The effect of cognitive fatigue on an individual's divided spatial attention

Name: Blaithin Lynch

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Supervisor: Dr. John Hyland

Head of Department: Dr. Sinead Eccles

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Department of Psychology

DBS School of Arts

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Index

Abstract

The effect of experimentally induced cognitive fatigue on divided spatial attention was assessed on a convenience sample of 30 participants, who participated in a dual attention/observation task. Participants were randomly assigned to an "Observer" (Obs) or a "Stimulus Provider" (SP) group. Both groups completed a computerised attention task. The SP group received audio cues to look left, middle or right. The Obs group were asked to note the time and direction they observed the SP group move their head while completing the task. Mental fatigue was induced by the experimental duration (two 25 minute trials). It was hypothesised that as mental fatigue increased, a greater number of errors in one or both of the cognitive tasks would occur, with a corresponding decrease in reaction times. Analysis of these results and their implications in the understanding of the role fatigue in dual-tasking will be discussed with regard to theory and application.

1. Introduction

What is attention? What constitutes a person applying attention to a stimulus or not? Psychological literature does not present a united opinion on the precise definition or concept of "attention". For some, such as William James (1890) it is the application of cognitive resources onto one stimulus, and in doing so, the withdrawal of cognitive resources from other stimuli (Styles, 2006), whereby the "focalisation, concentration, of consciousness are of its essence" (James, 1890, p. 404). Furthermore, attention may be active or passive, focussed or divided. Active attention is top-down processing of stimuli whereby the reaction to a stimulus is controlled by cortical areas such as the frontal and parietal lobes. These will be discussed in more detail below. Bottom-up processing is involved in passive attention, where the external stimulus causes an exogenous reaction to a person's nervous system which then communicates same via afferent neuronal networks to the central nervous system where a "decision" is made as to how to respond to the stimulus. When speaking of any action such as that outlined above, these actions are normally goal-driven and occur as endogenously or exogenously driven reactions to an internal or an external stimulus respectively (Keller Wascher, Prinz, Waszak, Kock, & Rosenbaum, 2006).

Early theories on focussed and divided attention outlined that both employed similar strategies for attending to presented stimuli. Hampson (1989) reported that the processes associated with focused and divided attention are more similar that previously thought. He did however note that task similarity within a divided attention task did result in a greater error rate and therefore that dissimilarity of tasks was the key to divided attention success.

Divided attention is defined as the ability to attend to two tasks simultaneously. Whether or not one can effectively do this is an issue debated in the literature and will be examined as part of this study. In order to attend to two stimuli effectively often depends on how different the stimuli are (Eysenck & Keane 2005). Hampson (1989) reported that errors made with divided attention are due to interference caused by the stimuli being presented in relatively similar modalities (e.g. both being a visual or an auditory stimulus). When dual-task completion relies on the same central executive processor, then a break-down in task completion occurs. Theorists believe the ability to effectively and accurately complete a dual-task relies on different cognitive processors being employed (Eysenck & Keane, 2005). For this to occur however, there must be a sufficient difference in task stimulus modality in order to ensure that two different modality processors are used.

1.1 *Traditional and current theories on divided attention*

The early theories concerned with divided attention, such as filter theory, proposed that only one processing channel was available to perceive one external stimulus at one time. Theories such as this placed an emphasis on a central executive which integrated top down and bottom up efferent and afferent information respectively in order to recognise and react to the stimulus. Each stimulus had to be processed independent of the other through a “sharing” of this cognitive filter.

Allport, Antonis and Reynolds (1972) disputed this theory of a single channel for processing stimuli. They asked experienced keyboard players to play the piano, sight read an unfamiliar piece of music and recite prose at a rate of 150 words per minute. The results from this complicated multi-task experiment showed that participants were capable of completing the tasks at a similar rate when combined together or singularly, thus questioning the existence of a single processing channel. Broadbent (1982) did critique this experiment, highlighting the fact that the tasks chosen by Allport et al did not require the participants to function at their perceptual limits for each of the tasks, thus possibly allowing some resource sharing during the trials. However, it did evoke interest in the topic and the development of alternative theories.

Theorist such as Broadbent have proposed a “bottleneck” metaphor to describe how a “general purpose, limited capacity, central processor” can process only one type of material at one time, but that stimuli requiring different lines of processing may be processed alongside one another (Styles, 2006, p. 154). However this theory is similar to the early filter theory which Broadbent concurred was not sufficient to explain how a person can divided their cognitive resources to attend to more than one task simultaneously.

Current theories resemble those of focussed attention theories such as the “spot light” or “zoom lens” theories, with the difference being in the shift of attention from one stimulus to another within a “divided attention” task. These theories appear to be more accommodating with current cognitive scientific empirical findings, however they are not without their discrepancies. Initially focussed attention was thought to be similar to a spot light, whereby cognitive resources are focussed on the stimulus in question (Eysenck & Keane, 2005). Erikson and St. James (1986) put forward a more intricate theory in relation to this called the “zoom lens” theory. This theory hypothesised that attention is directed towards a stimulus within a region of their visual field. However, this area can be increased or decreased depending on the demands of the task. This has provided the basis for hypotheses that divided attention is possible, once the different stimuli being attended to are within the same visual field.

However, as outlined by Jans, Peters and De Weerd (2010) the theory of divided spatial attention (in this case) is not unlike that of the biased competition model of attention (Desimone & Duncan, 1995). If the above example is taken, that a divided attention task is one in which two stimuli are attended to within the same visual field, then the biased competition model of attention may also function in this regard. “Competition” refers to the influence each stimulus has individually on the neuronal mechanisms within the receptive field. When this occurs, the influence of each stimulus is averaged and are not processed within any of the higher visual system levels. When attention is added to this scenario, attention is usually focussed on one of the competing stimuli and this stimulus will be processed to a greater degree than the other. According to this model and to that of divided spatial attention, Jans et al (2010) propose that it is not possible to provide equal attentional weight to both stimuli within the same visual field, therefore one is attended to more so than the other.

1.2 *Task Similarity*

As mentioned above, task similarity can have a negative effect on a person's ability to successfully complete a task that requires a level of divided attention. Task similarity may be the similarity of the presented modality (e.g. visual or auditory) and/or the similarity between the presented modality and the way in which it is recorded. For example, there may be greater interference in an attention task which involves observing two different stimuli and writing down the results than in one in which two different stimuli are observed and the response is verbalised (Treisman & Davis, 1973; McLeod, 1977). This is as a result of stimuli with similar presentation modes competing for the same cognitive resources involved in their processing and encoding. The rate which errors occur during these dual-attention tasks with similar delivery stimulus modalities depends on the combined cognitive cost on available resources. The tasks are viewed as being "time-shared" (similar to filter theory or the bottleneck theory) whereby the cognitive cost is shared between both stimuli, but is greater than if the stimuli were presented individually to the person (Stephan, Koch, Hendler & Huestegge, 2012).

As outlined above, task similarity and similarity of task recording can effect the accuracy of dual-attention tasks. Hazeltine, Ruthruff and Remington (2006) conducted an experiment showing how similarities in stimuli modality recording interfered with the accuracy of the tasks. Their study involved the pairing of 4 different tasks: visual-vocal (VV – spoke the words they saw on screen), visual-manual (VM – pressed a button in response to a screen stimulus), auditory-vocal (AV – said the words out loud that they heard) and auditory-manual

(AM – pressed a button in response to words they heard). Hazeltine et al (2006) found that less errors were made within the VM and AV groups than within the VV and AM groups. They explained these findings as being due to “preferred modality-specific S-R processing pathways” (Stephan et al, 2012, p. 90). Due to evolutionary practice, humans have learned to respond to certain stimuli in certain ways, resulting in natural responses to stimuli which do not deplete resources as much (e.g. verbalising a word just heard) as unnatural responses (pressing a button in response to a word just heard).

Another way to describe the interference caused by unnatural response characteristics is “ideomotor compatibility” (Greenwald, 1977). This theory proposes that actions to stimuli are coded in respect of the “anticipated mental image of the sensory feedback of the response” (Stephan et al, 2010, p. 91) and that this coding affects the dual-task cognitive costs. Therefore unnatural responses or pairings of tasks in a dual-task setting (e.g the AM task above) cause a certain degree of cognitive dissonance which requires a greater amount of resources to resolve this dissonance, resulting in a greater error rate, reduced reaction times etc.

1.3 *Task difficulty*

In order to accurately assess a person’s ability to perform a dual-task and show evidence of divided spatial attention, Jans et al (2010) outline that both tasks should be sufficiently difficult in order to ensure that the participant is functioning at their upper level of “attentional capacity limitations”. They believe that this factor has been omitted from tradition divided attention experiments and therefore the validity of these experiments is questionable. Accurate definitions of what constitutes a difficult task are not universal due to the subjective nature of “difficult”. A difficult task may be one that employs skills that a participant may not be familiar with (e.g. use of a keyboard or having to use both hands simultaneously to complete a dual-task) or may be comprised of modalities that compete with each other for cognitive resources.

Practice and the role of learning can have an impact on a person’s ability to divide their attention appropriately with difficult tasks. Simple and difficult combined tasks have been found to be able to be completed simultaneously, once the participants have practiced both tasks sufficiently so that their completion appears to become almost automatic (Hazeltine, Teague & Ivory, 2000; Schumacher, Seymour, Glass, Fencsik, Lauber, Kieras. Meyer, 2001). How a participant’s ability to complete such tasks with practice may be due to their development of more cognitively efficient processing strategies in order to reduce the level of resources required to attend to the stimuli (Eysenck & Keane, 2005).

1.4 *Task duration and subjective cognitive fatigue*

Prolonged maintained cognitive effort has been shown to deplete cognitive resources and result in cognitive fatigue. In a study involving 251 students by Ackerman and Kanfer (2009), personality traits were found to be related to a person’s perceived ability to complete tasks of a prolonged duration and their subjective cognitive fatigue following these tasks. Neuroticism and negative affect were particularly implicated in this study. These traits effected participant’s perceived ability to complete modified, lengthened SAT examinations. Participants scoring high on negative affect and/or neuroticism reported higher levels of perceived cognitive fatigue at the end of the trial and those who scored high on mastery reported lower levels of cognitive fatigue. However, the SAT results of participants with higher scores on neuroticism/negative affect scales did not appear to be effected by this subjective feeling of fatigue when compared with the other participants. This led Ackerman and Kanfer to suggest that they had increased their cognitive effort in line with their fatigue and employed a coping strategy to complete the examinations.

The duration of the two tasks, task difficulty and degree of learning that comes with practice of the tasks also effect a person’s ability to divide their attention successfully.

1.5 *Cortical areas involved in dual-tasks*

In order for a person to complete a goal directed activity, such as stimulus driven reaction or attention task, mental representations of the required reaction to the stimulus must be activated (e.g. schemas). These are combined with reaction motor codes in order to activate an “action-effect representation” (Wascher et al, 2006) and carry out the required reaction to the presented stimulus.

Haggard, Aschersleben, Gehrke and Prinz’s (2002) experiment using a Libet clock paradigm (Libet, Gleason, Wright & Pearl, 1983) found that there was a cognitive connection between a stimulus and the response required when it’s presented and the response and its effect. These temporary connections allow appropriate responses to stimuli to occur. If, however, the associations behind these connections are stored in a person’s memory, they can influence reaction times in future trials (i.e. occurrence of “learning”).

Temporal connections such as this enable “predictive coding” of information, which may interfere with dual-attention tasks due to the negative feedback aspect of the model (Spratling, 2008). Spratling’s computer model of this showed how top-down processing of visual stimuli may be suppressed by bottom-up feedback. According to Spratling, higher level “predictor nodes” are activated at the early stage of cognitive processing of a stimulus. For example, a participant is asked to press a key in response to a particular visual stimulus. Their predictor nodes are activated and are now “predicting” when this stimulus will be shown. But the activity of these nodes is supressed by negative feedback from “error-detecting nodes” which coordinate feedback from both top-down and bottom-up receptors and communicates the residual error back to the predicting nodes. Spratling applied this model to divided attention. When two stimuli are located within the same visual field, both compete for the attention of the receptor nodes. According to biased competition models, attention will favour only one of the stimuli. This is seen in the cell response to both stimuli which reacts to that preferred stimulus as it would do if it were perceived in isolation. Perception of the other stimulus is suppressed due to this biased competition. Attention may be drawn to one of the stimuli due to its saliency (Eysenck & Keane, 2005, Horrey et al, 2006). However if this stimulus is not the one predicted by the predictor nodes, then an error will occur in the dual-attention task due to the incorrect suppression of perception of the stimulus of interest in the task.

EEG studies have found the presence of "readiness potentials", i.e. movement-related potentials that are recorded before an intended movement. These are slow, negative cortical potentials thought to be associated with the preparation and initiation of voluntary movements (Libet et al, 1983). Cortical areas involved in these voluntary movements include the dorsolateral and lateral prefrontal cortex, the anterior cingulate and the supplementary motor area (Deecke & Lang, 1990). Of the aforementioned areas, the lateral prefrontal cortex appears to be the most important cortical area for control of movement in stimulus-dependant situations (Wascher et al, 2006; Thut, Hauert, Viviani, Morand, Spinelli, Blanke, Landis, & Michel, 2000).

Visual information collected at the point of stimulus projection is transferred via the dorsal and ventral systems to the motor system in order to produce the required motor response associated with the visual stimulus. The dorsal and ventral pathways are discussed in more detail below. In actions such as this, cortical areas such as the inferior parietal cortex, ventral premotor cortex and the anterior intraparietal area are activated (Wascher et al, 2006). When several different reactions are required to a stimulus (i.e. a decision between reactions is required) then the ventral prefrontal cortex is also involved (Passingham, Toni & Rushworth, 2000). This area may, according to Wascher et al (2006) set up a form of "attentional template" to recognise stimuli that require a certain action.

The role of these areas of the brain in the co-ordination of divided spatial attention has been shown in studies of patients, for example, with Alzheimer's disease. Functional MRIs carried out on such patients have shown that areas such as the lateral prefrontal cortex and the anterior cingulate have reduced functioning in patients such as these, which impairs their ability to carry out dual-tasks requiring divided attention (Logie, Cocchini, Della Sala & Baddeley, 2004). Contrary to previous studies however, Logie et al (2004) did not find a significant negative association between age related effects and results on their dual-task.

1.6 *Focal and ambient vision in dual-attention tasks*

When conducting a dual-attention task, participants utilise different types of scanning techniques in order to maximise their accuracy (Horrey, Wickens & Consalus, 2006). Horrey et al (2006) reported that the eye itself acts as a filter in dual-attention tasks, as a "single-server queue", controlling the amount of information presented exogenously at one time. This would appear to agree with Jans et al's (2010) uncertainty as to whether effective dual-attention tasks are possible.

Focal and ambient vision are scanning techniques employed during dual-attention tasks (Leibowitz & Post, 1982; Previc, 1998). Focal vision is involved in visual search and object recognition. Its strengths are greatest located within the fovea and its use it closely linked to the movement of the eye (Horrey et at, 2006). Although not reported in Horrey et al's paper, due to the function of focal vision being object recognition, it may be linked with the ventral pathway of the occipitotemporal pathway of the brain (Wiediger & Fournier, 2008). Projections from the occipital lobe to the temporal lobe enable this pathway to recall a memory representation of the visual stimulus in order to identify it.

Ambient vision is required to orientate a visual stimulus to "earth-fixed space" (Horrey et al, 2006). It is also involved in postural control when one walks, runs etc. Ambient vision functions best when used on stimuli on the periphery of vision and can be used to identify objects, however it is not as precise at identification as fovea vision. Due to its function in stimulus orientation, ambient vision may also be associated with the dorsal occipitoparietal pathway which serves to locate a stimulus in space (Wiediger & Fournier, 2006). The parietal lobe also enables cognitive manipulation of visual stimuli, which is often required during reverse-presented object recognition tasks.

Studies have shown that there is some hemispheric dissociation with regards to the dorsal and ventral pathways, with the dorsal pathway being associated with the left hemisphere and the ventral with the right (Gonzalez, Ganel & Goodale, 2006). This would be apparent in brain injury studies whereby participants with left hemispheric injury would have difficulty in visuomotor tasks associated with the dorsal pathway.

The current study involves a dual-attention task which aims to utilise both focal (attention aspect of the task) and ambient vision (observation aspect of the task) and thus the ventral and dorsal pathways. Horrey et al (2006) reported that tasks involving stimulus identification (i.e. attention task) require greater cognitive resources and thus take longer to complete than those that simply detect a stimulus (observation task). However, the observation aspect of the current study also employs an identification aspect, therefore both pathways will be employed simultaneously. This concurrent use of both pathways addresses Jans et als (2010) critique that many dual-task studies do not use several cognitive resources at the one time. This study aims to do so.

1.7 *The effect of cognitive fatigue on divided attention*

Cognitive fatigue has been examined in occupations such as those associated with the military where sustained operation periods before and during active service affect sleep cycles and cause a high degree of cognitive stress on army personnel (Neri, Shappell & DeJohn, 1992). This form of cognitive fatigue has been shown to result in a reduction in performance level and a greater number of errors made, in particular errors of omission (Neri et al, 1992). The level of errors made has been found to be associated with the nature, complexity, level of required attention, and sustained duration of the tasks (Kreuger, 1991).

Neri et al (1992) conducted an experiment with 12 male US marines (aged 23 – 28 years). After a 6 day training period, the participants took part in a “generic performance assessment battery” of tests comprised of reaction time test, linguistic/symbol manipulation and spatial processing tests. The experimental design was based on an actual sustained operations period and therefore induced similar levels of cognitive fatigue in the participants. Reaction time tasks improved over the course of the experimental period and this was not associated with learning due to the 6 days of training preceding the experiment. However, there was a linear increase in error rate with the spatial processing tasks. Neri et al (1992) explained this as because the participants were in a highly aroused state, therefore had increased selective attention in dual-attention tasks, reduced working memory capacity, and although their reaction time increased, this resulted in an increased error rate. The experimenters also noticed that the participants were highly motivated and competitive. Results also supported the COPE model where the fatigued participants made more risky choices (quicker responses with a greater error rate). The Choice of Probability and Effort Model (COPE), where chance of probability is positively correlated with level of effort, can be applied to understand why cognitively/physically fatigued people employ strategies requiring the minimum amount of effort to complete a task, even if they are aware that the strategy may fail. Fatigue effects a person’s short term memory as well as their ability to make decisions, therefore the ability to think beyond the moment may be impaired.

1.8 *The current study*

The current study aims to examine the effect of fatigue on a divided spatial attention task employing both the ventral and dorsal perceptual pathways. It is hypothesised that participant's perceived level of subjective fatigue will be negatively correlated with attention task reaction times and the number of correct observations made. It is also hypothesised that participant's feelings of self-efficacy will be positively correlated with their attention task reaction times and number of correct observations made. Secondary hypotheses include that women will perform better in the attention and observation tasks than men, and a greater number of errors in the attention and observation tasks will be recorded as the trial progresses.

2. Method

2.1 *Participants*

Participants from a convenience sample were invited to participate. Recruitment involved advertisements on social networking sites (Facebook) and within the author's workplace, attending lectures within the college (with permission from the lecturer) outlining the experiment to the students and requesting them to volunteer. Snowball sampling was also employed as each participant who agreed to volunteer was asked to bring one other person with them, as the experiment was a two-person trial. Two groups of participants agreed to repeat the trial in opposite roles so that 30 trials could be conducted.

Although 60 participants took part in the study, only the results of 30 participants in the "Observer" (Obs) role were of interest. Results from the "Stimulus Provider" (SP) group were not used for the purposes of this study.

Several participants (n = 6) had minimal computer exposure on a daily basis and they were not as comfortable with the attention aspect of the task (pressing a keyboard key in response to a letter on the screen) and this may have affected their attention task score in trial 1. However, due to the length of time in each trial, some degree of learning may have occurred and this was reflected in their reaction times and error rates during trial 2.

2.2 *Design*

A cross-sectional, quantitative, within-subjects, partly correlational designed experiment was conducted. The independent variables were age, levels of subjective cognitive fatigue and participant's scores on the Fatigue Assessment Scale (FAS), Generalised Self-Efficacy Scale (GSE) and the Fatigue Inventory Scale (FIS). The dependant variables were participant's performance on the attention task (reaction times and percentages of correct and incorrect responses) and their performance on the observation task (number of correct, incorrect and unobserved observations). The aim of this study was to examine the effect of induced mental fatigue (independent/predictor variable) on the reaction and error rates (dependant/criterion variables) of participants randomly allocated to the "Observer" group.

2.3 Materials

Four questionnaires were used. A demographic questionnaire, the Fatigue Assessment Scale (FAS), the Generalised Self-efficacy Scale (GSE) and a modified version of the Fatigue Inventory Scale (FIS). Verbal instructions were issued to participants, asking that they complete each questionnaire and that there were no correct or incorrect answers. Participants were also informed that their answers were confidential and that they would be allocated a study number (i.e. their name would not be associated with the questionnaire responses).

2.3.1 *Demographic Questionnaire*

This questionnaire recorded participant's age and sex. Participant were also asked to subjectively rate their current perceived level of "mental" (cognitive) fatigue on a scale of 1 to 10, where 1 was not mentally fatigued and 10 was mentally exhausted. Both figures were recorded on this questionnaire. See appendix 1 for questionnaire.

2.3.2 *Fatigue Assessment Scale*

The FAS (Michielsen, H.J., De Vries, J., Van Heck, G. L., Van de Vijver, F. J. R., & Sijtsma, K., 2004) is a 10 item questionnaire constructed from a review of 4 unidimentional questionnaires: the Checklist Individual Strength-20 (Vercoulen et al., 1999), the Emotional Exhaustion subscale from the Dutch version of the Maslach Burnout Inventory (Maslach & Jackson, 1986), the Energy and Fatigue subscale from the World Health Organization Quality of Life assessment instrument (EF-WHOQOL-100; WHOQOL group 1995), and the Fatigue Scale (Chalder et al., 1993). Participants chose an answer on a 5 point likhert scale where 1 is "never" and 5 is "always". Questions number 4 and 10 were reverse scored. A participant can score a maximum of 42 and a minimum of 18, with higher scores indicative of greater fatigue. See appendix 1 for questionnaire.

2.3.3 *Generalised Self Efficacy Scale*

The self-administered 10 item GSE scale (Schwarzer, R., & Jerusalem, M., 1995) assesses how the general population cope with daily hassles and other stressful life events. It can be completed by teenagers and adults, however it is not recommended for children aged 12 and under. Participant's select an answer on the 4 point scale where 1 is "not at all true" and 4 is "exactly true". Scores range from 10 to 40, with higher scores predicting greater coping skills/strategies. Reverse coding is not required with this scale. See appendix 1 for questionnaire.

2.3.4 *Fatigue Inventory Scale*

The 40 question FIS (Fisk, J. D., Ritvo, P. G., Ross, L., Haase, D. A., Marrie, T. J., & Schlech, W. F., 1994) has been developed to assess the cognitive, social and physical fatigue experienced by patients such as those with multiple sclerosis. As the aim of this study was to assess the effect of cognitive fatigue (primarily), 1 question pertaining to cognitive fatigue (question 30), 7 questions pertaining to social fatigue (questions 2, 16, 19, 22, 28, 36, 39) and 7 questions associated with physical fatigue (questions 3, 8, 13, 17, 29, 37, 38) were excluded. Crohnbergs reliability alpha score on the overall modified FIS was .95 and the apha score on the modified cognitive aspect of the FIS was .91.

The original questionnaire asked participants to report how much fatigue had been a problem for them in the past 4 weeks, including the day they completed the questionnaire. As this study was concerned only with current subject levels and associated cognitive costs of fatigue, participants were requested to complete the questionnaire referring only to the day in which they completed it.

Participants completed the scale by choosing an answer on a 5 point likhert scale where “0” indicated “no problem” and “4” indicated an “extreme problem”. Participants could score between 0 and 100 on this modified version of the FIS, with higher scores indicative of greater fatigue. See appendix 1 for questionnaire.

2.3.5 *Superlabs*

An attention task utilising Superlabs (version 4.5) was created with two trials containing 500 non-alphabetical letters per trial. Two computers (HP Compaq microtower Desktop 2.66ghz and a Lenovo Intel 2140 1.60hz, both running Windows XP) used in the experiment ran the same Superlabs attention task. The “SP” Superlabs programme also contained 15 audio cues linked with specific letters in the programme. These cues were “left”, “middle” and “right”. They occurred at different intervals for trial 1 and trial 2. See appendix 2 for programme outputs. The letters were presented on screen to the participants for a period of 3 seconds (independent of key-strike and correct response).

Results from Superlabs were exported to a Cedrus data viewer (version 2.0) where average reaction times and percentages of correct and correct attention task responses were then exported to SPSS.

2.3.6 *Microsoft Excel*

The Superlabs programme ran on two different PC models. As a result, the two programmes did not display the same letters at the same times. This resulted in an inability to accurately compare the "Obs" participant's reported observation of the "SP" group moving their head in accordance with the Superlabs timed cue to do so. To counterbalance this, Microsoft Excel (2010) was used to calculate the exact time the "SP" group moved their head, as seen by the "Obs" group. This involved dividing the milliseconds recorded by Superlabs by 60,000 to give minutes, then minus that time by the time of the 1st key strike (Superlabs recorded time from the moment instructions were displayed on screen and not when 1st key was struck), and then conversion of this decimelled time to a minutes and seconds time to correspond with the minutes and seconds score recorded by the "Obs" participants. See appendix 3 for an outline of same.

2.4 <u>Apparatus</u>

Two DBS desktop PCs were positioned side by side. The "Obs" participant sat on the left and the "SP" sat on the right. Three focus points were secured to the wall in front of the participants. Three white A4 sheets marked "L", "M", and "R" (bold, centralised, arial size 400) were placed to the left of the "Obs" participant, in the centre between the participants and to the left of the "SP" participant respectively (see appendix 4 for lab layout).

As two different PC models were used, the Superlabs programme did not run at the same speed for both computers. Excel was used to calculate the exact time the "Obs" group observed the "SP" group move their head, as outlined in 2.3.6 above.

A digital timer was used to allow the "Obs" group to record the time in minutes and seconds when they observed the "SP" group move their head. This was placed on the computer in front of the "Obs" group.

2.5 *Procedure*

When the participants entered the laboratory, they were asked to select one of two overturned sheets of paper marked "tester" (i.e. "Obs) and "driver" (i.e. "SP"). This was to ensure randomised selection of participants for the "Obs" and "SP" group.

Once the participants had selected a group, the "Obs" participant was asked to complete the questionnaire pack at a separate table as the experimenter asked the "SP" participant to sit at their PC. While the "Obs" participant completed the questionnaires, the "SP" participant received a verbal outline of the experiment (what the experiment entailed and highlighted the importance of them moving their head in the direction of the prompt as soon as they were prompted to do so) and any questions they had was answered at this time. This reduced the interaction between the "Obs" and the "SP" group which may have influenced the questionnaire marking. Both groups received written instructions outlining the nature of the study and were invited to keep same. The questionnaires took between 10-15 minutes to complete.

Upon finishing the questionnaires, the "Obs" participant was asked to rate their current subjective state of mental fatigue on a scale of 1 to 10 (see 2.3.1) and then asked to take a seat at their PC. When seated at their PCs, both participants were informed that they would be completing two 25 minute trials of an attention task and were also informed of the procedures of the attention task (i.e. were both asked to press "v" when they saw a vowel and "c" when they saw a consonant) and the "Obs" participant was also informed that they would be required to note the time and direction they observed the "SP" participant moving their head when prompted to do so in the headphones they were wearing. The "Obs" participant was informed that they would not hear this prompt but would be required to make as many accurate observations as possible while also completing the attention task to the best of their ability. Any questions from both participants were answered at this time. Both participants were then asked to begin the trial at the same time by pressing spacebar (i.e. the experimenter instructed "1, 2, 3 spacebar). The experimenter started the timer from the moment spacebar was pressed.

Upon completion of trial 1, both participants were given the opportunity to ask any further questions and were also offered some time for a break if necessary (all participants refused this break). Following this, they were informed that they would complete the same task for a second time, but with a different selection of letters. They received the same commencement instructions as per trial 1.

Upon completion of the 2 trials, the "Obs" participant was again asked to rate their subject sense of metal fatigue on the scale of 1 to 10. The participants were then offered confectionary and given the opportunity to ask questions in relation to the experiment and discuss same. Both participants received the email address of the experimenter and were invited to contact same if they wished to know the overall outcome of the experiment.

2.6 *Data Analysis*

The output from Superlabs was exported to a Cedrus programme which computed the total reaction times from the attention tasks, as well as the number of correct and incorrect responses and the percentage of correct and incorrect responses. These results were inputted into SPSS for statistical analysis.

Observation scores computed on excel were also inputted into SPSS for analysis. Descriptive and inferential statistics (independent and paired samples t-tests, pearsons correlations, simple linear regressions) were completed on this data, the results of which are outlined in section 3 below.

3. Results

3.1 *Descriptive Statistics*

60 participants took part in the experiment and of the 30 participants randomly allocated to the "Obs" group, 12 were male and 18 female (age range = 20 - 64 years, mean = 36.27, SD = 14.01 – see figure 1). All participants completed the FIS, GSE and FAS scales. Table 1 outlines the mean scores for both male and female participants.

Table 1. ***Mean scores for FIS, GSE and FAS scales***

	Male		**Female**	
	Mean	**SD**	**Mean**	**SD**
FIS	34.75	14.75	44.28	18.89
Cog FIS	18.67	7.82	22.50	9.03
GSE	30.25	4.09	30.50	4.23
FAS	19.83	3.86	21.06	6.71

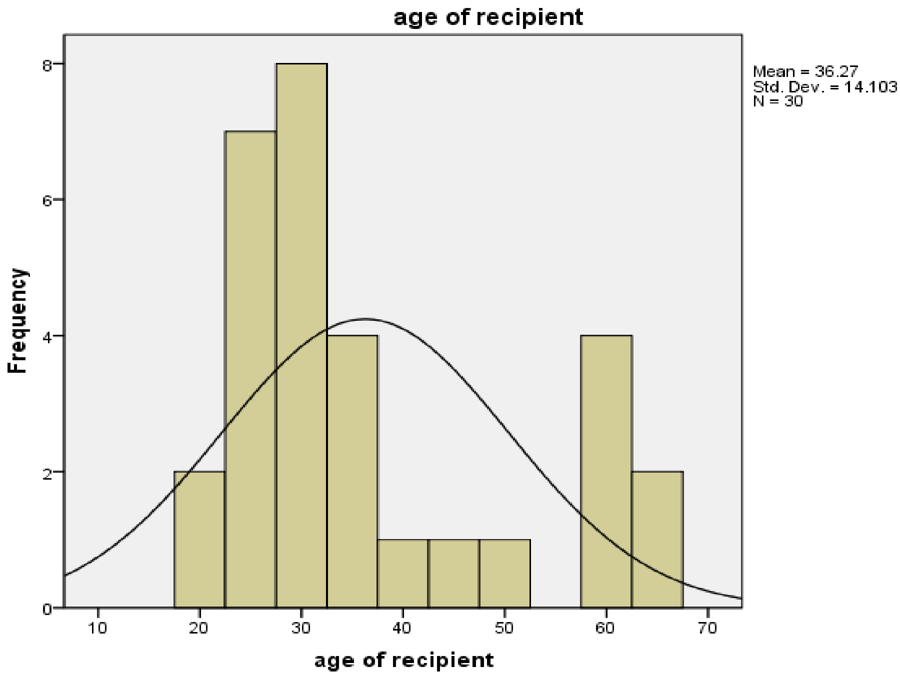

Figure 1. ***Outline of age of participants*.**

Reaction rates (table 2) and observation accuracy (table 3) were recorded from the "Obs" group. Observation accuracy was determined by coding the observations made (1 = correct observation of direction of head movement at correct time, 2 = correct time of observation but incorrect observation made of direction of head movement, 3 = no observation made). Participants with a lower observation score made more accurate observations than those with a higher score. A record of the number of extra observations (uncued and unintentional from "SP" group) made by the "Obs" group were also taken as an indicator of "hypervigalence". Male participants made an average of 6.42 (SD = 8.28) extra observations and female participants made an average of 3.11 (SD = 5.45) extra observations.

Table 2. ***Attention task reaction times***

	Male		Female	
	Mean	**SD**	**Mean**	**SD**
Attention task 1 total reaction time	895.62	155.99	791.45	76.69
Attention task 2 total reaction time	761.28	127.80	695.64	107.19
Attention task 1 correct response reaction time	884.31	171.32	796.94	119.69
Attention task 2 correct response reaction time	774.55	141.78	731.75	79.76
Attention task 1 incorrect response reaction time	743.26	203.88	584.03	291.21
Attention task 2 incorrect response reaction time	794.63	344.65	594.71	206.64

Table 3. ***Observation task scores***

	Male		Female	
	Mean	**SD**	**Mean**	**SD**
Total combined observation score	56.50	14.63	54.94	12.18
Total observation score trial 1	30.42	8.15	28.78	6.82
Total observation score trial 2	26.08	7.80	26.17	6.59

3.2 Inferential Statistics

3.2.1 *Fatigue and attention task reaction time score*

Fatigue was measured as a correlation between FIS, FAS, GSE scores and differences in perceived subjective cognitive fatigue, and the participant's reaction times over the course of trial 1 and trial 2.

The mean score for the FIS was 40.47 (SD = 17.73). The mean score for attention task 1 reaction time was 818.75ms (SD = 117.61) and for attention task 2 reaction time was 721.90ms

(SD = 118.32). A pearsons correlation found a moderately strong negative correlation between FIS scores and attention task 1 reaction times (r(28) = -.38, p = .04). When divided by gender, it was found that this significance was within the female sample only (r(16) = -.50, p = .04) and not within the male sample (r(10) = -.25, p = .44). Therefore the null hypothesis is rejected for the female sample in this correlation only, and accepted for the male sample correlation. A pearson correlation did not find a significant relationship between FIS scores and attention task 2 reaction time (r(28) = -.20, p = .28). The cognitive aspect of the FIS (mean = 20.97, SD = 8.64) did not show a significant correlation between the it and attention task 1 reaction times (r(28) = -.34, p = .07) or between the cognitive aspect of FIS and attention task 2 reaction times (r(28) = -.15, p = .42). Therefore the null hypothesis is accepted in this instance.

The mean score for the FAS was 20.57 (SD = 5.69) and the mean score for attention task 1 and 2 reaction times are outlined above. A pearsons correlation did not find a significant relationship between FAS scores and attention task 1 reaction times (r(28) = -.03, p =.88) or between FAS scores and attention task 2 reaction times (r(28) = .96, p = .62). Therefore the null hypothesis is accepted.

The mean score for the GSE was 30.40 (SD = 4.11). Mean scores for attention reaction times in trial 1 and trial 2 are outlined above. A pearsons correlation did not find a significant relationship between GSE scores and attention task 1 reaction times (r(28) = -.23, p =.22) or between GSE scores and attention task 2 reaction times (r(28) = -.11, p = .54). Therefore the null hypothesis is accepted.

The mean score for the difference in subjective cognitive fatigue levels between trial 1 was 2.70 (SD = 2.26). Mean scores for trial 1 and 2 attention task reaction times are outlined above. A pearsons correlation did not find a significant relationship between the difference in subjective cognitive fatigue scores (between trial 1 and 2) and trial 1 attention task reaction times (r(28) = -.13, p = .51) or between subjective cognitive fatigue scores and trial 2 attention task reaction times (r(28) = -.06, p = .75). Therefore the null hypothesis is accepted.

A pearsons correlation was also carried out to see if there was a relationship between the percentage of incorrect attention task responses made in trial one (mean = 5.75%, SD = 17.54) and trial 2 (mean = 5.09%, SD = 17.38) and the difference in subjective cognitive fatigue levels between trial 1 and trial 2. A pearsons correlation did not find a significant relationship between the difference in subjective cognitive fatigue scores and the percentage of incorrect responses made in attention task 1 (r(28) = -.11, p = .55) or between subjective cognitive fatigue scores and percentage of incorrect responses made in attention task 2 (r(28) = -.13, p = .51). Therefore the null hypothesis is accepted.

A pearsons correlation was also carried out to see if there was a relationship between the percentage of correct attention task responses made in trial 1 (mean = 91.78, SD = 17.51) and trial 2 (mean = 91.64, SD = 18.55) and the mean GSE score (mean and SD outlined above). A pearsons correlation did not find a significant relationship between GSE scores and the percentage of correct responses made in attention task 1 (r(28) = .06, p = .77) or between GSE scores and percentage of correct responses made in attention task 2 (r(28) = -.02, p = .94). Therefore the null hypothesis is assumed.

Table 4 provides a summary of the above correlations and significance values.

Table 4. ***Means, SDs, and correlations between attention task reaction times and FIS, GSE, FAS and subject fatigue level scores.***

	Mean	**SD**	**1**	**2**	**3**	**4**	**5**	**6**
1. Attention task 1 reaction times	818.75	117.61						
2. Attention task 2 reaction times	721.90	118.32						
3. % incorrect responses attention task 1	5.75	17.54						
4. % incorrect responses attention task 2	5.09	17.38						
5. % correct responses attention task 1	91.78	17.51						
6. % correct responses attention task 2	91.64	18.550						
FIS score	40.47	17.73	**-.38***	-.20				
Cog FIS score	20.97	8.64	-.34	-.15				
GSE score	30.40	4.11	-.23	-.11			.06	-.02
FAS score	20.57	5.69	-.03	.96				
Subjective cognitive fatigue score	2.70	2.26	-.13	-.06	-.11	-.13		

* significant at p < .05

3.2.2 *Fatigue and observation scores*

As outlined above, fatigue was measured as a correlation between FIS, FAS, GSE scores and differences in perceived subjective cognitive fatigue, and in this case the participant's observation scores over the course of trial 1 and trial 2.

The mean scores for results on the FIS was 40.47 (SD = 17.73), the mean observation score in trial 1 was 29.43 (SD = 7.29) and the mean observation score for trial 2 was 26.13 (SD = 6.97). A pearsons correlation did not find a significant correlation between FIS score and the observation score in trial 1 (r(28) = -.10, p = .76) or between the FIS score and the observation score in trial 2 (r(28) = -.22, p = .23). Therefore the null hypothesis is accepted.

The mean score for the cognitive aspect of the FIS was 20.97 (SD = 8.64). A pearsons correlation did not find a significant correlation between the cognitive aspect of the FIS and the observation score in trial 1 ($r(28) = -.06$, $p = .59$) or between FIS and the observation score in trial 2 ($r(28) = -.24$, $p = .21$). Therefore the null hypothesis is accepted.

The mean score for the GSE was 30.40 (SD = 4.11). Means and standard deviations for observation scores are outlined above. A pearsons correlation did not find a significant relationship between GSE scores and observation scores in trial 1 ($r(28) = .09$, $p =.63$) or between GSE scores and observation scores in trial 2 ($r(28) = .14$, $p = .45$). Therefore the null hypothesis is accepted.

The mean score for the FAS was 20.57 (SD = 5.69). Mean scores for the observation tasks are outlined above. A pearsons correlation did not find a significant relationship between FAS scores and observation scores in trial 1 ($r(28) = -.21$, $p = .27$) or between FAS scores and observation scores in trial 2 ($r(28) = -.28$, $p = .18$). Therefore the null hypothesis is accepted.

The mean score for the difference in subjective cognitive fatigue levels between trial 1 and two was 2.70 (SD = 2.26). Mean scores for observation tasks 1 and 2 are outlined above. A pearsons correlation did not find a significant relationship between the difference in subjective cognitive fatigue scores (between trial 1 and 2) and observation scores trial 1 ($r(28) = .12$, $p = .55$) or between subjective cognitive fatigue scores and observation scores trial 2 ($r(28) = .04$, $p = .83$). Therefore the null hypothesis is accepted.

A summary of the above results is shown in table 5 below.

Table 5. ***Means, SDs, and correlations between observation scores and FIS, GSE, FAS and subject fatigue level scores.***

		Mean	**SD**	**1**	**2**
1.	Observation score trial 1	29.43	7.29		
2.	Observation score trial 2	26.13	6.97		
	FIS score	40.47	17.73	-.10	-.22
	Cog FIS score	20.97	8.64	-.06	-.24
	GSE score	30.40	4.11	.09	.14
	FAS score	20.57	5.69	-.21	-.28
	Subjective cognitive fatigue score	2.70	2.26	.12	.04

3.2.3 *Age and attention task reaction scores, observation scores and difference in subjective fatigue levels correlations.*

A pearsons correlation did not find a significant relationship between age and attention task 1 reaction times ($r(28) = .16$, $p = .39$), attention task 2 reaction times ($r(28) = -.001$, $p = .99$), percentage of incorrect responses made in attention task 1 ($r(28) = .31$, $p = .10$), percentage of incorrect responses made in attention task 2 ($r(28) = .31$, $p = .10$), observation scores in trial 1 ($r(28) = .35$, $p = .06$), observation scores in trial 2 ($r(28) = .14$, $p = .46$), and the difference in subject fatigue levels ($r(28) = -.03$, $p = .89$). Table 6 outlines the means, SDs and correlations for the above variables.

Table 6. ***Means, SDs, and correlations between age, attention task reaction rates, observation score and difference in subjective fatigue levels.***

		Mean	SD	1	2	3	4	5	6	7
	Age	36.27	14.10	.16	-.001	.31	.31	.35	.14	-.03
1.	Attention task 1 reaction times	818.75	117.61							
2.	Attention task 2 reaction times	721.90	118.32							
3.	% incorrect responses attention task 1	5.75	17.54							
4.	% incorrect responses attention task 2	5.09	17.38							
5.	Observation score trial 1	29.43	7.29							
6.	Observation score trial 2	26.13	6.97							
7.	Subjective cognitive fatigue score	2.70	2.26							

3.2.4 *Paired Samples t-tests*

10 paired samples t-tests were conducted (see table 7 for outline of results). A strong relationship was reported in 8 of the 10 pairings.

The mean number of non-cued responses made in trial 1 was 3 (SD = 14.68). However the mean number of un-cued observations made in trial 2 was lower at 1.73 (SD = 4.68). The 95% confidence limits indicates the variables population mean difference lies between .066 and 2.467. A paired samples t-test showed a significant strong difference between non-cued responses made in trial 1 and trial 2 ($t(29) = 2.16$, $p = .039$). Therefore the null can be rejected.

Similarly strong significant differences were found for paired sample t-tests conducted between attention task 1 reaction times (mean = 818.72, SD = 117.60) and attention task 2 reaction times (mean = 721.89, SD = 118.32) ($t(29) = 6.94$, $p <.001$), attention task 1 correct response reaction time (mean = 831.88, SD = 146.38) and task 2 correct response reaction time (mean = 748.87, SD = 108.67) (t(29) = 4.56, p <.001), total observation score in trial 1 (mean = 29.43, SD = 7.29) and total observation score trial 2 (mean = 26.13, SD = 6.97) (t(29) = 3.07, p = .005), total number of correct observations made in trial 1 (mean = 6.7, SD = 7.29) and number of correct observations made in trial 2 (mean = 8.63, SD = 3.58) (t(29) = -3.11, p = .004), percentage of incorrect responses made in attention task 1 (mean = 5.74, SD = 17.54) and percentage of incorrect responses in attention task 2 (mean = 5.09, SD = 17.38) (t(29) = 2.49, p = .019). The null can be rejected for all of the above.

A paired samples t-test showed a moderately strong difference perceived level of subjective fatigue in trial 1 (mean = 4.17, SD = 2.31) and perceived level of subjective fatigue in trial 2 (mean = 6.87, SD = 2.21) (t(29) = -6.540, p <.001). Therefore the null can be rejected.

95% confidence intervals limits indicating where the variables population mean differences of the above variable pairings lie are outlined in table 7.

Table 7. ***Paired t-test 95% confidence interval limits***

	95% confidence intervals of the difference	
	Lower	**Upper**
Number of un-cued responses made trial 1 – number of un-cued responses made trial 2.	.066	2.467
Attention task 1 reaction times – attention task 2 reaction times.	68.294	125.35
Attention task 1 correct response reaction times – attention task 2 correct response times	45.764	120.274
Total observation score trial 1 – total observation score trial 2.	1.100	5.499
Number of correct observations trial 1 – number of correct observations trial 2.	-3.204	-.663
Percentage of incorrect responses attention task 1 – percentage of incorrect responses attention task 2.	.116	1.183

Perceived level of subject fatigue trial 1 – perceived level of subject fatigue trial 2.	-3.544	-1.856

3.2.5 *Independent samples t-tests*

Independent samples t-tests were carried out between gender and attention task reaction times, percentage of correct and incorrect attention task responses, observations scores, number of extra observations made and the total difference in subjective fatigue levels. Confidence intervals for these tests can be found in table 8.

Females (mean = 791.45, SD = 96.69) reaction times in trial 1 were slightly faster than males (mean = 859.62, SD = 155.99). However an independent samples t-test did not find a significant difference between the two reaction times (t (14.59) = 1.41, p = .181). A similar result was observed in attention task 2 where female participant's reaction times (mean = 695.64, SD = 107.19) was quicker than male's reaction times (mean = 761.28, SD = 127.80). Again, an independent samples t-test did not find a significant difference between the two reaction times (t (28) = 1.52, p = .139).

The percentage of correct attention task responses made by males (mean = 94.87, SD = 3.65) was greater than those of females (mean = 89.71, SD = 22.43). However an independent samples t-test did not find a significant difference between these two groups (t (28) = .79, p = .439). Males percentage of correct responses increased in trial 2 (mean = 96.75, SD = 88.23), whereas females percentage of correct responses decreased (mean = 88.23, SD = 23.51). An independent samples t-test did not find this difference significant (t (28) = -.83, p = .224).

Females (mean = 7.57, SD = 22.65) had a higher percentage of incorrect attention task responses in trial 1 than males (mean = 2.99, SD = 2.20). However an independent samples t-test did not find a significant difference between these set of percentages (t (28) = -.69, p = .494). In trial 2, both groups improved however, female participants (mean = 7.25, SD = 22.41) continued to make more errors in the attention task than males (mean = 1.87, SD = 1.02). The difference between these scores was not found to be significant (t (28) = -.83, p = .416).

Males observation scores in trial 1 (mean = 30.42, SD = 8.15) were greater than females (mean = 28.78, SD = 6.82), indicating that females performed better in this task. However an independent samples t-test did not find a significant difference between these set of scores (t (28) = .60, p = .556). In trial 2, females performed marginally poorer (mean = 26.17, SD = 6.59) than males (mean = 26.08, SD = 7.80) however this difference was not found to be significant (t (28) = -.03, p = .975).

The number of extra observations made was an indicator of hypervigalence. In trial 1 males made a greater number of extra observations (mean = 4.25, SD = 6.15) than females (mean = 2.17, SD = 3.31). However an independent samples t-test did not find a significant difference between these two scores (t (15.29) = 1.07, p = .299). Males reduced the number of extra observations made (mean = 2.17, SD = 2.44) however they continued to make more uncued observations than females (mean = 1.44, SD = 2.48). An independent samples t-test did not find a significant difference between these two groups (t (28) = .79, p = .44).

Male (mean = 2.75, SD = 2.14) and female (mean = 2.66, SD = 2.40) did not differ substantially in their total difference of subjective fatigue scores. An independent samples t-test did not find a significant difference between these two groups (t (28) = .10, p = .923).

Table 8. ***Independent samples t-test 95% confidence interval limits***

	95% confidence intervals of the difference	
	Lower	**Upper**
Attention task 1 total reaction time	-35.51	171.85
Attention task 2 total reaction time	-22.71	153.97
% correct responses attention task 1	-8.30	18.61

% correct responses attention task 2	-5.52	22.55
% incorrect responses attention task 1	6.60	-18.09
% incorrect responses attention task 2	6.51	-18.72
Total observation score trial 1	2.75	-3.99
Total observation score trial 2	2.64	-5.50
Number of extra observations made trial 1	-2.04	6.21
Number of extra observations made trial 2	-1.16	2.60
Total difference in subjective fatigue between trial 1 and 2	-1.67	1.84

3.2.6 *Simple linear regressions*

Using simple regression, it was found that the difference in subjective fatigue levels did not significantly predict the reaction times in trial 1 ($F(1,28) = .107$, p = .745, $R^2 = .02$) (subjective fatigue, beta = -.126, p = .507) or in trial 2 ($F(1,28) = .452$, p = .507, $R^2 = .004$) (subjective fatigue, beta = -.62, p = .745).

A simple linear regression found that the difference in subjective fatigue levels did not significantly predict the percentage of incorrect responses in the 1st attention task ($F(1,28) = .362$, p = .552, $R^2 = .013$) (subjective fatigue, beta = -.113, p = .552) or in attention task 2 ($F(1,28) = .447$, p = .509, $R^2 = .016$) (subjective fatigue, beta = -.125, p = .509).

A simple linear regression found that the difference in subjective fatigue levels did not significantly predict the observation scores in trial 1 ($F(1,28) = .375$, p = .546, $R^2 = .013$) (subjective fatigue, beta = .115, p = .546) or in trial 2 ($F(1,28) = .045$, p = .834, $R^2 = .002$) (subjective fatigue, beta = .04, p = .834).

4. Discussion

The aim of this study was to examine the relationship between cognitive fatigue and divided spatial attention. A secondary aim was to assess the effect of levels of perceived self-efficacy and participant's ability to accurately perform both tasks. This area of psychology has received much attention in the past, however psychologists have argued that many experiments conducted in this area have failed to actually test divided spatial attention. This is because the experiments either have not been difficult enough (i.e. cognitive resources have not been sufficiently challenged in one or both of the tasks), or similar cognitive pathways were employed for both task and therefore attention was not divided (e.g. visual stimuli from both tasks appearing in the same visual field).

Divided attention in this current study was achieved by devising tasks that utilised both the dorsal occipitoparietal and ventral occipitotemporal pathways simultaneously. The attention aspect of the dual-task involved the ventral "what" occipitotemporal pathway and focal vision in order to identify what letter was presented and then to make a decision as to whether it was a verb or a consonant. The cognitive processes in this task alone were deemed by the author to be sufficiently difficult as per Jans et al's (2010) criteria for a dual-task. The observation aspect of the task involved the dorsal "where" pathway. In order to observe the "SP" group moving their head, the "Obs" participant used their peripheral ambient vision, and the location of the "SP"'s head in that visual field was orientated by the function of the dorsal stream of the visual pathway. However, this task may have also utilised parts of the ventral pathway as this task required the participant to identify what direction the "SPs" head was turned to. The author was not in a position to test this hypothesis as a fMRI would have been required to do same.

4.1 *Summary of study findings*

The primary aim of the current study was to examine the effect of cognitive fatigue on divided spatial attention. Fatigue was assessed using scales such as the FIS, FAS and a subjective fatigue scale from 1-10 (the difference between trial 1 and trial 2 was taken to be an indicator of test-induced subjective fatigue). Statistical analysis found a moderately strong negative correlation between female FIS scores and their attention task 1 reaction time, however further analysis did not find a significant relationship between these scales and other attention task reaction times or observation task score in the male or the female participants. Similarly feelings of self-efficacy (GSE scores) were not found to be significantly related to participants attention task reaction times and observation task scores.

With regards to the attention and observation tasks, it was hypothesised that women would perform better than men, that their reaction times would be faster and they would make fewer observation errors than men. The results of this study partly supported this hypothesis. Female participant reaction times were faster than male reaction times on average. However, female's incorrect reaction time was also quicker than the male's incorrect reaction time, and females also made a greater percentage of incorrect responses on the attention task. The COPE model outlined above may explain this result (Neri et al, 1992). As previously discussed, as a person becomes increasingly cognitively fatigued, they attempt to minimise the amount of effort required to complete a task, even if they are aware that this strategy may result in errors. The increased error reaction time in the female sample may reflect such a strategy being employed. Female participants scored higher on each of the fatigue scales, indicating a higher level of cognitive fatigue at the beginning of the trial.

On the observation task, men made more errors than women in trial 1 and also made a greater depreciation in scores between trail 1 and 2 than women. However, in trial 2, men made more correct observations than women. Female participant's reduced performance in trial 2 may be explained by the COPE model. However, the fact that men performed better than women in trial 2 may be explained by another result – the number of extra uncued observations made. This result was an indicator of impulsivity and/or hypervigalence. Jentsch and Taylor (2003) reported on the sex-related difference between male and female's ability to complete divided spatial attention tasks. Their study was based on studies of children with ADHD, where female children with ADHD were found to be less impulsive than males. The authors did report that the reason behind this was, at that time, unknown. However sex hormones, in particular oestrogen, were thought to mediate frontal lobe neurotransmitters such as noradrenalin and dopamine, and thus impulsivity in this case. In their study, Jentsch and Taylor found that the more impulsive male rats also made more errors. This result is reflected above with male participants in this current study making more uncued observations (greater impulsivity) and yet making more observation errors in trials 1 and 2 combined than female participants.

However in the attention task, the opposite was the case, although it was not found to be statistically significant. Men's attention task reaction times were slower than the female participants. Men also had a higher percentage of correct responses in the attention task than women. This result runs contrary to Jentsch and Taylor's results above. As the attention task was more cognitively demanding than the observation task, one might expect to see a greater level of impulsivity within the male sample, as witnessed in the observation task. This was not the case. The reason for this was also not apparent in the results of the task.

The role of practice in improving one's ability to carry out a divided attention task was apparent from the results. A significant difference was reported between participant's scores in trial 1 and trial 2 in both the attention task and the observation task – reaction times improved, attention task scores improved, there were a greater number of correct observations made in trial 2 and fewer extra uncued observations noted.

4.2 *Study limitations*

The overall results of this study did not support the main hypothesis, that subjective cognitive fatigue has an adverse effect on a person's divided spatial attention. There are several limitations associated with this study that may provide an insight into this. Firstly, is the use of FIS and FAS questionnaires. Both questionnaires have been developed to assess the impact of fatigue on the daily life of people with MS, cancer etc. They were not specially developed for a healthy population. The author had difficulty sourcing a scale such as these for a healthy population and so a simple subjective fatigue self-report scale was utilised. This scale may not have been sensitive enough to accurately assess the effect of trial-induced fatigue on the participant's results.

Secondly, the length of the trial may not have been sufficient in order to induce a significant level of cognitive fatigue on the participants. The break allocated between trial 1 and trial 2 was inconsistent between trials, with some being of a longer duration than others. Greater levels of cognitive fatigue may have been observed if the trial was a single 50 minute trial, rather than 2 25 minute trials. However trial length proved to be in itself a limiting factor as it was difficult to recruit participants due to this.

Also, the two computers utilised in the experiment ran the Superlabs programme at different speeds, with the "SP" programme finishing on average 9 letters before the "Obs" group. This resulted in the "Obs" group having more opportunities of observing the "SP" group's head movements throughout the trials. This limitation could have been avoided using one hard drive with 2 screens, thus ensuring that both participants were completing the same programme at the same time.

4.3 *Implications for future research*

The role of practice and learning in a person's ability to accurately carry out divided spatial attention tasks, is an area that could be developed in light of this study. As previously outlined above, attention task reaction times and observation scores both improved over the course of the experiment, regardless of level of cognitive fatigue. The cause of this could not be determined by this study. However, future studies with similar degrees of dual-task difficulty and diversity of tasks, utilising PET scans or fMRI may provide greater insight into the degree of cortical specialisation that occurs through practice and learning, and possibly help identify gender difference, if any, in such specialisation.

4.4 *Application of study findings*

The results of this study are applicable to areas such as occupational, educational and health psychology. As cognitive fatigue is a very subjective perceived state and differs amongst individual personality traits (Ackerman & Kanfer, 2009), different individuals will react to similar levels of cognitive fatigue in different ways. This is an important consideration in the area of occupational psychology. In the current economic client, employees are often expected to multitask to a high degree with a high level of accuracy. This may be felt as a form of eustress for employees possessing high levels of traits such as “mastery” and an internal locus of control. However, for employees scoring high on level of negative affect and/or neuroticism this may create a stressful, cognitively draining work environment. As Ackerman and Kanfer (2009) reported, such individuals may learn to avoid such situations. In this case this would result in a high rate of recurrent employee absenteeism, and a large company overhead.

A similar application may be made to the area of educational psychology, for both teachers and students alike. By identifying individuals with personality traits more susceptible to cognitive fatigue, these individuals may be made aware of resources available to them to help them cope with situations requiring a high degree of dual-tasking.

In the area of health psychology, the results of this study contributes to the empirical evidence on how and when divided attention fails due to cognitive fatigue. Studies such as these have proved instrumental, for example, in establishing new road laws prohibiting the use of hand held phones while driving (Strayer & Johnston, 2001).

4.5 *Conclusion*

Reported subjective cognitive fatigue was not found to have a significant effect on participant's ability to complete a divided spatial attention task. The results however, did highlight areas for future research, such as PET and fMRI studies to establish cortical patterns of practice-induced learning. The results of this study may be applied to areas such as occupational and educational psychology, and will help supplement empirical evidence in areas of health psychology such as road safety.

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Appendix 1

The Generalized Self-Efficacy Scale (Wegner et al, 1993)

		Not at all true	Barely true	Moderately true	Exactly true
1.	I can always manage to solve difficult problems if I try hard enough.	1	2	3	4
2.	If someone opposes me I can find means and ways to get what I want.	1	2	3	4
3.	It is easy for me to stick to my aims and accomplish my goals.	1	2	3	4
4.	I am confident I could deal efficiently with unexpected events.	1	2	3	4
5.	Thanks to my resourcefulness, I know how to handle unforeseen situations.	1	2	3	4
6.	I can solve most problems if I invest the necessary effort.	1	2	3	4
7.	I can remain calm when facing difficulties because I can rely on my coping abilities.	1	2	3	4
8.	When I am confronted with a problem, I can usually find several solutions.	1	2	3	4
9.	If I am in a bind, I can usually think of something to do.	1	2	3	4
10	No matter what comes my way, I'm usually able to handle it.	1	2	3	4

Fatigue Impact Scale (Fisk et al, 1991) – the original version.

Patient Number: Date:

Below is a list of statements that describe how fatigue may cause problems in people's lives. Please read each statement carefully. Circle the number that indicates best how much of a problem fatigue has been for you these **past four (4) weeks**, including today. Please circle one number for each statement and do not skip any statements.

	Circle one number on each line	No Problem	Small Problem	Moderate Problem	Big Problem	Extreme Problem
1	Because of my fatigue… **I feel less alert.**	0	1	2	3	4
2	Because of my fatigue… **I feel that I am more isolated from social contact.**	0	1	2	3	4
3	Because of my fatigue… **I have to reduce my workload or responsibilities.**	0	1	2	3	4
4	Because of my fatigue… **I am more moody.**	0	1	2	3	4
5	Because of my fatigue… **I have difficulty paying attention for a long period of time.**	0	1	2	3	4
6	Because of my fatigue… **I feel like I cannot think clearly.**	0	1	2	3	4
7	Because of my fatigue… **I work less effectively. (This applies to work inside or outside the home).**	0	1	2	3	4
8	Because of my fatigue… **I have to rely more on others to help me or do things for me.**	0	1	2	3	4
9	Because of my fatigue… **I have difficulty planning activities ahead of time because my fatigue may interfere with them.**	0	1	2	3	4
10	Because of my fatigue… **I am more clumsy and uncoordinated.**	0	1	2	3	4
11	Because of my fatigue… **I find that I am more forgetful.**	0	1	2	3	4
12	Because of my fatigue… **I am more irritable and more easily angered.**	0	1	2	3	4

13	Because of my fatigue… **I have to be careful about pacing my physical activities.**	0	1	2	3	4
14	Because of my fatigue… **I am less motivated to do anything that requires physical effort.**	0	1	2	3	4
15	Because of my fatigue… **I am less motivated to engage in social activities.**	0	1	2	3	4
16	Because of my fatigue… **My ability to travel outside my home is limited.**	0	1	2	3	4
17	Because of my fatigue… **I have trouble maintaining physical effort for long periods.**	0	1	2	3	4
18	Because of my fatigue… **I find it difficult to make decisions.**	0	1	2	3	4
19	Because of my fatigue… **I have few social contacts outside of my own home.**	0	1	2	3	4
20	Because of my fatigue… **Normal day-to-day events are stressful for me.**	0	1	2	3	4
21	Because of my fatigue… **I am less motivated to do anything that requires thinking.**	0	1	2	3	4
22	Because of my fatigue… **I avoid situations that are stressful for me.**	0	1	2	3	4
23	Because of my fatigue… **My muscles feel much weaker than they should.**	0	1	2	3	4
24	Because of my fatigue… **My physical discomfort is increased.**	0	1	2	3	4
25	Because of my fatigue… **I have difficulty dealing with anything new.**	0	1	2	3	4
26	Because of my fatigue… **I am less able to finish tasks that require thinking.**	0	1	2	3	4
27	Because of my fatigue… **I feel unable to meet the demands that people place on me.**	0	1	2	3	4
28	Because of my fatigue… **I feel less able to provide financial support for myself and my family.**	0	1	2	3	4
29	Because of my fatigue… **I engage in less sexual activity.**	0	1	2	3	4
30	Because of my fatigue… **I find it difficult to organize my thoughts when I am doing things at home or at work.**	0	1	2	3	4
31	Because of my fatigue… **I am less able to complete tasks that require physical**	0	1	2	3	4

	effort.					
32	Because of my fatigue… **I worry about how I look to other people.**	0	1	2	3	4
33	Because of my fatigue… **I am less able to deal with emotional issues.**	0	1	2	3	4
34	Because of my fatigue… **I feel slowed down in my thinking.**	0	1	2	3	4
35	Because of my fatigue… **I find it hard to concentrate.**	0	1	2	3	4
36	Because of my fatigue… **I have difficulty participating fully in family activities.**	0	1	2	3	4
37	Because of my fatigue… **I have to limit my physical activities.**	0	1	2	3	4
38	Because of my fatigue… **I require more frequent or longer periods of rest.**	0	1	2	3	4
39	Because of my fatigue… **I am not able to provide as much emotional support to my family as I should.**	0	1	2	3	4
40	Because of my fatigue… **Minor difficulties seem like major difficulties.**	0	1	2	3	4

Fatigue Impact Scale (Fisk et al, 1991) – Purpose modified version.

Participant Number: Date:

Below is a list of statements that describe how fatigue may cause problems in people's lives. Please read each statement carefully. Circle the number that indicates best how much of a problem fatigue has been for you these **past four (4) weeks**, including today. Please circle one number for each statement and do not skip any statements.

	Circle one number on each line	No Problem	Small Problem	Moderate Problem	Big Problem	Extreme Problem
1	Because of my fatigue… **I feel less alert.**	0	1	2	3	4
4	Because of my fatigue… **I am more moody.**	0	1	2	3	4
5	Because of my fatigue… **I have difficulty paying attention for a long period of time.**	0	1	2	3	4
6	Because of my fatigue… **I feel like I cannot think clearly.**	0	1	2	3	4
7	Because of my fatigue… **I work less effectively. (This applies to work inside or outside the home).**	0	1	2	3	4
9	Because of my fatigue… **I have difficulty planning activities ahead of time because my fatigue may interfere with them.**	0	1	2	3	4
10	Because of my fatigue… **I am more clumsy and uncoordinated.**	0	1	2	3	4
11	Because of my fatigue… **I find that I am more forgetful.**	0	1	2	3	4
12	Because of my fatigue… **I am more irritable and more easily angered.**	0	1	2	3	4
14	Because of my fatigue… **I am less motivated to do anything that requires physical effort.**	0	1	2	3	4
15	Because of my fatigue… **I am less motivated to engage in social activities.**	0	1	2	3	4
18	Because of my fatigue… **I find it difficult to make decisions.**	0	1	2	3	4
20	Because of my fatigue… **Normal day-**	0	1	2	3	4

	to-day events are stressful for me.					
21	Because of my fatigue… **I am less motivated to do anything that requires thinking.**	0	1	2	3	4
23	Because of my fatigue… **My muscles feel much weaker than they should.**	0	1	2	3	4
24	Because of my fatigue… **My physical discomfort is increased.**	0	1	2	3	4
25	Because of my fatigue… **I have difficulty dealing with anything new.**	0	1	2	3	4
26	Because of my fatigue… **I am less able to finish tasks that require thinking.**	0	1	2	3	4
27	Because of my fatigue… **I feel unable to meet the demands that people place on me.**	0	1	2	3	4
31	Because of my fatigue… **I am less able to complete tasks that require physical effort.**	0	1	2	3	4
32	Because of my fatigue… **I worry about how I look to other people.**	0	1	2	3	4
33	Because of my fatigue… **I am less able to deal with emotional issues.**	0	1	2	3	4
34	Because of my fatigue… **I feel slowed down in my thinking.**	0	1	2	3	4
35	Because of my fatigue… **I find it hard to concentrate.**	0	1	2	3	4
40	Because of my fatigue… **Minor difficulties seem like major difficulties.**	0	1	2	3	4

Clinician's Guide for Interpreting the Fatigue Impact Scale

(this sheet is NOT to be given to the patient)

The Fatigue Impact Scale is a self report outcome instrument designed to measure the effect of fatigue on activities of daily living. The Fatigue Impact Scale rates how much of a problem fatigue has caused during the past month. The Fatigue Impact Scale consists of 40 items that are divided into three subscales: Cognitive, Physical and Social.

The scale ranges from 0 - 4 with the higher scores indicating greater fatigue. The Fatigue Impact Scale demonstrates a very high internal consistency, thus suggesting that the scale provides a valid measure of impact of fatigue on quality of life.

Have the patient write the number that best describes how they have felt during the past month for each question. Look at the breakdown below to determine if their fatigue is primarily due to cognitive, physical or social concerns.

Question Breakdown of each Subscale:

Cognitive Fatigue: 1 4 5 6 11 12 18 21 26 30 33 34 35

Social Fatigue: 2 9 15 16 19 20 22 25 27 28 32 36 39

Physical Fatigue: 3 7 8 10 13 14 17 23 24 29 31 37 38 40

Scoring sheet retrieved from:

http://www.cptrehab.com/agencyforms/CPT%20forms/Fatigue_impact_scale_clinician_guide.pdf

Fatigue Assessment Scale (FAS) – (Michielsen et al, 2004)

The following ten statements refer to how you usually feel. For each statement you can choose one out of five answer categories, varying from Never to Always. 1 = Never, 2 = Sometimes; 3 = Regularly; 4 = Often; and 5 = Always.

		Never	Sometimes	Regularly	Often	Always
1	I am bothered by fatigue	1	2	3	4	5
2	I get tired very quickly	1	2	3	4	5
3	I don't do much during the day	1	2	3	4	5
4	I have enough energy for everyday life	1	2	3	4	5
5	Physically, I feel exhausted	1	2	3	4	5
6	I have problems starting things	1	2	3	4	5
7	I have problems thinking clearly	1	2	3	4	5
8	I feel no desire to do anything	1	2	3	4	5
9	Mentally, I feel exhausted	1	2	3	4	5
10	When I am doing something, I can concentrate quite well	1	2	3	4	5

Note: Items 4 and 10 require reversed scoring. The scale score is calculated by summing all items.

Demographic Questionnaire

1. Are you male [ ] or female [ ]
2. Age? [ ]
3. Trial 1: On a scale of 1 to 10, where 1 is not mentally tired and 10 is mentally exhausted, how do you feel at this moment in time [ ]
4. Trial 2: On a scale of 1 to 10, where 1 is not mentally tired and 10 is mentally exhausted, how do you feel at this moment in time [ ]

Appendix 2

Sequence of displayed letters trial 1 and trial 2, with accompanying verbal instructions to look left, middle or right (verbal instructions only heard by "SP" group).

Trial 1		Trial 2	
Trial Name	**Event Name**	**Trial Name**	**Event Name**
T1	show C	T1	show E
T2	show X	T2	show X
T3	show D	T3	show A
T4	show Z	T4	show K
T5	show V	T5	show V
T6	show R	T6	show A
T7	show M	T7	show Y
T8	show T	T8	show Y
T9	show I	T9	show K
T10	show N	T10	show J
T11	show P	T11	show R
T12	show X	T12	show E
T13	show K	T13	show U
T14	show T	T14	show N
T15	show U	T15	show M
T16	show R	T16	show O
T17 audio Right	show E	T17	show W
T18	show P	T18	show M
T19	show I	T19	show Q
T20	show I	T20	show I
T21	show R	T21	show A
T22	show L	T22	show R
T23	show M	T23	show F
T24	show T	T24 audio Left	show S
T25	show U	T25	show K
T26	show M	T26	show T
T27	show W	T27	show R
T28	show Q	T28	show E
T29	show E	T29	show I
T30	show H	T30	show Q
T31	show K	T31	show W
T32	show I	T32	show J
T33	show H	T33	show B
T34	show U	T34	show J
T35	show W	T35	show L
T36	show R	T36	show Y
T37	show K	T37	show R
T38	show B	T38	show K

T39	show D	T39	show A
T40	show G	T40	show M
T41	show A	T41	show V
T42	show N	T42	show S
T43	show D	T43	show B
T44	show E	T44	show G
T45 audio Left	show P	T45	show Y
T46	show K	T46 audio Right	show W
T47	show X	T47	show D
T48	show J	T48	show J
T49	show O	T49	show M
T50	show R	T50	show Z
T51	show S	T51	show B
T52	show O	T52	show N
T53	show M	T53 audio Left	show Z
T54	show P	T54	show J
T55	show V	T55	show E
T56	show W	T56	show F
T57	show O	T57	show G
T58 audio Left	show Z	T58	show M
T59	show X	T59	show W
T60	show M	T60	show N
T61	show R	T61	show T
T62 audio Left	show M	T62	show M
T63	show C	T63	show A
T64	show B	T64	show J
T65	show N	T65	show N
T66	show R	T66	show O
T67	show I	T67	show X
T68	show V	T68	show Y
T69	show D	T69	show E
T70	show J	T70	show X
T71	show E	T71	show X
T72	show Y	T72	show G
T73	show B	T73	show J
T74	show Q	T74	show J
T75	show V	T75	show S
T76	show V	T76	show O
T77	show Y	T77	show I
T78	show E	T78	show N
T79	show F	T79	show X
T80	show C	T80	show B
T81	show S	T81	show S
T82	show L	T82	show L
T83	show U	T83	show U
T84	show X	T84	show U

T85	show X	T85	show R
T86	show O	T86	show U
T87	show U	T87	show P
T88	show F	T88	show A
T89	show Q	T89	show A
T90	show U	T90	show R
T91	show F	T91	show K
T92	show Y	T92	show V
T93 audio Middle	show U	T93	show K
T94	show P	T94	show J
T95	show E	T95	show F
T96	show Q	T96	show C
T97	show M	T97	show M
T98	show S	T98	show B
T99	show U	T99	show D
T100	show H	T100	show T
T101	show I	T101	show J
T102	show S	T102	show B
T103	show S	T103	show F
T104 audio Right	show X	T104	show Y
T105	show W	T105	show U
T106	show X	T106	show S
T107	show X	T107 audio Right	show F
T108	show O	T108	show C
T109	show E	T109	show R
T110	show O	T110	show X
T111	show D	T111	show W
T112 audio Middle	show Y	T112	show Y
T113	show D	T113 audio Right	show L
T114	show W	T114	show R
T115	show J	T115	show F
T116	show U	T116	show W
T117	show J	T117	show J
T118	show W	T118	show N
T119	show T	T119	show F
T120	show B	T120	show M
T121	show E	T121	show C
T122	show E	T122	show J
T123	show I	T123	show I
T124	show H	T124	show G
T125	show P	T125	show Y
T126	show M	T126	show X
T127	show J	T127	show L
T128	show T	T128	show Q
T129	show O	T129	show H

T130	show U	T130	show J
T131	show Y	T131	show P
T132	show S	T132	show H
T133	show E	T133	show F
T134	show Y	T134	show Q
T135	show Y	T135	show L
T136	show E	T136	show T
T137	show X	T137	show G
T138	show Z	T138	show U
T139	show J	T139	show I
T140	show K	T140	show H
T141	show V	T141	show T
T142	show X	T142	show T
T143	show K	T143	show U
T144	show D	T144	show G
T145	show N	T145	show M
T146	show R	T146	show I
T147	show O	T147	show D
T148	show N	T148	show T
T149	show N	T149	show U
T150	show X	T150	show Y
T151	show T	T151	show C
T152	show N	T152	show Q
T153	show N	T153 audio Left	show R
T154	show O	T154	show N
T155	show E	T155	show D
T156	show X	T156	show T
T157	show L	T157	show M
T158	show M	T158	show T
T159	show A	T159	show I
T160	show D	T160	show X
T161	show J	T161	show Q
T162	show U	T162	show T
T163	show E	T163	show X
T164	show B	T164	show K
T165	show L	T165	show W
T166	show E	T166	show P
T167	show I	T167	show S
T168	show X	T168	show H
T169	show V	T169	show G
T170	show A	T170	show J
T171	show F	T171	show E
T172	show D	T172	show I
T173	show G	T173	show S
T174	show M	T174	show E
T175	show A	T175	show R

T176	show H	T176	show W
T177	show Q	T177 audio Right	show F
T178	show U	T178	show J
T179	show Q	T179	show C
T180	show Z	T180	show N
T181	show Y	T181	show R
T182	show U	T182	show Y
T183	show U	T183	show D
T184	show B	T184	show Y
T185	show T	T185	show Z
T186	show P	T186	show I
T187	show V	T187	show P
T188	show P	T188	show P
T189	show L	T189	show P
T190	show B	T190	show J
T191	show L	T191	show H
T192	show H	T192	show P
T193	show A	T193	show L
T194	show K	T194	show P
T195	show F	T195	show W
T196	show X	T196	show N
T197	show E	T197	show W
T198	show C	T198	show O
T199	show M	T199	show C
T200	show S	T200	show U
T201	show W	T201	show Y
T202	show I	T202	show S
T203	show Z	T203	show Y
T204	show W	T204 audio Middle	show K
T205	show X	T205	show I
T206	show F	T206	show X
T207	show R	T207	show O
T208	show Y	T208	show X
T209	show S	T209	show C
T210	show L	T210	show O
T211	show Z	T211	show R
T212	show S	T212	show K
T213	show Y	T213	show Q
T214	show Z	T214	show X
T215	show Z	T215	show I
T216	show N	T216	show M
T217	show S	T217	show B
T218	show R	T218	show L
T219	show Y	T219	show K
T220	show P	T220	show D

T221	show J	T221	show F
T222	show X	T222	show W
T223	show C	T223	show P
T224	show I	T224	show I
T225	show O	T225	show Z
T226	show B	T226	show S
T227	show B	T227	show Q
T228	show A	T228	show S
T229	show T	T229	show M
T230	show C	T230	show N
T231 audio Middle	show O	T231	show D
T232	show U	T232	show K
T233	show U	T233	show O
T234	show U	T234	show P
T235	show A	T235	show S
T236	show D	T236	show O
T237	show F	T237	show H
T238	show K	T238	show G
T239	show C	T239	show K
T240	show E	T240	show R
T241	show Y	T241	show G
T242	show X	T242	show C
T243	show K	T243 audio Right	show X
T244	show U	T244	show Z
T245	show F	T245	show G
T246	show P	T246	show M
T247	show W	T247	show H
T248	show H	T248	show B
T249	show Y	T249	show F
T250	show G	T250	show F
T251	show L	T251	show Q
T252	show I	T252	show I
T253	show Y	T253	show X
T254	show C	T254	show G
T255	show H	T255	show R
T256	show X	T256	show I
T257	show J	T257	show V
T258 audio Left	show Y	T258	show I
T259	show O	T259 audio Middle	show K
T260	show L	T260	show U
T261	show N	T261	show E
T262	show F	T262	show F
T263	show Q	T263	show M
T264	show N	T264	show X

T265	show A	T265	show X
T266 audio Right	show G	T266	show E
T267	show R	T267	show J
T268	show U	T268	show F
T269	show B	T269	show A
T270	show F	T270	show C
T271	show S	T271	show E
T272	show G	T272	show Y
T273	show C	T273	show Q
T274	show M	T274	show L
T275	show V	T275	show R
T276	show C	T276	show O
T277	show O	T277	show I
T278	show S	T278	show N
T279	show M	T279	show A
T280	show K	T280	show C
T281	show Y	T281	show D
T282	show L	T282	show Q
T283	show W	T283	show R
T284	show F	T284	show E
T285	show N	T285	show T
T286	show W	T286	show X
T287	show M	T287	show F
T288	show Z	T288	show W
T289	show T	T289	show S
T290	show R	T290	show C
T291	show T	T291	show V
T292	show A	T292	show T
T293	show Z	T293	show X
T294	show M	T294	show G
T295	show X	T295	show J
T296	show P	T296	show Y
T297	show W	T297	show G
T298	show X	T298	show Z
T299	show V	T299	show T
T300	show R	T300	show H
T301	show N	T301	show D
T302	show R	T302	show Q
T303	show K	T303	show S
T304	show L	T304	show Z
T305	show B	T305	show M
T306	show Y	T306	show Y
T307	show C	T307	show N
T308	show D	T308	show H
T309	show X	T309	show X
T310	show O	T310	show S

T311	show D	T311	show L
T312	show E	T312	show D
T313	show V	T313	show H
T314	show N	T314	show A
T315	show D	T315	show O
T316	show H	T316	show C
T317	show O	T317	show Z
T318	show I	T318	show T
T319	show E	T319	show W
T320 audio Right	show T	T320	show T
T321	show W	T321 audio Left	show K
T322	show C	T322	show H
T323	show M	T323	show X
T324	show Y	T324	show A
T325	show L	T325	show G
T326	show B	T326	show Q
T327	show N	T327	show H
T328	show O	T328	show R
T329	show U	T329	show B
T330	show J	T330	show E
T331	show H	T331	show I
T332	show J	T332	show F
T333	show I	T333	show C
T334	show M	T334	show D
T335	show Y	T335	show X
T336	show W	T336	show N
T337	show L	T337	show J
T338	show T	T338	show Y
T339	show Q	T339	show F
T340	show Y	T340	show N
T341	show H	T341	show D
T342	show R	T342	show X
T343	show H	T343	show U
T344	show B	T344	show E
T345	show Q	T345	show N
T346	show S	T346	show M
T347	show T	T347	show D
T348	show Q	T348	show E
T349	show T	T349	show B
T350	show K	T350	show I
T351	show S	T351	show R
T352	show A	T352	show A
T353	show L	T353 audio Middle	show X
T354	show T	T354	show J
T355	show X	T355	show U

T356	show V	T356	show X
T357	show U	T357	show P
T358	show M	T358	show J
T359	show B	T359	show H
T360	show S	T360	show Z
T361	show V	T361	show M
T362	show X	T362	show M
T363	show O	T363	show Z
T364	show J	T364	show X
T365	show Y	T365	show H
T366	show J	T366	show N
T367	show Y	T367	show O
T368	show K	T368	show I
T369	show F	T369	show L
T370	show S	T370	show N
T371	show O	T371	show F
T372	show B	T372	show A
T373	show X	T373	show E
T374 audio Right	show K	T374	show X
T375	show S	T375	show E
T376 audio Left	show P	T376	show V
T377	show E	T377	show Q
T378	show D	T378	show O
T379	show P	T379	show P
T380	show K	T380	show A
T381	show W	T381	show A
T382	show D	T382	show R
T383	show N	T383	show Q
T384	show M	T384	show I
T385	show R	T385	show F
T386	show Q	T386	show P
T387	show M	T387	show N
T388	show A	T388	show F
T389	show L	T389	show L
T390	show E	T390	show L
T391	show U	T391	show U
T392	show S	T392	show C
T393	show I	T393	show Z
T394	show F	T394	show G
T395	show I	T395	show B
T396	show C	T396	show S
T397	show K	T397	show L
T398	show J	T398	show P
T399	show G	T399	show F
T400	show D	T400	show H
T401	show L	T401	show F

T402	show N	T402	show O
T403	show D	T403	show K
T404	show Z	T404	show S
T405	show V	T405	show M
T406	show V	T406	show X
T407	show Y	T407	show J
T408	show I	T408	show E
T409 audio Middle	show P	T409	show V
T410	show S	T410	show B
T411	show M	T411	show V
T412	show B	T412	show F
T413	show W	T413	show M
T414	show P	T414	show I
T415	show O	T415	show E
T416	show M	T416	show K
T417	show B	T417	show D
T418	show N	T418	show S
T419	show X	T419	show A
T420	show C	T420	show P
T421	show V	T421	show B
T422	show U	T422	show V
T423	show G	T423	show X
T424	show U	T424	show Q
T425	show A	T425	show H
T426	show D	T426	show Y
T427	show I	T427	show X
T428	show E	T428	show B
T429	show I	T429	show I
T430	show A	T430	show F
T431	show S	T431	show X
T432	show W	T432	show S
T433	show L	T433	show J
T434	show D	T434	show N
T435	show A	T435	show L
T436	show V	T436	show V
T437	show W	T437	show Z
T438	show G	T438 audio Middle	show D
T439	show Q	T439	show I
T440	show Y	T440	show J
T441	show V	T441	show L
T442	show Z	T442	show H
T443	show H	T443 audio Middle	show Z
T444	show Q	T444	show R

T445	show L	T445	show K
T446	show Y	T446	show F
T447	show A	T447	show D
T448	show B	T448	show V
T449	show E	T449 audio Left	show I
T450	show Y	T450	show N
T451	show U	T451	show V
T452	show O	T452	show J
T453	show X	T453	show T
T454	show U	T454	show W
T455	show I	T455	show J
T456	show K	T456	show U
T457	show D	T457	show F
T458	show R	T458	show L
T459	show I	T459	show K
T460	show R	T460	show I
T461	show Y	T461	show M
T462	show K	T462	show V
T463	show S	T463	show O
T464	show H	T464	show F
T465	show K	T465	show C
T466	show H	T466	show D
T467	show K	T467	show D
T468	show R	T468	show Q
T469	show F	T469	show F
T470	show M	T470	show O
T471	show D	T471	show S
T472	show N	T472	show R
T473	show S	T473	show Y
T474	show D	T474	show M
T475	show N	T475	show F
T476	show K	T476	show J
T477	show H	T477	show M
T478 audio Middle	show M	T478	show P
T479	show H	T479	show U
T480	show T	T480	show E
T481	show I	T481	show R
T482	show P	T482	show A
T483	show W	T483	show R
T484	show I	T484	show M
T485	show F	T485	show Q
T486	show U	T486	show R
T487	show H	T487	show P
T488	show M	T488	show W
T489	show O	T489	show D

T490	show S	T490	show H
T491	show Y	T491	show J
T492	show R	T492	show A
T493	show K	T493	show X
T494	show X	T494	show B
T495	show E	T495	show E
T496	show O	T496	show V
T497	show S	T497	show N
T498	show M	T498	show M
T499	show A	T499	show W
T500	show I	T500	show O

Appendix 3

Calculation of observation time from initial millisecond (ms) Superlabs recorded time.

A	B	C	D	E	F	G	H
ms		**Min**	**Minus time**	**Correct for start time**	**Min**	**Direction**	**Correct?**
X	60000	X/60000 = Y	Cumulative start time (Z)	Y – Z = T	Min & Seconds	Right, left or middle	1, 2, or 3

1 = correct observation at correct time in correct direction

2 = observation at correct time but incorrect direction

3 = incorrect observation/no observation made

Appendix 4

Experiment set up