples). As previous experiments using these stimuli have determined that direction has no influence on performance, only anti-clockwise versions of these shapes were used. The width of the white line was kept the same across all conditions (120mm), while the overall size of the global objects differed slightly (circle = 10cm x 10cm, broken = 9.5cm x 9.5cm).

5.3.3. Procedure

The experiment was performed by participants in groups of three to four people in a windowless computer laboratory. Each participant was assigned into one of four conditions; circle-no transition, broken-no transition, circle-transition to broken, or broken-transition to circle.

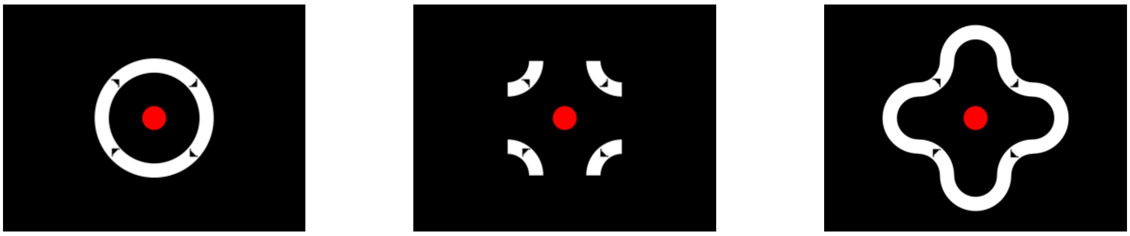


Figure 5.1. Examples of the visual stimuli.

Participants were shown a brief instructional screen, followed by a thirty-second practice period of the task. During the task, participants were required to monitor brief displays of the stimuli and respond whenever one of the four black arrows was orientated in an opposite direction to the other three black arrows. The opposite arrow could occur on any of the 4 positions shown in Figure 5.1. Responses made by pressing the central space bar of a standard computer keyboard. Each trial of the task consisted of; the red central circle being displayed for 500ms, followed by the global shape displayed for 500ms, followed by the red central circle being displayed for a further 1000ms. It was during this period that participant responses were recorded. Each trial was 2000ms in duration. There were 120 trials per period, with each period being 4 minutes in duration. Participants completed 6 of these periods of watch consecutively. The overall time of the vigil, including practice periods and all trial periods, was 24.5 minutes. Distracter and target stimuli were presented in random order with a target display probability of 6.6 percent, and a neutral display probability of 93.4 percent. This probability was consistent between the practice trials and main trials. For the circle and broken conditions, participants were only ever exposed to one shape for the entire vigil. For the transitioning groups (broken-to-circle and circle-to-broken), participants were exposed to 3 periods of their initial shape, before transitioning to the other shape for the final 3 periods. Immediately following the experiment each participant was debriefed regarding the task, and compensated for their time before leaving.

5.4. Results

For each subject and for each period of watch, the proportion of hits, the proportion of false alarms, and the signal detection perceptual sensitivity measure, *A′*, was calculated. *A′* is considered the optimal correction method when extreme hit rates are present (Brown & White, 2005). Detection times were subjected to a $\log_{10}$ transformation, as recommended by Maxwell and Delaney (2004).

Performance during the practice period was assessed with a series of one-way repeated measures ANOVAs in order to determine whether any significant differences occurred at this stage. No significant differences were found between groups in terms of hits, false alarms, *A'* or reaction times. To assess changes over periods of watch, a series of orthogonal polynomial contrasts were employed. While repeated-measures ANOVA is much more commonly used in vigilance research, orthogonal polynomial contrasts are 1-df contrasts, which eliminates any concerns regarding sphericity. They also allow direct tests of specific trends. Some statisticians advocate abandoning repeated-measures ANOVAs altogether in preference for orthogonal polynomial contrasts (Rosenthal & Rosnow, 1985; Rosenthal, Rosnow & Rubin, 2000; Rosnow & Rosenthal, 1996). Although polynomial contrasts serve as our main test of choice from which to test hypotheses, omnibus tests are also included for comparison with published research. For ease of analysis, as well as allowing more direct assessment of the effects of a transition, the pre-transition and post-transition scores were analysed separately. This also maintained similarity to the analysis performed on the task transition data in Chapter 2.

5.4.1. Pre-change

The pre-change (periods 1, 2, and 3) hits were subjected to a 2 (group: broken vs circle) x 2 (change vs no-change) x 3 (period of watch) repeated measures ANOVA with orthogonal polynomial contrasts. For periods of watch there were no significant linear trends, $F(1, 56) = .11$, $p = .744$, $\eta_p{}^2 = .002$, nor quadratic trends, $F(1, 56) = .68$, $p = .413$, $\eta_p{}^2 = .012$. Moreover, there were no significant trends for period by group, period by transition, or period by group by transition. There was a significant group effect, $F(1, 56) = 7.26$, $p = .009$, $\eta_p{}^2 = .115$, with the circle group showing a higher hit rate than the broken group. There was, however, no significant transition main effect, $F(1, 56) = .14$, $p = .713$, $\eta_p{}^2 = .002$. The pre-change hits for the circle and broken conditions are shown in Figure 5.2 (left).

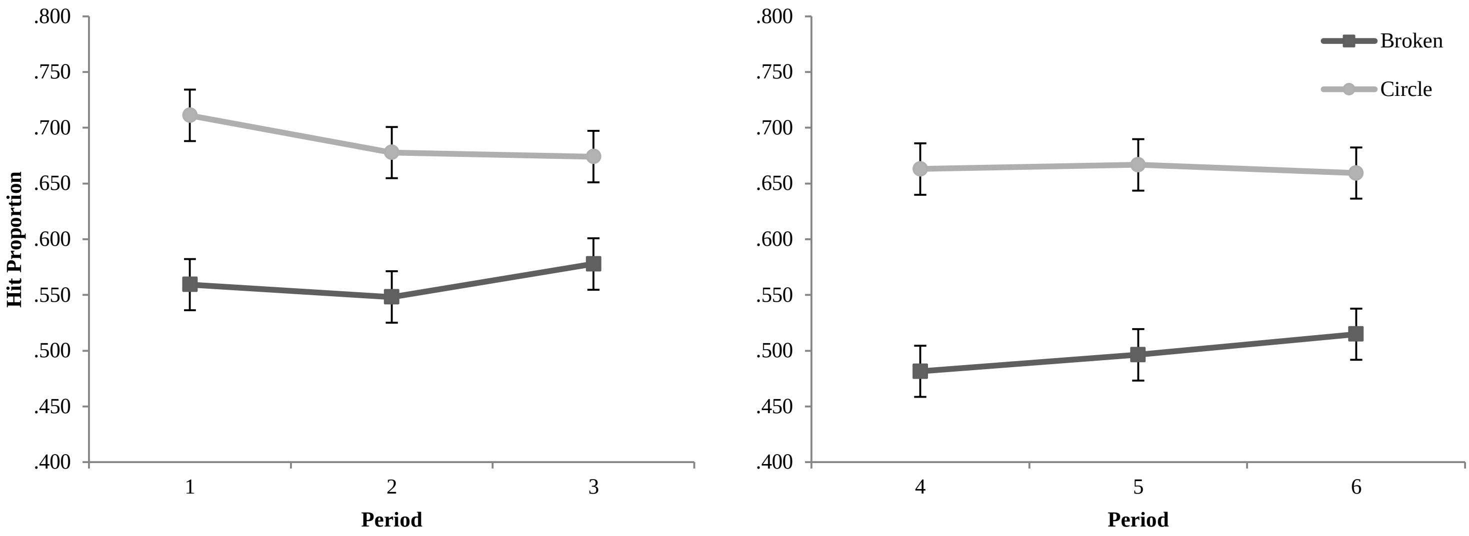


Figure 5.2. Mean hit proportions for broken and circle conditions during pre-transition (left) and post-transition (right) periods of watch. Error bars depict standard error.

The pre-change false alarms were subjected to a 2 (group: broken vs circle) x 2 (change vs no-change) x 3 (period of watch) repeated measures ANOVA with orthogonal polynomial contrasts. For periods of watch there was a significant linear trend, $F(1, 56) = 12.58$, $p = .001$, $\eta_p{}^2 = .183$, with false alarms decreasing with time on task. There was no significant group main effect, $F(1, 56) = .00$, $p = .985$, $\eta_p{}^2 = .000$, nor was there a significant transition main effect, $F(1, 56) = 1.88$, $p = .176$, $\eta_p{}^2 = .032$. It should be noted that total false alarm rates were very low (M = .03 to .02). The pre-change false alarms for the circle and broken conditions are shown in Figure 5.3 (left).

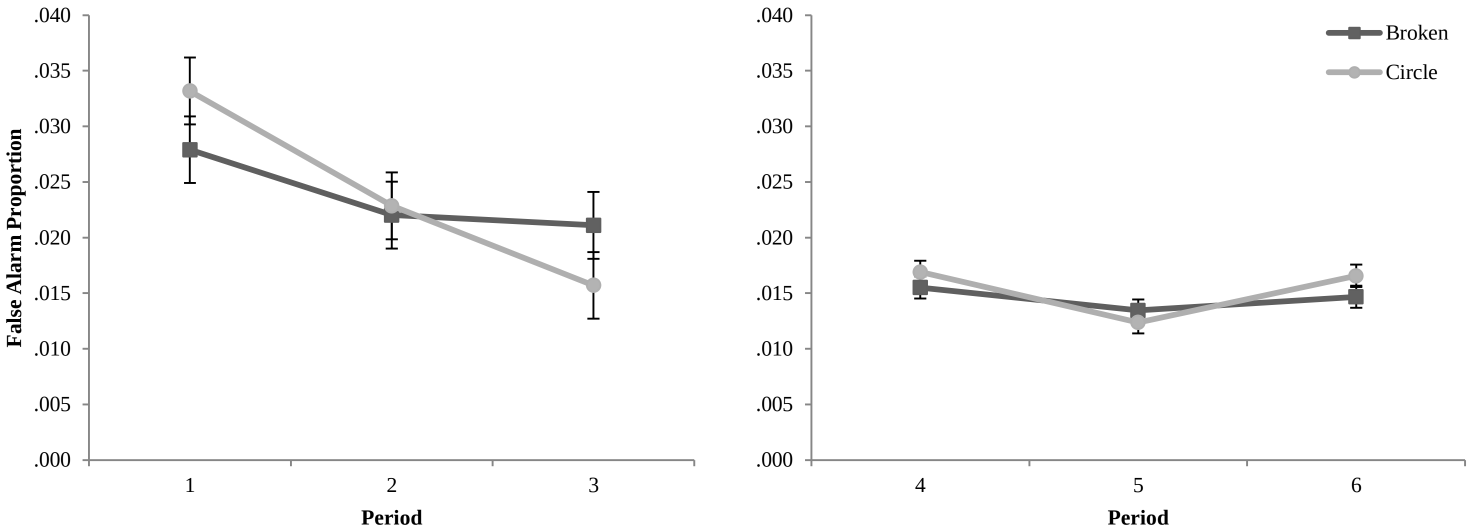


Figure 5.3. Mean false alarm proportions for broken and circle conditions during pre-transition (left) and post-transition (right) periods of watch. Error bars depict standard error.

The pre-change *A'* scores were subjected to a 2 (group: broken vs circle) x 2 (change vs no-change) x 3 (period of watch) repeated measures ANOVA with orthogonal polynomial contrasts. For periods of watch there were no significant linear trends, $F(1, 56) = .08$, $p = .778$, $\eta_p^2 = .001$, nor quadratic trends, $F(1, 56) = .96$, $p = .333$, $\eta_p^2 = .017$. There were no significant period by group, period by transition, nor period by group by transition linear or quadratic trends. Similar to hit rate, there was a significant group main effect, $F(1, 56) = 6.84$, $p = .011$, $\eta_p^2 = .109$. There was, however, no significant transition main effect at this stage, $F(1, 56) = .50$, $p = .484$, $\eta_p^2 = .009$. The pre-change *A'* scores for the circle and broken conditions are shown in Figure 5.4 (left).

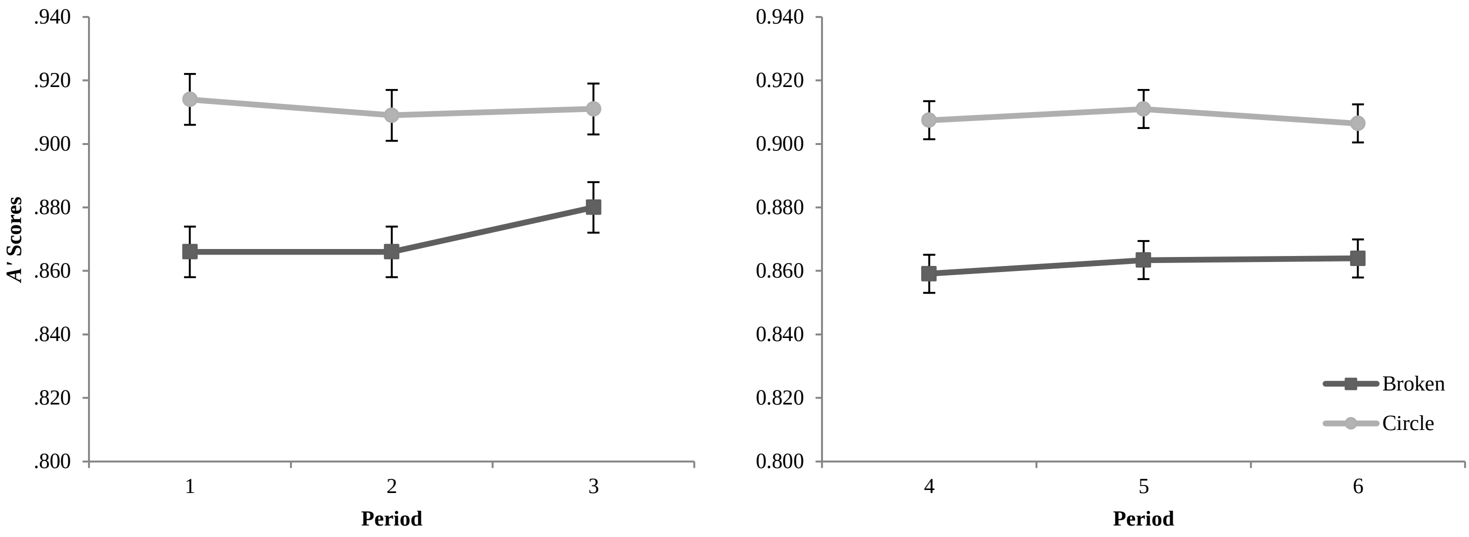


Figure 5.4. Mean *A'* Scores for broken and circle conditions during pre-transition (left) and post-transition (right) periods of watch. Error bars depict standard error.

The pre-change $\log_{10}$ reaction times were subjected to a 2 (group: broken vs circle) x 2 (change vs no-change) x 3 (period of watch) repeated measures ANOVA with orthogonal polynomial contrasts. For periods of watch there was a significant linear trend, $F(1, 55) = 21.45$, $p = .000$, $\eta_p^2 = .281$, with reaction times in all groups increasing over time. There was also a significant period by group by transition linear trend, $F(1, 55) = 5.04$, $p = .029$, $\eta_p^2 = .084$. While there are no significant reaction time differences between the circle and broken conditions in the no-transition groups, there is a significant group difference between the conditions in the transition conditions, with the broken group displaying longer reaction times comparative to the circle group. The omnibus test revealed a significant group main effect, $F(1, 55) = 6.86$, $p = .011$, $\eta_p^2 = .111$, a significant transition main effect, $F(1, 55) = 6.94$, $p = .011$, $\eta_p^2 = .112$, and a significant group by transition interaction, $F(1, 55) = 4.54$, $p = .038$, $\eta_p^2 = .076$. All log10 reaction times for the broken and circle groups are shown on Figure 5.5. The pre-change reaction times for the no-transition conditions can be observed on the top left, while the pre-change reaction times for the transition conditions are shown on the bottom left.

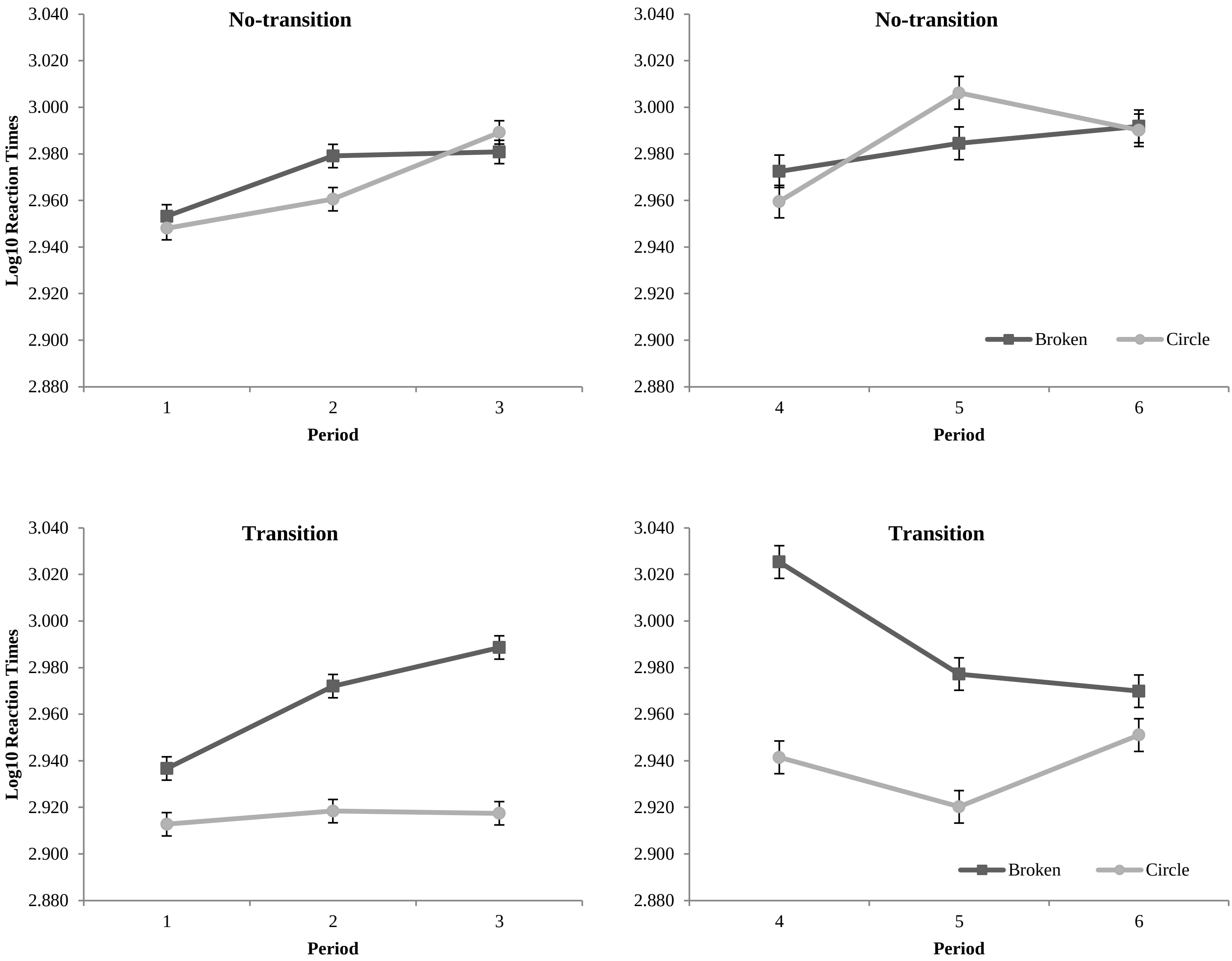


Figure 5.5. Mean Logl0 reaction times for broken and circle groups in the transition (bottom) and no-transition (top) conditions during pre-change (left) and post-change (right) periods of watch. Error bars depict standard error.

5.4.2. Post-change

The post-change (periods 4, 5, and 6) hits were subjected to a 2 (group: broken vs circle) x 2 (change vs no-change) x 3 (period of watch) repeated measures ANOVA with orthogonal polynomial contrasts. For periods of watch there were no significant linear trends, $F(1, 56) = .49$, $p = .488$, $\eta_p^2 = .009$, nor quadratic trends, $F(1, 56) = .01$, $p = .922$, $\eta_p^2 = .000$. Additionally, there were no significant period by group, period by transition, or period by group by transition linear or quadratic trends. There was a significant group effect, $F(1, 56) = 13.02$, $p = .000$, $\eta_p^2 = .189$, with the circle conditions showing a higher hit rate compared to broken conditions. Similar to pre-change scores, there was no significant transition main effect, $F(1, 56) = .42$, $p = .521$, $\eta_p^2 = .007$, nor was there a significant group by transition main effect, $F(1, 56) = 2.61$, $p = .112$, $\eta_p^2 = .045$. The post-change hits for the circle and broken conditions are shown in Figure 5.2 (right).

The post-change false alarms were subjected to a 2 (group: broken vs circle) x 2 (change vs no-change) x 3 (period of watch) repeated measures ANOVA with orthogonal polynomial contrasts. For the period effect, there was no significant linear trend, $F(1, 56) = .085$, $p = .772$, $\eta_p^2 = .002$, nor was there a significant quadratic trend, $F(1, 56) = 2.61$, $p = .112$, $\eta_p^2 = .044$. There was, however, a significant period by transition linear trend, $F(1, 56) = 7.93$, $p = .007$, $\eta_p^2 = .124$. False alarms continue to decrease over time in the no-transition conditions, while the transition conditions show an increase in false alarms. This was evidenced by a significant transition main effect, $F(1, 56) = 15.14$, $p = .000$, $\eta_p^2 = .213$, while no significant group or group by transition main effects were found ($p > .05$). Again, it should be noted that total false alarm rates were very low. The post-change false alarms for the circle and broken conditions are shown in Figure 5.3 (right). The pre- and post- change false alarms for the transition and no-transition conditions are shown in Figure 5.6 (right).

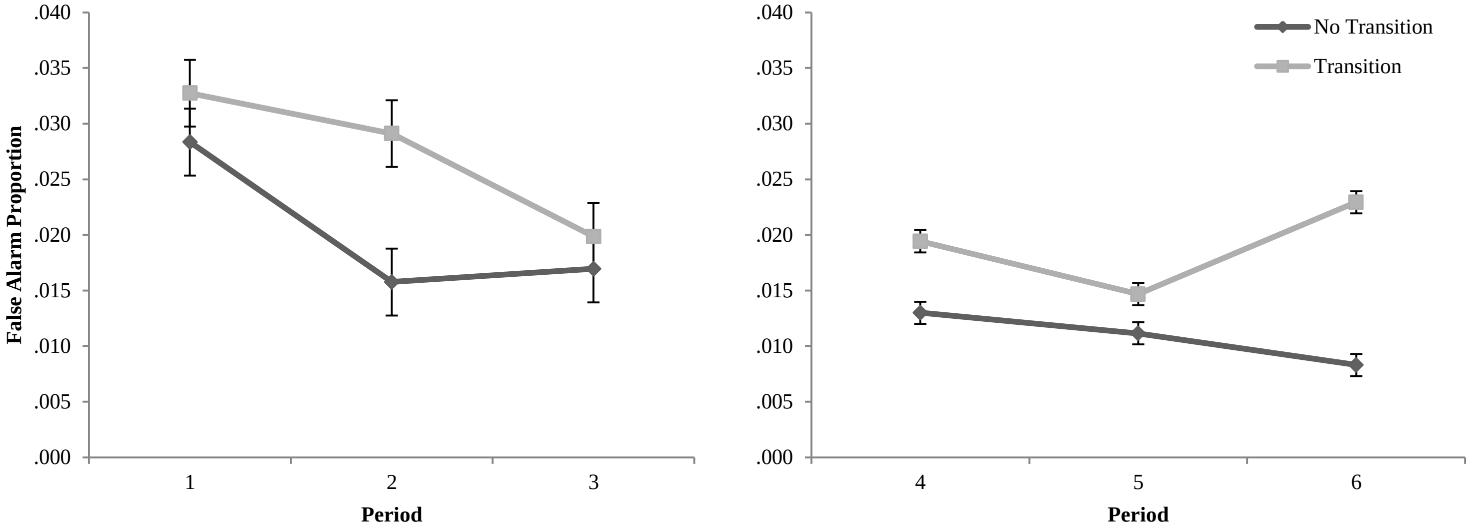


Figure 5.6. Mean false alarm proportions for change and no change conditions during pre-transition (left) and post-transition (right) periods of watch. Error bars depict standard error.

The post-change *A'* scores were subjected to a 2 (group: broken vs circle) x 2 (change vs no-change) x 3 (period of watch) repeated measures ANOVA with orthogonal polynomial contrasts. For periods of watch there were no significant linear trends, $F(1, 55) = 1.28$, $p = .264$, $\eta_p^2 = .023$, nor quadratic trends, $F(1, 55) = .00$, $p = .956$, $\eta_p^2 = .000$. There were also no significant period by group, period by transition, or period by group by transition trends (linear or quadratic). There was, however, a significant group main effect, $F(1, 55) = 12.10$, $p = .001$, $\eta_p^2 = .180$, with the circle conditions showing high *A'* scores compared to the broken conditions. Neither the transition main effect nor the group by transition interaction reached significance ($p > .05$). The post-change *A'* scores for the circle and broken conditions are shown in Figure 5.4 (right).

The post-change $\log_{10}$ reaction times were subjected to a 2 (group: broken vs circle) x 2 (change vs no-change) x 3 (period of watch) repeated measures ANOVA with orthogonal polynomial contrasts. For periods of watch there was no significant linear trend, $F(1, 54) = .015$, $p = .903$, $\eta_p^2 = .000$, nor a significant quadratic trend, $F(1, 54) = .14$, $p = .712$, $\eta_p^2 = .003$. There was a significant period by group linear trend, $F(1, 54) = 5.27$, $p = .026$, η_p^2

= .089, with the circle conditions displaying a linear increase in reaction times over time, while the broken conditions show a decrease over time. Unlike the pre-change findings, there was no significant period by transition by group interaction trend. There was a significant period by transition linear trend, $F(1, 54) = 8.30$, $p = .006$ $\eta_p^2 = .133$, as well as a significant period by transition quadratic trend, $F(1, 54) = 5.47$, $p = .023$, $\eta_p^2 = .092$. There was no significant group main effect, $F(1, 54) = 3.77$, $p = .057$, $\eta_p^2 = .065$, nor a significant transition main effect, $F(1, 54) = 2.31$, $p = .134$, $\eta_p^2 = .041$, however a significant group by transition interaction was found, $F(1, 54) = 4.50$, $p = .039$, $\eta_p^2 = .077$. Visual inspection suggested that some of the reaction time effects may have been obscured during initial analysis. Therefore, in order to examine reaction time data further, two 3 (period of watch) by 2 (group: broken vs circle) repeated measures ANOVAs with orthogonal polynomial contrasts were performed on the transition and no-transition groups individually. For the no-transition groups, there was a significant increasing linear trend, $F(1, 27) = 6.49$, $p = .017$, $\eta_p^2 = .194$. There were, however, no significant group differences, or group by period interactions, with the broken and circle groups displaying similar reaction times. For the transition groups, there was a significant group by period of watch linear trend, $F(1, 27) = 5.85$, $p = .023$, $\eta_p^2 = .178$, as well as a significant group effect, $F(1, 27) = 7.07$, $p = .013$, $\eta_p^2 = .208$. Here, reaction times in the broken group start at a higher level before decreasing over time. In contrast, reaction times in the circle group start lower and display an overall increase over time. Reaction times in the circle group remain faster than those in the broken group across all periods of watch. The post-change log10 reaction times for the circle and broken groups are shown in Figure 5.5, with the no-transition groups shown on the top right, while the transition groups are shown on the bottom right.

5.5. Discussion

One of the aims of the current experiment was to examine the effects that a transition between two stimuli that vary in their configural elements may have on vigilance performance. Specifically, this transition occurred between an object that formed a completed global figure and one that did not. This research combines elements of previous investigations found in Chapters 2 and 3. A secondary aim was to determine whether these more complex objects evoked similar patterns of response over time to simpler local-global objects, thus forming a link between the experiment presented in Chapter 2 and the stimuli used in the remaining chapters.

For accuracy, the proportion of hits was significantly higher for the circle shape compared to the broken shape both before and after the transition (Figure 5.2). Moreover, there were no significant linear trends over time (i.e. vigilance decrement was not observed). These findings are in line with hypothesized group accuracy results, given the lack of an accuracy decrement and similar group differences observed in earlier chapters. This was also reflected in *A'* scores, where again there were significant group differences between the circle and broken conditions, as well as no significant linear trends over time (Figure 5.4). Again this was hypothesized given the results from previous investigations. These group difference findings may lend further support to the argument previously put forward that a configural superiority effect may be influencing performance with this stimulus set. Additionally, the lack of a vigilance decrement over time lends support to the argument that increased bilateral activation may be occurring as a result of the increased requirement to employ local feature processing, due to the configurative nature of the stimuli used. Again however, this can only be hypothesized currently, as no measure of cerebral activation is used in this investigation, and is an area for further research (which is presented in Chapter 6).

There were no significant differences observed in hit rate or *A'* scores between the transition and no-transition groups in either the pre-change or post-change periods. A transition between stimuli with different configural properties does not appear to result in accuracy differences using either of these two metrics. This is comparable to findings reported in Chapter 2, where no significant differences in the post-transition periods were found between the change and no-change groups using Navon-like stimuli. The accuracy differences in the post-transition periods can be attributed to the particular configuration, not transition demands. Another possible interpretation is that these two task discrimination types do not necessarily differ largely from each other in regards to task demands, given that both object types require a certain level of processing of configural information. Increased difficulty (as indicated by the significant differences between discrimination groups) may not necessarily be synonymous with increased task demand. Chapter 6, which investigates cerebral activation during a task using these objects, indicates that these objects have a similar activation profile in the initial stages of the vigil. If hemodynamic activity is representative of cognitive demands, this may explain the relative lack of transition effects on hit rate and accuracy.

False alarms were characterized by a linear trend over time in the pre-change periods, with false alarms decreasing with time on task. There was no significant linear trend in the post-change periods; however it is suspected that this may be due to a floor effect, as false alarm rates were extremely low initially. This is similar to the patterns of false alarms found in Chapters 3, 4 and 6 which also use these stimuli. There were also no group differences between circle and reconnected conditions over time in either the pre-change or post-change conditions (Figure 5.3). Differences do exist, however, when comparing the transition versus no transition groups in the post-change periods, where the no-transition group false alarms continue to decrease with time on task while the transition group false alarms increase

(Figure 5.6). The no-change groups have more opportunity to adjust to the task demands; therefore false alarms continue to decrease in a linear trend over the six periods in these groups. The change groups, in contrast, must adjust to a new object in the latter periods. Essentially, participants in these groups must begin the process of understanding the task demands again. The trend observed in the post-transition phase may represent the effects of practice with a new task. Practice effects of this type are well established within vigilance literature, and would appear to be the same here (Head & Helton, 2015; Wantanabe et al., 2002; Wantanabe, Nanez & Sasaki, 2001).

There were a number of statistically significant reaction time effects. A significant linear trend was found in the pre-change periods, with reaction times increasing over these three periods; a vigilance decrement. There was also a significant period by group by transition interaction. Reaction times in the no-transition groups increased linearly over the three periods, with no differences between groups. In the transition groups however, the broken group displayed longer reaction times compared to the circle group, as well as displaying a steeper decrement trend in this period. This is a somewhat concerning result, as performance should have been uniform in the pre-change periods of watch. This finding has resulted in caution being taken when making claims regarding transition versus no transition reaction time differences in the post-change periods. In the post-change periods, reaction times in the no-transition periods continued to show no group differences and an increasing linear trend over time, indicative of a vigilance decrement. For the transition groups however, there was a significant group difference observed, as well as a significant period by group interaction. Reaction times in the broken group started at a much higher level before becoming quicker over time. Reaction times in the circle group, in contrast, start lower and display an overall increase across the three periods of watch. The circle group does however remain faster than the broken condition across all three periods.

An explanation for this decline in the final periods for the broken condition may be that it is a reflection of an initial "shock" when changing conditions from a lower demand object (circle) to a higher demand object (broken). This is reflected by the significant period by transition effects that were found for the post-change periods, where the no-transition groups show increasing reaction times over periods of watch, while the transition groups show an initial decrease in reaction times before stabilizing. The no-transition reaction times follow a stable, traditional vigilance decrement pattern over time, while the transition reaction times show transition effects in the final periods. As stated previously however, some caution should be taken with these interpretations, given the differences found in the pre-change periods of watch. Further research is required to examine these reaction time effects, and why they have been found here and not in the experiments presented in Chapters 3 and 4.

One of the main aims of the current experiment was to explore behavioural similarities between the experiment presented in Chapter 2 which used Navon stimuli and the configural stimuli derived presented in the remaining chapters. The findings of the Chapter 2 investigation suggested that differences in the post-transition periods of the task were mainly due to the discrimination type required, rather than the effect of transitioning. While the transition groups in Chapter 2 did show a slowing of the vigilance decrement, there were no significant differences found between the discrimination groups. The current experiment is slightly more complex compared to the investigation presented in Chapter 2 in terms of objects used (Navon objects versus configural objects), signal event rates, and data gathered (accuracy and reaction time data versus only reaction time data in Chapter 2). While not entirely conclusive, some similar trends to those presented in Chapter 2 are found. The findings presented in this chapter show significant group differences between the circle and broken conditions, while transition effects are confined to false alarms and reaction times metrics. The post-change hits, *A'* scores and false alarms in the change conditions did not significantly differ from their no-change counterparts. There were significant reaction time differences and trends however, which do suggest that some transition effects exist. This is understandable due to the increased complexity of the stimulus set used in this experiment compared to the Navon objects used in Chapter 2. These reaction time differences should, however, be observed with caution, given the lack of reaction time differences found with this stimulus set previously. The findings of the current experiment provide an important link between experiments that use simple local-global objects (Chapter 2) and those that use more complex local-global objects (Chapters 3 and 4), suggesting that they do indeed evoke similar behavioural responses, and perhaps similar cognitive processes, over time.

Chapter 6

A functional near-infrared spectroscopy study of the effects of configural properties on sustained attention

6.1. Abstract

The current experiment extends studies of the effects of the configural properties of stimuli on vigilance performance by including measures of cerebral hemodynamic activity in the pre-frontal cortex during the vigil. Forty-five participants completed a vigilance task during which they were required to respond to a critical signal at a local feature level, while the global display was altered between groups. This critical local feature element (directional arrow shapes) was displayed either on a circle, a circle broken apart and reversed, or a reconnected figure. The shapes used in two of the groups formed a configurative whole (the circle and reconnected conditions), while the remaining shape had no discernible or complete global element (broken circle). Performance matched the results found in the previous experiments, where a configural superiority effect was found to be influencing accuracy over time. Physiological data revealed elevated activation in the right pre-frontal cortex during the task compared to the left pre-frontal cortex. Additionally, bilateral activation was found in the conditions that formed configurative wholes, while hemispheric differences over time were found in the condition that did not. These findings suggest that configural aspects of stimuli may explain why deviant laterality effects have been found in similar research. This finding provides considerations for future researchers who seek to use novel stimuli in their investigations.

6.2. Introduction

The task of monitoring ones' immediate environment for rarely occurring or critical stimuli is a requirement for many people in everyday life, particularly for those in workplaces where a large amount of information is received. Psychologists refer to this process as vigilance or sustained attention (Davies & Parasuraman, 1982; Warm, 1984). A consistent finding in vigilance research is that sustained attention evokes right-hemisphere lateralization in the brain. That is, blood flow and metabolic activity is elevated in the right hemisphere in comparison to the left hemisphere, an outcome which has been found using a variety of brain imaging techniques, including; functional magnetic resonance imaging (fMRI), positron emission tomography (PET), transcranial Doppler sonography (TCD), and functional near-infrared spectroscopy (fNIRS; Berman & Weinberger, 1990; Buchsbaum et al., 1990; Cohen et al., 1988; Helton et al., 2007; Hitchcock et al., 2003; Lewin et al., 1996; Parasuraman, Warm & See, 1998; Shaw et al., 2009; Stroobant & Vingerhoets, 2000; Warm, Matthews & Parasuraman, 2009; see Helton et al., 2010 for overview). Moreover, research with commissurotomized (split-brain) patients has demonstrated improved performance during vigilance tasks when signals are presented to the right hemisphere as opposed to the left hemisphere (Diamond, 1979a; 1979b).

Although sustained attention often results in a right hemisphere lateralization effect, it is also possible that stimuli characteristics, such as object feature hierarchy, may be influential in regards to hemispheric lateralization. Visual objects are ordered in a hierarchical fashion, where larger objects are composed of a number of smaller features or shapes, which in turn could themselves also be composed from even smaller elements. The small components of an object are commonly referred to as local features, while the large components are commonly referred to as global features. A common finding in local-global feature discrimination literature is that the right hemisphere shows an increase in activity during global feature discrimination, while the left hemisphere shows increased activity during local feature discrimination (Flevaris, 2010; Lux et al., 2004; Manjaly et al., 2007; Stone & Tesche, 2009; Van Kleeck, 1989; Weissman & Woldorff, 2005; Yamaguchi, Yamagata & Kobayashi, 2000). One issue with these investigations however is that they tend to adopt more perception-based paradigms, in that sustained attention to objects is not a central component of the task. Local-global feature discrimination or hierarchical discrimination during vigilance tasks has not received as much investigation; however recent research has begun to address this.

Investigations that have been undertaken in this area yield results which suggest that discrimination between hierarchical elements of a shape results in patterns of hemodynamic response and performance which differ from those from purely sustained attention or perception-based paradigms. For example, investigations using perception-based approaches to local-global feature discrimination commonly reveal a global precedence; where global objects are responded to more readily than local objects (Kimchi, 1992; Lamb & Roberston, 1990; Navon, 1977). Under sustained attention conditions however, tasks in which local feature discrimination is required have been found to result in faster reaction times compared to those that require global feature discrimination; a local precedence effect (Chapter 2; de Joux et al., 2013; Helton, Hayrynen & Schaeffer, 2009). These investigations also reveal differing trends over time, with quadratic trends observed in local discrimination, compared with a more traditional linear decrement observed in global feature discrimination. These performance differences are theorized to be partially due to corresponding differences in patterns of hemodynamic response found during the tasks. Local feature discrimination is found to result in higher levels of bilateral activation compared to global feature discrimination, where more right hemisphere lateralization is found. This appears to be the result of global feature processes (right hemisphere dominant) and sustained attention processes (right hemisphere dominant) combining to place higher demand on the right hemisphere, whereas local feature discrimination processes (left hemisphere dominant) combined with sustained attention processes (right hemisphere dominant) do not produce the same load placement on one hemisphere. Additionally, bilateral activation may allow more cognitive resources to be recruited towards the task.

While differences in performance and cerebral activation were observed in the de Joux et al. (2013; Chapter 2) and Helton et al. (2009) investigations, the stimuli used in these investigation were of a relatively simple nature. Nonetheless, they do raise questions as to how configural properties of more complex stimuli may influence task performance and cerebral activity by evoking local-global feature discrimination, and whether investigations that deviate from traditional cerebral activation patterns found during vigilance tasks may in some part be due to the requirement to engage local-global discrimination processes. Funke et al. (2010; 2012) and Nelson et al. (2014), for example, employed a task designed to simulate radar detection. In this task, participants were required to monitor four arrows which were positioned on a background circle, and were orientated in the same clockwise or anti-clockwise direction. Participants were required to respond when one of those arrows was orientated in the opposite direction to the other three. Using TCD and fNIRS as measurements of cerebral hemodynamic activity, the usual right hemisphere lateralized patterns associated with vigilance tasks were not observed. While the right hemisphere did show an elevated level of activity in comparison to the left hemisphere, increased bilateral activation was found to occur during the tasks (left hemisphere trends matched those of the right hemisphere). A possible explanation for these deviant laterality findings is that the task requirements evoke, at least in part, local-feature processing, which results in increased bilateral activation over time rather than a unilateral right hemisphere bias.

Chapters 3, 4 and 5 began to explore this possibility by extending the Funke et al. (2010; 2012) investigates to examine behavioural differences between stimuli which had varying configurative properties. Three global shapes were used: a circle, a reversed and broken apart circle, and a reconnected shape (see Figure 6.1 for examples). The circle shape provided a similar configuration to that used by Funke and colleagues. The reversed broken circle shape consisted of the same overall level of visual information in terms of surface area; however by splitting and reversing the circle, the overall global shape no longer formed a complete and connected figure. The reconnected shape was the reversed broken circle shape that had been extended at the break points, which resulted in the object reconnecting with itself to form a full global shape. This shape retained some aspects of the broken shape, in that the reversed nature of the object remained the same; however, it also shared some aspects with the circle shape, specifically in that it formed a configurative whole. In terms of local-global features, the circle and reconnected shapes were considered to be local targets on a global object, while the broken shape was considered to be local targets on separate local shapes. The results revealed that the broken group showed impaired performance compared to the circle and reconnected groups. The circle and reconnected groups were also found to show highly similar performance trends throughout the task. These findings were considered to be indicative of a configural superiority effect, in which stimuli that form a full or complete global form are processed more efficiently than those that do not (see also, Bennett & Flach, 2011; Pomerantz & Kubovy, 1986; Pomerantz & Pristach, 1989; Pomerantz, Sager & Stoever, 1977). Additionally, traditional vigilance decrement patterns were not observed in this experiment. While this study did not employ a measure of hemodynamic response, it was suggested that this may have been partially due to an increase in bilateral activation, as reported in the Funke et al (2010; 2012) investigations.

In the current experiment, the investigation presented in Chapter 3 is extended by employing a measure of cerebral hemodynamic activity during the task, as well as extending the vigil length in order to more clearly assess time-on-task effects. Cerebral hemodynamic response has been closely linked to neural activity during sustained attention tasks (Moore & Cao, 2007; Raichle, 1998). Studies have found that this response occurs in a number of areas, most commonly the right inferior parietal regions, basal ganglia, right intralaminar region of the thalamus, reticular formation, and the inferior prefrontal cortex (Kinomura, Larsson, Gulyas, & Roland, 1996; Langner et al., 2012; Langner & Eickhoff, 2013; Ogg et al., 2008; Parasuraman, Warm, & See, 1998). The current research focuses on activity in the inferior prefrontal cortex for two reasons. First, this area has been the focus of similar research investigating configural properties (de Joux et al., 2013; Chapter 2; Helton et al., 2009). Second, investigations as to the neural underpinnings of the configural superiority effect have found the 'higher' regions of the brain (i.e. the prefrontal cortex) to be crucial in the formation of full Gestalt figures (Biederman, 1987; Riesenhuber & Poggio, 1999). The specific instrumentation used in the current investigation is functional near-infrared spectroscopy (fNIRS). fNIRS uses wavelengths of light to measure oxygenated and deoxygenated haemoglobin. These measurements have been found to correlate with the BOLD response found in both fMRI (Kleinschmidt et al., 1996; Steinbrink et al., 2005; Strangman et al., 2002) and EEG measures of cerebral activity (Meltzer, Negishi, Mayes, & Constable, 2007; Moosmann et al., 2003). The fNIRS presents a useful tool for researchers to investigate cerebral activity during tasks by providing quieter, less restricting, and less costly imaging when compared to fMRI and PET.

Chapter 3 found similar performance between the reconnected and circle conditions. Therefore it was hypothesized that the circle and reconnected conditions would show similar patterns of performance over time, with no significant differences between them.

Additionally, it was expected that these two groups would display a higher level of performance compared to the broken condition, as was observed in Chapter 3. The broken condition showed a slight improvement in performance over time in the previous experiment; however this was expected to be reversed in the longer vigil of the current experiment.

Although previous investigations do find increased bilateral activation (i.e., similar trends over time) in studies requiring more local feature discrimination, the right hemisphere still shows elevated levels of cerebral oxygenation comparative to the left hemisphere. This was expected to be replicated in the current experiment, given the sustained attention component of the task. In line with previous investigations, all three groups are expected to show increased bilateral activation rather than the traditional right hemisphere bias which is commonly found in vigilance tasks (Funke et al., 2010; Funke et al., 2012; Nelson et al., 2014). This is interpreted as both hemispheres displaying similar trends of activation over time, regardless of the elevated right hemisphere activation.

Differences in bilateral activation are expected between groups. Specifically, we expect that the circle and reconnected conditions should display similar patterns of cerebral activation over time, due to the aforementioned configural superiority effect found with these two objects. The broken condition should display a pattern of activation unlike that which is found in the circle and reconnected conditions. This is suspected due to the configural superiority effect observed in Chapters 3, 4 and 5.

6.3. Method

6.3.1. Participants

Participants were 45 students (21 males, 24 females) from the University of Canterbury in Christchurch, New Zealand. Their ages ranged from 19 to 33 years (M = 23.9 years, SD = 2.3). All participants were right handed, which was indicated by the participant and confirmed through observation of hand use while signing the consent form, completion of questionnaires and key responses during the vigilance task. All participants had normal or corrected-to-normal vision.

6.3.2. Materials

The 45 participants (15 participants per group, genders balanced) were assigned at random to either a circle, broken or reconnected object vigil. Participants were tested individually in a windowless laboratory room. Participants were seated approximately 40cm from a 270mm x 340mm video terminal display, which was positioned at the eye level of the participant. Participants were unrestrained throughout the duration of the task; however they were instructed to minimize any unnecessary head movements which could displace the fNIRS sensors, as well as any sudden body movements which could result in the fNIRS sensor units being moved. All participants were briefed regarding the task, and informed of the fNIRS and its function, before they provided their written consent to undertake the study.

Each participant was fitted with the fNIRS instrumentation, which was the Nonin Near-Infrared Cerebral Oximeter using Equanox sensors. The sensors were placed at Fp1 and Fp2 positions (using standard 10/20 configuration for EEG placement) on the forehead, and secured using a customized adjustable headset. The Fp1 and Fp2 positions were chosen because they are commonly used during clinical use of the fNIRS (Kim et al, 2000; Scheeren, Schober & Schwarte, 2012), as well as aligning with previous investigations involving vigilance tasks (Chapter 2; de Joux et al., 2013; Helton et al., 2007; Punwani et al., 1998). Additionally, investigations into the configural superiority effect have found the prefrontal cortex to be crucial in the formation of Gestalt figures (Biederman, 1987; Riesenhuber & Poggio, 1999). The Nonin Near-Infrared Cerebral Oximeter measures cerebral oxygen saturation (rSO_2). This is calculated by determining the relative amounts of oxyhemoglobin (O_2HB) and deoxyhemoglobin (HHb) in each hemisphere. The Nonin Near-Infrared Cerebral Oximeter requires two sensor pads (specifically the Equanox Advance Model 8004CA pads) to be attached to the forehead of the participant throughout the entirety of the task. The Equanox pads consist of two light emitters and two light detectors, with each detector receiving light from each light emitter. The emitters to detector distances are 20mm and 40mm. Four different wavelengths of light are used (725nm, 755nm, 805nm and 875nm). Readings are obtained at 3-second intervals.

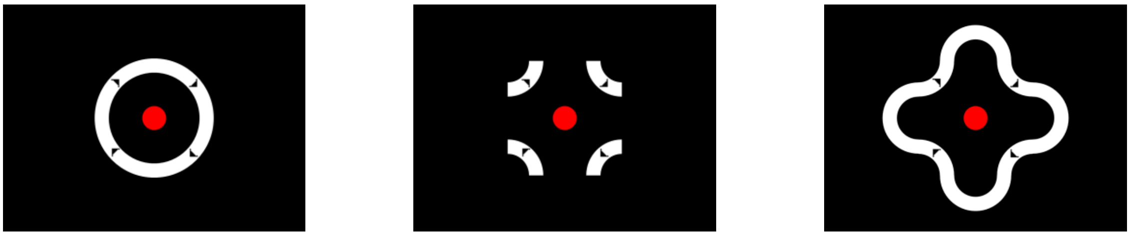


Figure 6.1. Examples of the visual stimuli.

Participants performed a detection task using objects which were composed of different configural properties (see Figure 6.1). These properties consisted of a set of four black arrows placed on a white background shape, which was itself encompassing a solid red central circle that acted as a central fixation point. The black arrows act as the local component of the overall object, while the white shapes are considered the global component. The screen position and size (75 mm x 80 mm) of the black arrows was uniform across all conditions, while the white global shape was manipulated. Three manipulations of the white global shape were presented: enclosed circle (circle); disconnected "broken" circle (broken); and reconnected "broken" circle (reconnected). The width of the white line was kept the same across all conditions (120 mm), while the overall size of the global objects differed slightly (circle = 10 cm x 10 cm; broken = 9.5 cm x 9.5 cm; reconnected = 15cm x 15cm).

Each participant was also required to complete an 11-item self-report stress scale before and after the task. This scale has been used in previous studies (Blakely, 2014; Hancock, 2015; Wilson, Finkbeiner, de Joux, Head & Helton, 2014), with factor analysis revealing a 3-factor solution of; distress, task engagement, and mind-wandering.

6.3.3. Procedure

Upon entering the experiment room, each participant completed the questionnaire by relating each item to their activities in the previous 5-10 minute period. This was to serve as a baseline subjective rating for that participant. Upon completion of the pre-test questionnaire, participants were assigned to one of the three experimental conditions described above, before being fitted with the fNIRS. Once correctly fitted with the device, each participant undertook a five minute period in which their baseline fNIRS readings were recorded. During this period participants were instructed to maintain a state of "relaxed wakefulness" while seated in front of a blank display. They were to remain silent, minimize body movement, and maintain regular breathing patterns, similar to how they would react in the vigil. Cerebral oxygenation during the final minute of this baseline period was used as a baseline index (Aaslid, 1986). The final minute of the 5 minute period was used as baseline to allow time for participants to become accustomed to the device attached to their forehead and for their rSO_2 levels to stabilize.

Participants were shown a brief instructional screen to outline the task, before performing a 2-minute practice period. The task required participants to monitor brief displays of the stimuli and respond whenever one of the four black arrows was orientated in an opposite direction to the other three black arrows (target). The opposite target could occur at any of the 4 positions shown in Figure 6.1. Results from previous experiments using these stimuli revealed that the orientation of the arrows had no effect on responses (Chapters 3 and 4). Therefore the arrows were clockwise, while the critical target arrow was pointed an anti-clockwise. Responses were made by pressing the central space bar on a computer keyboard. During each trial the red central circle alone was first displayed for 500ms, followed by the target shape being displayed for 500ms, before the red central circle was again displayed for 1000ms. It was during this 1500ms period that participant responses were recorded. Each individual trial was 2000ms in duration. There were 60 trials per trial period, and each period was 2 minutes in duration. Participants completed 16 trial periods in total, which were completed consecutively with no breaks between periods. The overall time including all fNIRS baseline testing, trial periods, practice periods was 39 minutes, with 34 minutes allocated to the vigil itself. Distracter and target stimuli were presented in random order with a target display probability of 13.33 percent, and a neutral display probability of 86.66 percent in both practice and main trials. In total, 8 trials per period contained target objects. Participants were not informed of this target probability.

Immediately following completion of vigil task, the fNIRS was removed from the participants' forehead. Participants were then asked to complete the post-test questionnaire. Following this, participants were debriefed about the experiment and its purpose before receiving compensation for their time.

6.4. Results

6.4.1. Performance

For each participant the proportion of correct detections (hits), the proportion of false alarms (false alarms) and the signal detection theory metric *A'* (A Prime) was calculated for each period of watch. *A'* is a metric used in signal detection theory to measure perceptual sensitivity (Stanislaw & Todorov, 1999). Also for each individual, the reaction time to each correctly detected target was averaged for each period of watch. Average reaction times for each participant for each period of were then subjected to a $\log_{10}$ transformation, as recommended by Maxwell and Delaney (2004) regarding treatment of reaction times during such tasks. A 3 (shape: circle, broken, and reconnected) by 16 (periods of watch) repeated measures ANOVA with orthogonal polynomial contrasts was performed for each of the above metrics (Keppel & Zedeck, 2001; Ross et al., 2014; Ruxton & Beauchamp, 2008). Orthogonal contrasts are more a powerful statistical test compared to repeated-measures

ANOVA, which is the more commonly used statistical analysis method in vigilance research (Rosenthal & Rosnow, 1985; Rosnow & Rosenthal, 1996; Rosenthal, Rosnow & Rubin, 2000). Such tests avoid problems related to the assumption of sphericity and are a direct test of trend differences (changes over periods of watch) between conditions. This allows direct tests for specific trends of interest. For the pre-planned orthogonal polynomial contrasts we limited the contrasts to the linear and quadratic trends. In keeping consistency with other experiments presented in this thesis, both the trend analyses and the more commonly used repeated measures ANOVA results are reported.

Hit Proportions

In the case of hit proportions, there were no significant linear trends, $F(1, 42) = .23$, $p = .637$, $\eta_p^2 = .005$, or quadratic trends, $F(1, 42) = 3.72$, $p = .060$, $\eta_p^2 = .081$, for periods of watch. Nor were there any significant period by shape linear, $F(2, 42) = .12$, $p = .891$, $\eta_p^2 = .005$, or quadratic trends, $F(2, 42) = .68$, $p = .511$, $\eta_p^2 = .031$. There was, however, a significant main effect for shape, $F(2, 42) = 10.14$, $p = .000$, $\eta_p^2 = .326$. Similar to analysis in Chapter 3, a series of planned comparison analyses were performed. This revealed a significant difference between the combined circle and reconnected groups versus the broken group, $F(1, 42) = 20.27$, $p = .000$, $\eta_p^2 = .325$. There were no significant differences between the circle and reconnected conditions alone, $F(1, 42) = .00$, $p = .956$, $\eta_p^2 = .023$. Hit proportions are displayed in Figure 6.2.

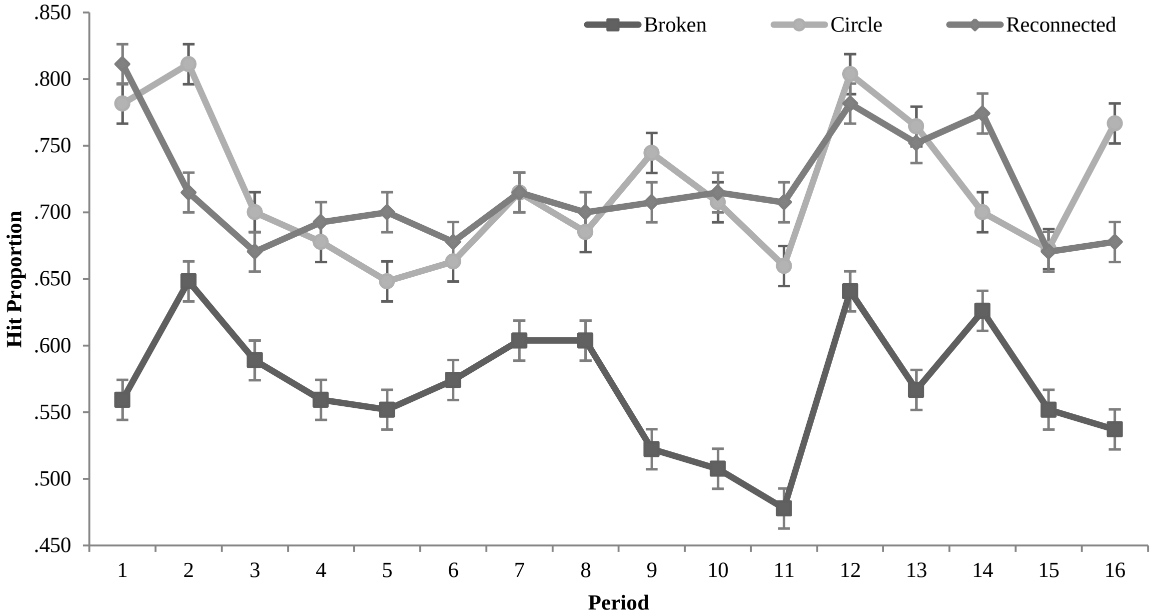


Figure 6.2. Mean proportions of hits over 16 periods of watch. Error bars depict standard error.

False Alarms

For false alarm proportions, there was a significant linear trend, $F(1, 42) = 30.41$, $p = .000$, $\eta_p^2 = .420$, and significant quadratic trend, $F(1, 42) = 17.42$, $p = .000$, $\eta_p^2 = .293$, for time on task, with false alarms decreasing over time. There were no significant shape by period linear, $F(1, 42) = .12$, $p = .891$, $\eta_p^2 = .006$, or quadratic interaction trends found, $F(1, 42) = 1.04$, $p = .362$, $\eta_p^2 = .047$. Additionally, there was no significant main effect for shape, $F(2, 42) = 1.47$, $p = .241$, $\eta_p^2 = .065$. Mean proportion of false alarms are presented in Figure 6.3. All conditions exhibit a decrease in false alarms over time, with little difference between shapes. It is important to note that overall the false alarm rate was low in all groups ($M = .024$).

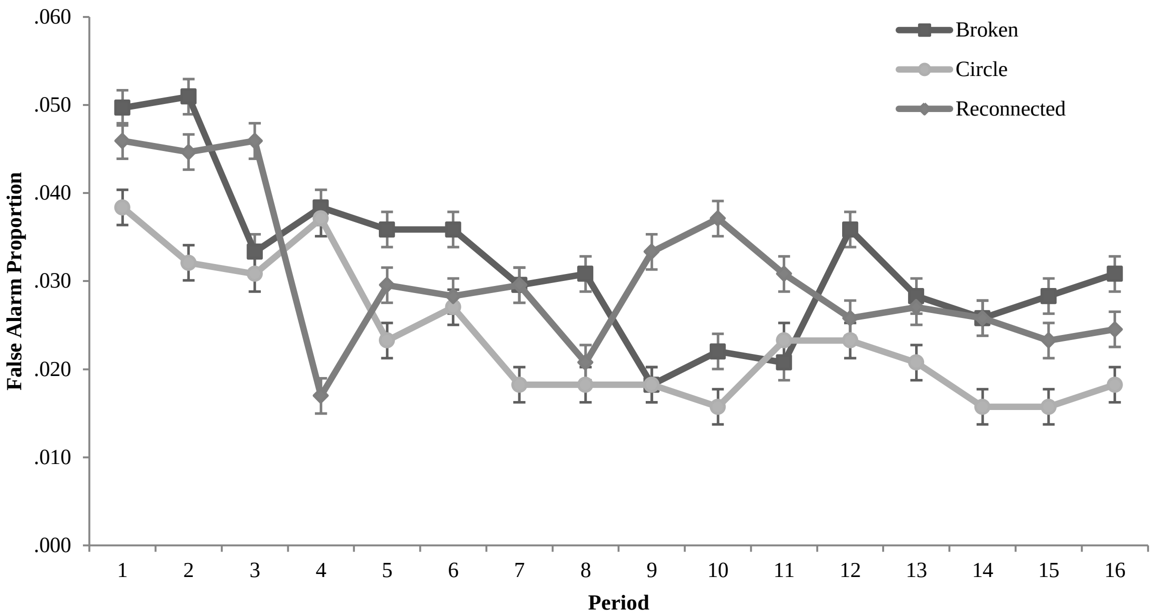


Figure 6.3. Mean proportions of false alarms over 16 periods of watch. Error bars depict standard error.

A' Scores

In the case of *A′* scores, there was no significant linear trend, $F(1, 42) = .58$, $p = .450$, $\eta_p{}^2 = .014$, or quadratic trend, $F(1, 42) = .98$, $p = .329$, $\eta_p{}^2 = .023$, for period of watch. Nor were there any shape by period linear, $F(2, 42) = .02$, $p = .985$, $\eta_p{}^2 = .001$, or quadratic trends, $F(2, 42) = .86$, $p = .429$, $\eta_p{}^2 = .040$. Similar to hit proportions, there was a significant main effect for shape, $F(2, 42) = 10.20$, $p = .000$, $\eta_p{}^2 = .327$. Similar to analysis for hit proportions, a series of pre-planned orthogonal comparison analyses were performed. These revealed a significant difference between the combined circle and reconnected groups versus the broken group, $F(1, 42) = 20.27$, $p = .000$, $\eta_p{}^2 = .326$, with the combined circle and reconnected groups showing greater target sensitivity. There was no significant difference in target sensitivity between between the circle and reconnected conditions, $F(1, 42) = .14$, $p = .715$, $\eta_p{}^2 = .023$. Mean *A′* scores are presented in Figure 6.4.

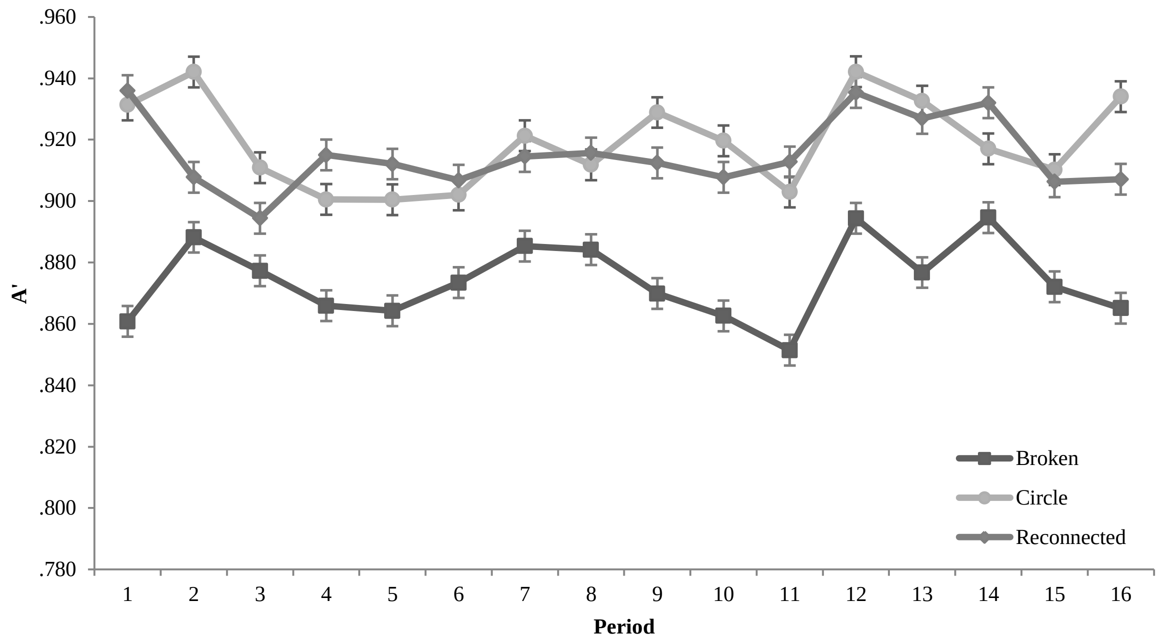


Figure 6.4. Mean *A'* scores over 16 periods of watch. Error bars depict standard error.

Reaction Times

For the $\log_{10}$ transformed reaction times, there was no significant linear trend, $F(1, 42) = 1.16$, $p = .29$, $\eta_p^2 = .027$, for periods of watch, however there was a significant quadratic trend, $F(1, 42) = 15.43$, $p = .000$, $\eta_p^2 = .269$. Here, reaction times increased initially overall, before becoming quicker in the later periods of watch. There was no period by shape linear trend, $F(2, 42) = .32$, $p = .727$, $\eta_p^2 = .015$, nor quadratic trend, $F(2, 42) = .51$, $p = .605$, $\eta_p^2 = .024$. The omnibus test revealed a significant main effect for shape, $F(2, 42) = 7.61$, $p = .002$, $\eta_p^2 = .266$. A series of pre-planned orthogonal contrasts were performed. This analysis revealed a significant difference between the combined circle and reconnected condition versus the broken condition, $F(1, 42) = 10.53$, $p = .002$, $\eta_p^2 = .200$. There was also a significant difference found between the circle and reconnected conditions, $F(1, 42) = 4.69$, $p = .036$, $\eta_p^2 = .100$, however there was no significant difference between the reconnected and broken conditions, $F(1, 42) = 2.98$, $p = .091$, $\eta_p^2 = .066$. A final contrast comparing the combined reconnected and broken conditions versus the circle condition revealed a significant difference, $F(1, 42) = 12.23$, $p = .001$, $\eta_p^2 = .226$. These results suggest the circle condition has the fastest reaction times overall, followed by the reconnected and broken conditions respectively. Mean $\log_{10}$ reaction times scores are presented in Figure 6.5.

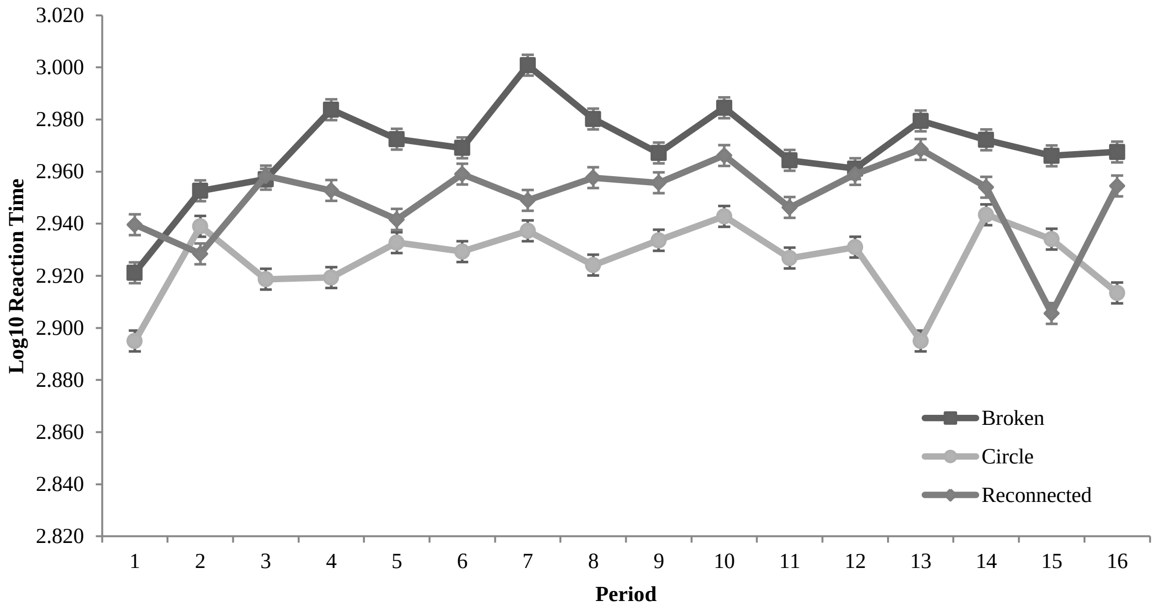


Figure 6.5. Mean Log10 reaction times over 16 periods of watch. Error bars depict standard error.

6.4.2. Physiology

In line with previous studies that have used fNIRS for vigilance research, a relative measure of regional oxygen saturation (rSO_2) was used during analyses (de Joux et al., 2013; Chapter 2; Helton et al., 2007; Yoshitani, Kawaguchi, Tatsumi, Kitaguchi, & Furuya, 2002). These scores are based on the percentage change relative to the individuals' resting baseline. A score of 0 indicates zero change from the baseline. These rSO_2 change scores were examined using a 3 (shape: circle, broken, and reconnected) x 2 (hemisphere: right or left) x 16 (period of watch) mixed between-within repeated measures ANOVA. Similar to performance scores, orthogonal polynomial contrasts were also employed to assess specific trends of interest.

Regarding total oxygenation, while there was no significant linear trend, $F(1, 42) = 3.33$, $p = .075$, $\eta_p^2 = .073$, there was a significant quadratic trend for period, $F(1, 42) = 30.81$, $p = .000$, $\eta_p^2 = .423$, with rSO_2 initially decreasing over the first four periods of watch before increasing over the final four periods of watch. This is shown in Figure 6.6. There were no significant differences between groups in regards to total oxygenation, nor were there any significant period by group effects.

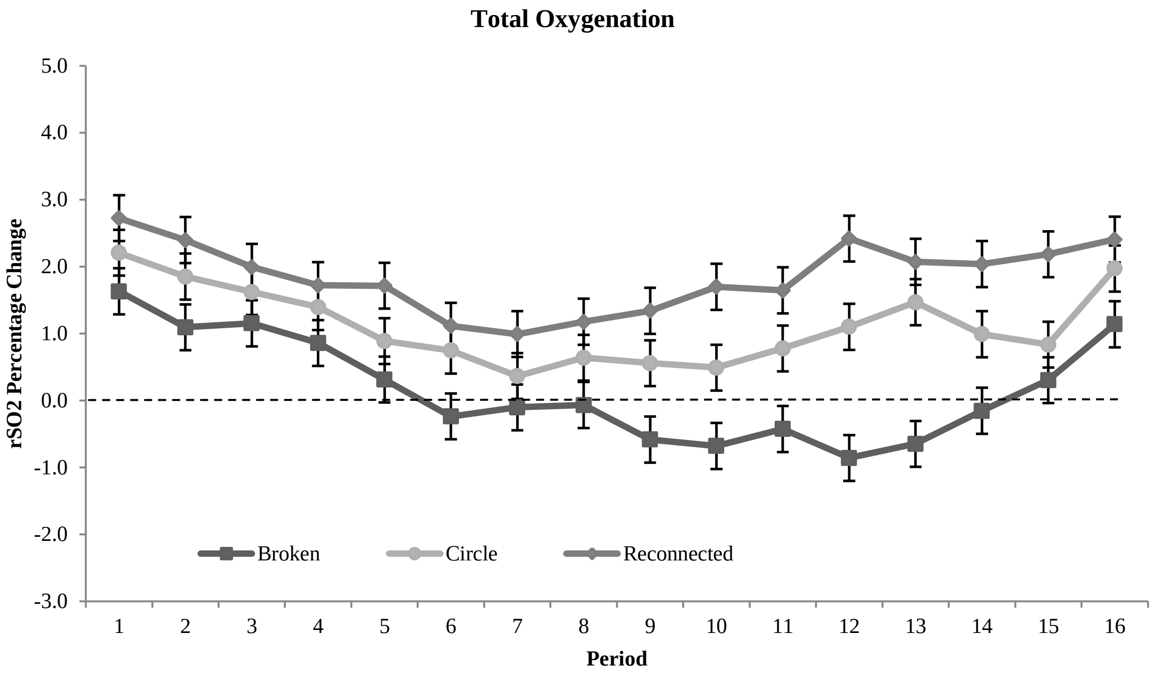


Figure 6.6. Mean percentage rSO2 change scores for total oxygenation in each condition over 16 periods of watch. The dashed line represents a change score of 0, or zero change. Error bars depict standard error.

There was a significant hemisphere difference, $F(1, 42) = 4.85$, $p = .033$, $\eta_p^2 = .104$, with the right hemisphere (total mean = 1.324) showing higher levels of oxygenation compared to the left hemisphere (total mean = 0.769). This is shown in Figure 6.7.

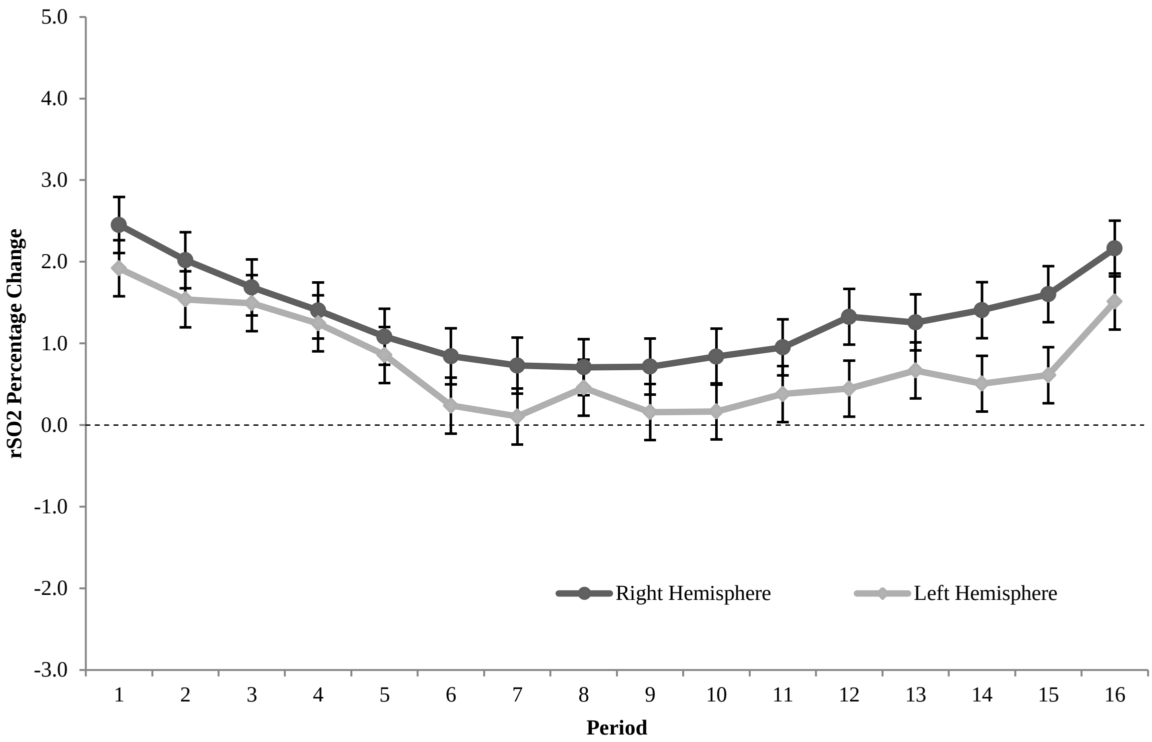


Figure 6.7. Mean percentage rSO2 change scores for total oxygenation of each hemisphere over 16 periods of watch. The dashed line represents a change score of 0, or zero change. Error bars depict standard error.

There was a significant period by hemisphere by group 3-way interaction, $F(30, 630) = 1.52$, $p = .038$, $\eta_p^2 = .068$. This appears to be a result of a deviant left hemisphere trend in the broken condition. Right hemisphere oxygenation reveals a similar trend across all groups. To further examine this 3-way interaction, each hemisphere was individually examined with a 3 (shape: circle, broken, and reconnected) by 16 (period of watch) repeated-measures ANOVA. For the right hemisphere, there was no significant main effect for group, $F(2, 42) = 2.65$, $p = .083$, $\eta_p^2 = .112$. There was a significant quadratic trend for period of watch, $F(1, 42) = 31.29$, $p = .000$, $\eta_p^2 = .427$. A decrease in rSO_2 was observed over the first half of the vigil, before an in rSO_2 occurs in the final half. There were no significant period by group linear trends, $F(2, 42) = .28$, $p = .762$, $\eta_p^2 = .013$, or quadratic trends, $F(2, 42) = .05$, $p = .951$, $\eta_p^2 = .002$. The right hemisphere rSO_2 percentage change scores are presented in Figure 6.8 (right side).

For the left hemisphere, there was no significant main effect for group $F(2, 42) = 1.27$, $p = .291$, $\eta_p^2 = .057$. There was, however, a significant linear trend, $F(1, 42) = 7.63$, $p = .008$, $\eta_p^2 = .154$, and a significant quadratic trend, $F(1, 42) = 20.29$, $p = .000$, $\eta_p^2 = .326$. There was also a significant period by group linear trend, $F(2, 42) = 4.34$, $p = .019$, $\eta_p^2 = .171$. The circle and reconnected conditions show a similar trend to that of the right hemisphere, with a decrease in rSO_2 was observed over the first half of the vigil, before an increase in rSO_2 occurs in the final half. For the broken condition however, the initial decrease in rSO_2 continues for a longer time into the latter periods of the vigil compared to the circle and reconnected groups. The left hemisphere rSO_2 percentage change scores are presented in Figure 6.8 (left side).

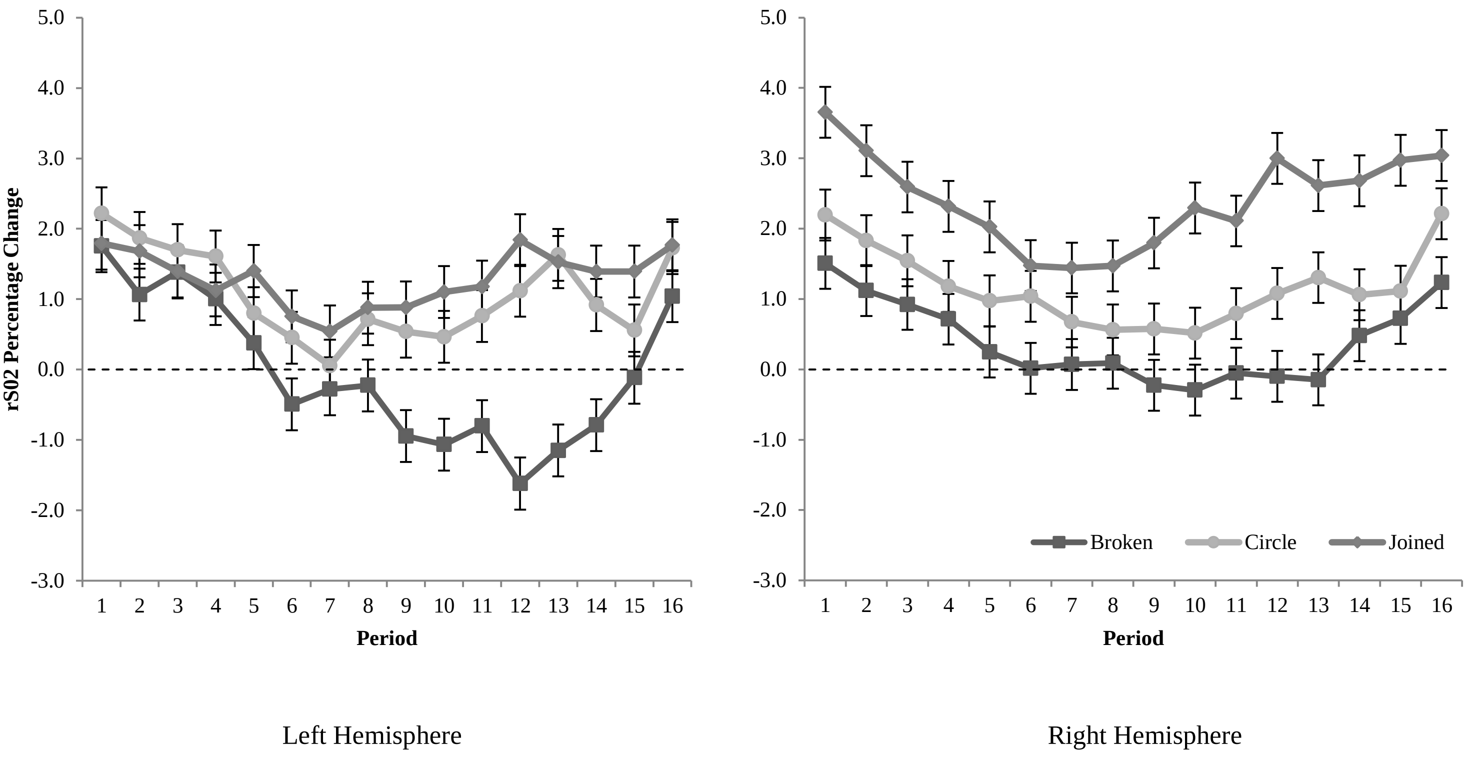


Figure 6.8. Mean percentage rSO2 change scores for the left hemisphere and right hemisphere for each group over 16 periods of watch. The dashed line represents a change score of 0, or zero change. Error bars depict standard error

6.4.3. Questionnaire

The self-report stress scale items were combined to form three factors of; fatigue/effort, task engagement, and mind wandering. The change scores of these three factors were then examined with a series of one-way ANOVAs to assess group differences. There were no significant differences between groups for either fatigue/effort, $F(2, 44) = .10$, $p = .909$, $\eta_p^2 = .005$, or mind wandering, $F(2, 44) = 1.34$, $p = .272$, $\eta_p^2 = .060$. There was a significant difference between groups for task engagement, $F(2, 44) = 4.71$, $p = .014$, $\eta_p^2 = .183$. Mean questionnaire scores for each group are shown in Figure 6.9.

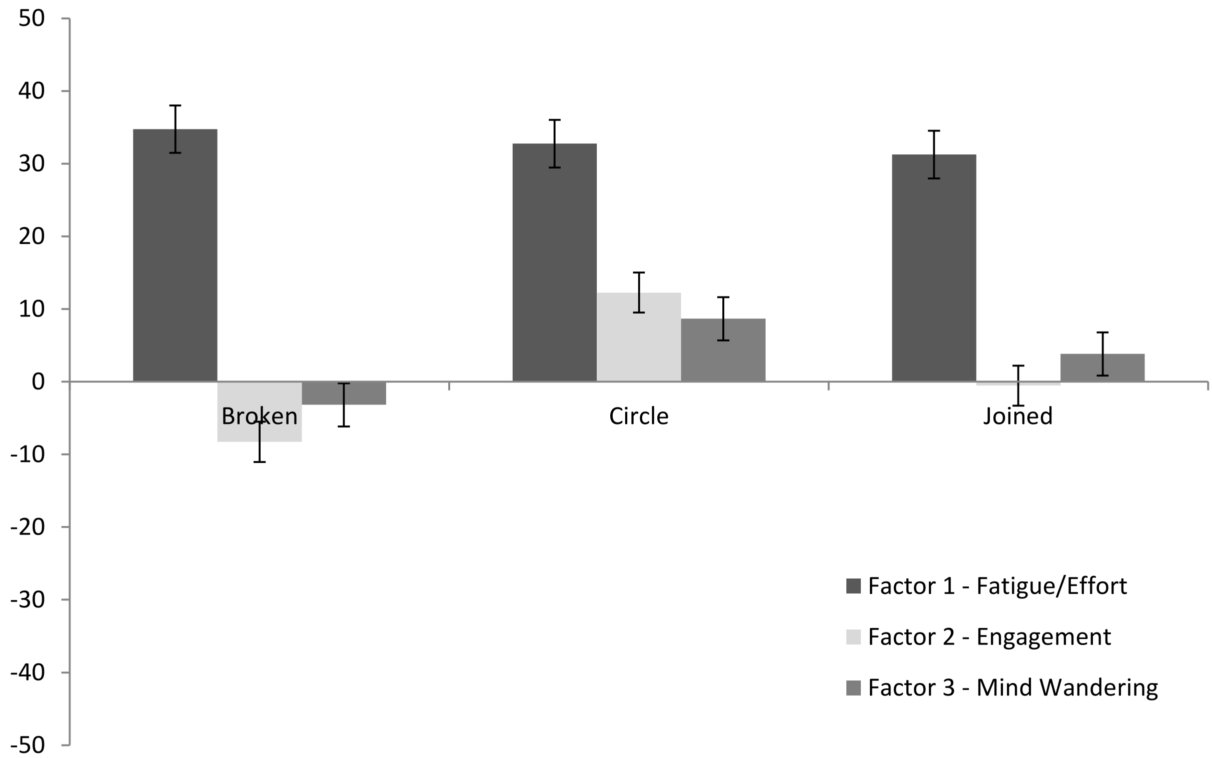


Figure 6.9. Mean questionnaire change scores for each factor for each group. Error bars depict standard error.

6.5. Discussion

It was hypothesized that the reconnected and circle conditions would show similar patterns of accuracy over time, as well as no significant differences in level of accuracy. It was also hypothesized that these two conditions would show a higher level of performance compared to the broken condition. Both of these hypothesized results were found in the current experiment, as evidenced by hit rate and *A'* trends over time. It was also hypothesized that none of the conditions would show a significant vigilance decrement. Consistent with the decrement hypothesis, no statistically significant decline in performance over periods of watch was detected. The group differences in accuracy, as well as the observed patterns over time, are extremely similar to those found in Chapter 3. The lack of difference between the circle and reconnected conditions, as well as the differences between these two conditions compared to the broken condition, supports the configural superiority effect in which objects that form a whole are processed more efficiently than those which do not (Pomerantz, Sager & Stoever, 1977; Pomerantz & Kubovy, 1986; Pomerantz & Pristach, 1989). The broken shape, having no discernible global aspect, made it more difficult for participants to allocate attention to the target locations, thus the lower accuracy. As stated, these results were hypothesized to occur.

For reaction time there were significant differences between the groups, with the circle group showing the quickest reaction times, followed by the reconnected condition, and the broken condition showing the fastest responses. There were no hypotheses pertaining to reaction time data because there were no reaction time differences between the three groups in the Chapter 3 and 4 experiments. However, in the current experiment a significant quadratic trend over periods of watch was found in which reaction times increased during the first half of the vigil before becoming quicker in the final periods. The group differences in reaction time may, however, provide additional support to the configural superiority hypothesis presented earlier. One possible cause of the reaction time differences between the circle and reconnected conditions is the spatial extension of the reconnected shape compared to the circle shape. The extended spatial information provides more information that is required to be processed before a decision is to be made. While the configural superiority effect influences performance in regards to target detection, this may come at the expense of speed with reconnected shape. The finding of significant reaction time differences in the current experiment, as opposed to that of Chapter 3 and 4, could possibly be attributed to the extended vigil length allowing more time for differences to become apparent, as well as greater power for the statistical tests.

The rSO_2 percentage change scores were characterised by a number of trends. First, there was a significant hemisphere difference, with the right hemisphere showing high levels of activation compared to the left hemisphere. This finding was hypothesized, as regardless of trend differences over time, the right hemisphere is typically found to be more activated during vigilance tasks (Parasuraman, Warm & See, 1998; Shaw et al., 2009; Stroobant & Vingerhoets, 2000; Warm, Matthews & Parasuraman, 2009).

Second, total oxygenation showed a significant quadratic trend, with rSO_2 initially decreasing before increasing in the latter periods of watch. Negative change from baseline is not entirely unexpected in vigilance research (Chapter 2; Hancock, 2015; Jeroski, Miller, Langhals & Tripp, 2014; Shaw et al., 2013), however a positive change from baseline is a more common finding (Bogler, Mehnert, Steinbrink & Haynes, 2014; de Joux et al., 2013; Derosière, Mandrick, Dray, Ward & Perrey, 2013). It has been suggested by researchers using similar tasks that negative rSO_2 percentage change over time is the result of a decrease in blood flow demand to those neural areas. This phenomenon can occur when total available resources are near maximum capacity levels; or when less cognitive function is required (Jeroski et al., 2014; Satterfield, Shaw & Finomore, 2014). An increase in cerebral oxygenation is in turn seen as the result of an increase in blood flow demand to these areas, a phenomenon that occurs when these areas are unable to match the required resource level. The trends observed of cerebral activation found in the current experiments could be interpreted as participants reaching a stable asymptote during the task. Resource theorists have proposed that vigilance tasks result in participants reaching a stable asymptote, or a point in which the cognitive resource demands of the task are matched by the resources replenishing (Humphreys & Revelle, 1984; Parasuraman & Giambra, 1991). This asymptote is also suspected to be the cause of the stable level of task performance found in all three conditions, as well as the stable accuracy found in Chapters 3 and 4. The decrease in cerebral oxygenation may be a representation of this asymptote being reached. The increase in oxygenation in the second half of the vigil may then represent the more typical trends found in vigilance tasks, due to the inability to maintain the required workload level. In other words, the quadratic trend may represent a "feeling out" process in which an appropriate level of output is matched, before a traditional oxygenation pattern brought about through resource-depletion is observed.

A third notable trend is the bilateral activation observed in the circle and reconnected conditions. It is possible to attribute the observed bilateral activation to task difficulty demands in the task, a similar observation made by Satterfield, Shaw and Finomore (2014) in a task measuring cerebral blood flow velocity. This possibility was also raised for previous experiments presented in this thesis. Subjective measures of workload appear to support this, as results indicate an increase in task effort/fatigue from baseline levels, indicating an increased workload. Some of the results found in the current experiment may not, however, quite fit with this explanation of task difficulty being the main cause of bilateral activation found here. Particularly, a period of watch by hemisphere by group interaction was observed, with a significant hemisphere by period effect being found in the broken condition, indicating hemisphere differences over time (i.e., increased right hemisphere activation compared to the left hemisphere). This is despite the broken condition being the most difficult of the three conditions by traditional objective measures (lowest hit rate, lowest *A'* score, longest reaction time). In contrast, the circle and reconnected conditions, which were the least difficult conditions by objective measures (high hit rates, high A' scores, quicker reaction time), showed bilateral activation and greater total activation overall. The task difficulty explanation should mean increased bilateral activation in the broken groups, and less in the reconnected and circle groups. Alternatively, the differences in hemisphere trends for the broken condition could be explained as a result of the requirement to recruit additional local processing resources above and beyond those of which are activated due to task difficulty, as well as increased expertise at processing local information. It is established that a decrease in blood flow is observed with expertise or practice (Anderson, 2000; Shaw, Satterfield, Ramirez & Finomore, 2013). The decrease in blood flow in the left hemisphere in the broken condition may be due to the increased level of local processing that is required with this shape (due to being local target shapes on multiple local objects). As local processing is more left hemisphere dominant (Lux et al., 2004; Yamaguchi, Yamagata, & Kobayashi, 2000), the decrease could be a reflection of increased practice and expertise of processing local information and shapes. The broken condition shows similar patterns to the circle and reconnected conditions in the initial phases of the task, and overall displays the same quadratic trend observed in these conditions (albeit not a significant one), however it is the final periods of the vigil in which the lateralization trend is observed. The right hemisphere in the broken condition does show a similar pattern to those found in the other groups; however the left hemisphere continues to show a decrease for a more extended period of time. This extended decrease over time is due to the requirement to engage in a greater amount of local processing compared to the circle and reconnected conditions, and the associated processing efficiency that comes with increased expertise. The hemisphere trends in the circle and reconnected groups may then be explained by the requirement to engage in near equal amounts of local and global feature processing. The local-global processing requirements explanation provides a better explain to the differences found in the current results compared to the solely task difficulty explanation.

The differences in bilateral activation trends between the circle/reconnected and broken conditions provides support to the suggestion that non-typical laterality profiles found in previous research using similar stimuli and tasks are influenced by local-global processing requirements, evoked by the configural properties of stimuli used in these tasks (Funke et al., 2010; Funke et al., 2012; Jeroski et al., 2014; Nelson et al., 2014; Shaw et al., 2013). The circle and reconnected shapes, both of which form configurative wholes, exhibit bilateral activation. In contrast the broken shape, which does not form a configurative whole, exhibits increased right hemisphere activation compared to the left hemisphere in the latter periods of the vigil. Although bilateral activation is a function of task difficulty (Helton et al., 2010), the laterality profiles found here cannot be solely attributed to task difficulty demands, due to these patterns of activation being found in the better performing conditions. It is also proposed that the differences in activation over time found in this experiment may explain performance differences found in previous experiments using these stimuli (Chapters 3, 4 and 5). This suggests that the differences found in these chapters are predominantly due to local-global feature discrimination rather than associated difficulty. These findings may be of use to researchers who are investigating hemodynamic activity during vigilance tasks and do not find typical laterality profiles, given that certain stimuli may evoke the need for processing of local-global objects. These findings may also be of use to researchers who are seeking to use more complex or novel stimuli in vigilance tasks, as local-global processing requirements may cause significant effects via influencing bilateral activation trends over time.

Chapter 7

7.1. Overview of Experiments

7.1.1. Chapter 2

Chapter 2 investigated the effects that a transition between local and global processing had on vigilance performance. Performance data indicated that a transition resulted in the lessening of the vigilance decrement compared to the no-transition conditions, although the transition conditions did show worse performance overall. A local precedence effect, where local discrimination tasks showed superior performance compared to global discrimination tasks, was also found. This further supports previous research in the area of local-global feature discrimination during sustained attention. Cerebral hemodynamic response in the prefrontal cortex was recorded during the vigil using Functional Near-Infrared Spectroscopy. Increased bilateral activation was found in the transition tasks compared to the no-transition tasks. Combined with corresponding performance data the results provide further evidence to suggestions from previous investigations that local-global feature discrimination result in performance and physiological differences over time.

7.1.2. Chapter 3

Chapter 3 extended investigations into local-global feature discrimination by employing more complex stimuli that had local and global feature elements. The stimuli bore resemblance to a previous investigation by Funke et al. (2010); an investigation where the typical right hemisphere lateralization effect was not found during the vigilance task. The primary goal of this experiment was to determine whether the non-typical laterality profiles may have been influenced by the requirement to engage in local-global processing. This experiment established a behavioural base before employing a measure of hemodynamic activation in a later experiment (Chapter 6). The results lead to the suggestion that a configural superiority effect influenced performance, given the superior accuracy found in the conditions that form a configurative whole compared to the condition that did not. Additionally, given the lack of a vigilance decrement over time, the results provided some support for the suggestion that increased bilateral activation (whether a function of task difficulty or local-global processing) may be associated with performance benefits over time.

7.1.3. Chapter 4

The main aim of the experiment reported in this chapter was to further examine the configural superiority effect found in Chapter 3, as well as the effects that the dynamic presentation of stimuli may have on the perception of a coherent global form. Dynamic presentation of has been found in the past to evoke motion processing. It was found that one of the conditions that formed a full and completed object (reconnected) was adversely affected when presented dynamically compared to its stationary counterpart in Chapter 3. It was also found that motion processing aided the perception of a coherent global form in the condition that did not form a full and completed shape (broken). This caused a reversal of the Chapter 3 findings regarding overall group performance between these two conditions. The results of the broken group are interpreted as supporting the “motion streaks” theory, where moving objects leave residual neural activity that aids motion processing. The findings were interpreted as supporting the configural superiority effect observed in Chapter 3.

7.1.4. Chapter 5

Chapter 5 investigated the effects of a transition between two objects with different configural properties. This experiment combined elements of Chapter 2 (transition between simple objects requiring local-global processing) and Chapter 3 (more complex objects with more levels of local-global information). One of the aims of this experiment was to form a link between these investigations, given that Chapter 2 used different stimuli compared to the remaining investigations. Group differences similar to those observed in Chapters 3, 4 and 6 were found; providing further support to the configural superiority effect explanation of task performance with this stimulus set. It was also found that, while transition effects did exist, they were small in comparison with the stronger effects of configuration type (circle, broken and reconnected). These findings are similar to those from Chapter 2 using less complex stimuli where a transition was performed.

7.1.5. Chapter 6

Chapter 6 examined cerebral hemodynamic response in the prefrontal cortex during a vigilance task using the configural stimuli employed in Chapters 3, 4 and 5. The main aim of this experiment was to examine bilateral activation differences during the task, which was foreshadowed as a possible explanation for performance differences found in previous experiments. Another aim of the investigation was to examine why non-typical laterality profiles have been found in previous experiments using a similar stimulus set (i.e. higher levels of left hemisphere activation than expected). Performance differences between groups, as well as group trends over time, matched those found in Chapter 3. Additionally, reaction time differences between groups were found, with the circle group having faster reaction times compared to the reconnected and broken groups. While this finding was not expected, given the lack of reaction time group differences found in Chapter 3, it does fit with the configural superiority explanation of results. Hemodynamic response revealed increased bilateral activation in the two conditions that formed a configurative whole, similar to the non-typical laterality profiles found in the previous experiments using similar stimuli. However, hemispheric differences were found in the condition that did not form a full gestalt, where the right hemisphere showed significantly higher levels of activation compared to the left hemisphere, as well as a different trend over time (quadratic vs linear). This finding further supports the argument that the non-typical laterality profiles found previous experiments may be due to increased local-global processing. It also provides evidence that the differences found in Chapters 3, 4 and 5 may be due to the recruitment of cognitive resources from separate resource pools as a result of local-global processing requirements.

7.2. General Discussion

The combined results of the five experiments presented in this thesis provide strong support for the argument that the local-global configurations of stimuli used in visual vigilance tasks have significant effects on the vigilance decrement and the associated cerebral activation. As described in Chapter 1, the effects of local-global feature discrimination during vigilance tasks have been relatively under-examined. Moreover, the investigations that have been performed in this area have focussed mainly on simple local-global objects. The experiment presented in Chapter 2 also uses simple local-global objects, and again it is found that local feature discrimination is advantageous under vigilance conditions. However, findings in later chapters using stimuli that vary in the degree to which they form whole objects suggest that this effect may not extend to more complex stimuli with multiple levels of local components. When multiple levels of local and global features are present, it appears that other perceptual processes may come into effect; specifically, the configural superiority effect. This effect appears to be influential across all experiments that used the more complex stimuli. Given that the configural superiority effect is founded on the principle that objects which form a full and coherent global shape are more readily processed, these results further illustrate the importance of local-global configurations of objects in vigilance tasks. This also suggests that some caution may need to be taken when assessing the impact of local-global features during tasks. Local-global feature discrimination tasks, when using simple objects, show superior performance for local discrimination. This does not mean that increasing the amount of local discrimination required will always result in improved performance however, given the findings presented in chapters 3 to 6 when using more complex local-global based stimuli. Further manipulation of local-global discrimination with complex stimuli is needed to determine the point at which local feature discrimination induces performance impairment. In other words, at what point is there too much of a requirement to engage in local feature processing. Additionally, further investigations as to the nature of the configural superiority effect during vigilance tasks should be undertaken. As presented in Chapter 4, the rotation of the broken and reconnected shapes resulted in a reversal of the group differences that were found when these objects were presented in a stationary manner. This is interpreted as the broken shape becoming more coherently organized, while the reconnected shape became less coherently organized. If coherent organization is influencing performance under these conditions, then perhaps different organizations of the global figure which result in unusual yet complete configurations could yield different findings. For example, such investigations could examine whether the configural superiority effect influences performance for a cross-like shape; a complete global figure, yet unlike the stimuli used here does not result in an enclosed loop. These investigations would likely require the assessment of search strategies during the task, an area which has not been a main point of focus for the current research.

A further point of interest from two of the experiments presented in this thesis are the bilateral activation patterns observed during the tasks, particular in the experiment presented in Chapter 6. This experiment showed higher levels of bilateral activation compared to those traditionally found in sustained attention tasks, specifically in the two tasks where a coherent global object is present. Along with providing a possible explanation to the unexpected laterality findings of similar experiments (Funke et al., 2010; 2012; Nelson et al., 2014; Jeroski et al., 2014), the findings of this experiment suggest a neural correlate with the configural superiority effect and the associated behaviour patterns. Given that these trends are similar to those found in experiments using simple local-global features, specifically Chapter 2 and de Joux et al. (2013), it is suggested that these more complex objects are indeed recruiting similar resources during these tasks that are recruited during simple local-global paradigms. The finding of the bilateral activation profiles in the full gestalt shapes, and the right hemisphere bias in the incomplete shape, is particularly noteworthy as it provides a possible explanation to the laterality profiles observed by Funke and associates. If the bilateral activation was more a function of task difficulty, as has been noted in previous research (Helton et al., 2010), it would be fair to assume that the broken group in Chapter 6 would show no differences in hemisphere trends over periods of watch. By all performance metrics however, the broken object is the more difficult task presented in the experiment. The hemisphere group and trend differences found in the broken condition are better explained by the increased requirement to engage in local-feature processing, which results in decreased blood flow in the left prefrontal cortex compared to the right as participants become more adept at processing local information. The circle and reconnected groups do not gain this expertise throughout the task, hence maintaining similar hemispheric trends throughout the vigil. This finding further illustrates that local-global feature processing is influential during vigilance tasks.

As mentioned in the introduction, it was not a goal of these investigations to debate the nature of the resources suggested within the resource theory of vigilance (i.e. a unitary resource pool versus multiple resource pools). However, the differences found between local and global feature discrimination during Chapter 2, and the increased bilateral activation found in Chapter 6, may lend more support towards the suggestion that multiple resource pools are present. Unitary resource theory may be able to explain the overall hemisphere differences and hemispheric trends found in the broken group in Chapter 6, given that these differences occurred in the hardest condition; unitary resource theory proponents may suggest that differences in activation between hemispheres over time are due to task difficulty effects. However, a unitary resource perspective may find difficulty in explaining the increased bilateral activation in the two less taxing conditions. It would also be more difficult to explain local-global differences found in Chapter 2, given the aforementioned suggestion that different discrimination types recruit from separated resource pools across hemispheres. A multiple resource theory perspective more readily explains the differences in Chapter 2 for the above reason, and may explain the increased left hemisphere activation and similar hemisphere trends in Chapter 6 as a result of the requirement to recruit both local processing and global processing resource pools. Therefore, the suggestion is that these findings may be more indicative that nature of the 'resources' suggested within resource theory is that of multiple pools rather than a unitary one. It should be noted that these hemispheric differences relate only to prefrontal cortex activation. It is possible that other areas of the brain may be active during the tasks, which may result in the prefrontal cortex laterality findings here. Further research investigating this possibility may be needed to determine whether these hemisphere trends are broad, or confined only to the prefrontal cortex regions.

The finding of similarities between simple and complex local-global objects is important to note, given one of the potential limitations of this series of experiments; that the stimuli used in Chapters 3, 4, 5 and 6 may be evoking another process other than local-global processing. While local-global processing can be more clearly observed when using simple objects, both in previous experiments and in Chapter 2, the complexity of the objects used in the later experiments in this thesis could be seen to be evoking alternative processes. Specifically, it is not entirely clear whether the configural superiority effect is due to local-global processing or another perceptual process. The Chapter 5 experiment was partially designed with the goal of bridging this gap, and behavioural similarities are observed. Given the somewhat similar transition effects between Chapters 2 and 5, and the similar cerebral activation profiles between Chapters 2 and 6, there may be some indication that similar processes are evoked during the tasks with more complex objects. This may be a potential area for future researchers, as presumably stimuli with increased complexity would begin to evoke other perceptual processes beyond that of local-global processing (such as object recognition and feature integration). This is observed in Chapter 4, where the addition of motion processing is found to improve the perception of a coherent global figure in the broken condition.

7.3. Concluding Statement

The purpose of this thesis was to perform a series of experiments which systematically and empirically investigated the potential impact that local-global feature processing may have on sustained attention performance and cerebral activation; an area which has not received a large amount of dedicated research. Each chapter serves as an individual experiment presented as a separate journal article, with each chapter providing its own contribution to the general body of knowledge on sustained attention. Each chapter is linked to the wider, over-arching theme of local-global processing or configurative element processing during vigilance tasks. Although the work reported is not able to provide a definitive conclusion to all aspects of how these additional processing demands influence vigilance performance over time, it does provide a foundation for future research. It also provides a number of considerations for future researchers who may be seeking to employ complex or unusual stimuli in their own investigations during vigilance tasks. In particular, researchers will need to be aware that more complex stimuli will evoke local-global processing during a vigilance task, which in turn lessens the impact of the vigilance decrement. Additionally, the research provides insight as to why some vigilance tasks may result in non-typical laterality profiles; a potentially valuable finding for vigilance researchers.

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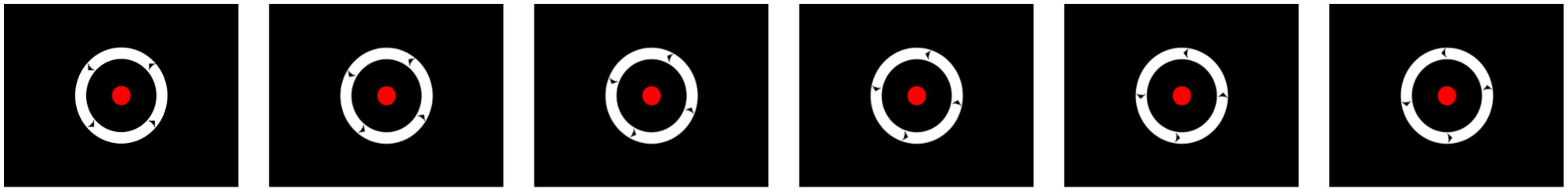
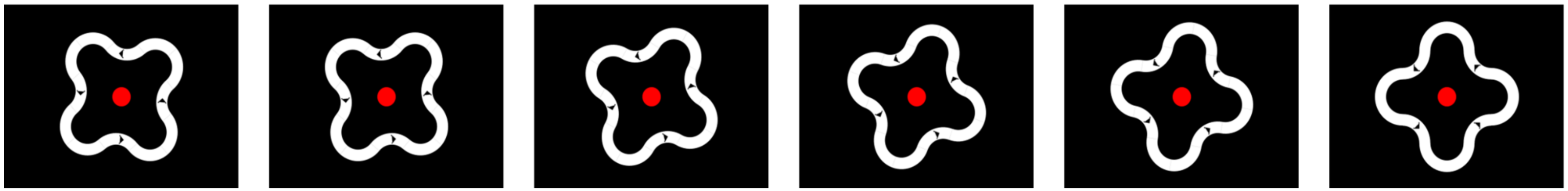
Appendix A – Examples of stimuli used in Chapter 4.

Broken

Circle



Reconnected



Appendix B. Questionnaire used in Chapter 6.

MALE or FEMALE (circle one) Age: ____________________

For the following items use the response scale below the item by circling the vertical line closest to your answer; the scale goes from 0 (**very low**) to 100 (**very high**). These questions refer to you experience during the task.

1. **Physical Fatigue** – How physically exhausted and tired did you feel?

0 25 50 75 100

2. **Mental Fatigue** – How mentally exhausted and tired did you feel?

0 25 50 75 100

3. **Tense** – How tense or anxious did you feel?

0 25 50 75 100

4. **Unhappy** – How unhappy did you feel?

0 25 50 75 100

5. **Motivation** – How motivated were you to do well?

0 25 50 75 100

6. **Task Interest** – How interesting was the task?

0 25 50 75 100

7. **Self Related Thoughts** - How much did you think about yourself?

0 25 50 75 100

8. **Concentration** – How focused on the task were you?

0 25 50 75 100

9. **Confidence** – How confident were you during the task?

0 25 50 75 100

10. **Task Related Thoughts** - How much did you think about the task?

0 25 50 75 100

11. **Task Unrelated Thoughts** – How much did you think about something other than the task?

0 25 50 75 100