Change Blindness: Effects of Fatigue & Music Presence on Reaction Time

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Abstract

The abilities of visual perception are often misunderstood, with errors occurring more frequently than is often realised. The aim of the research was to investigate the visual error phenomenon of change blindness. An experiment using the flicker task paradigm explored the effects of fatigue, music presence, age and sex as influencing factors affecting task performance. Performance was measured via analysis of mean reaction times for correct responses. The sample comprised 60 participants (*m*=29, *f*=31), who fell into one of three age categories: 18-34 (*n*=32), 35-54 (*n*=18) & 55+ (*n*=10). Findings revealed that sleep deprivation had a negative impact on performance, as did increased age. Presence of music was also shown to have a positive significant impact, but only for the group of participants who reported feeling more fatigued than usual. Results verify the importance of sleep for attention related tasks, and real-world implications concern issues such as driving ability.

1. Introduction

1.1 *Visual Scene Perception*

Humans are capable of successfully searching for objects amongst cluttered scenes, to an ability level that remains unmatched by machines, due to a highly evolved visual system that prioritises and facilitates rapid search practices (Koehler & Eckstein, 2017). Scene perception is a very selective, temporary and complex process. Research shows that the visual system is only capable of recalling small amounts of detailed information while glancing between scenes. Interpretations about the layout and general gist of the scene tend to be the initial observations made, rather than focusing on the finer details (Simons & Levin, 1997). Visual search is usually strongly guided using internal contextual information relating to the target object (Koehler & Eckstein, 2017), but this is of no benefit when the target object is unknown. In this instance, the opposite effect occurs whereby similarity of items relating to the target object makes the search more difficult (Chun, 2000).

Resources for perceiving visual representations are distributed accordingly via attention, a concept often presenting with various definitions, although the process of selectivity always remains the core element (Cavanagh, 1992). Attention is a process involving the selecting and directing of focus, which enables the development of some information, while disregarding other information as less important (Posner & Peterson, 1990). This process involves top-down processing, and sometimes mistakes can occur resulting from overuse of top-down processing. These errors can be referred to as ‘smart mistakes’, and one such example is the incidence of change blindness (Most, Scholl, Clifford & Simons, 2005).

1.2 ***The Change Blindness Phenomenon***

Change Blindness (CB) is a phenomenon that occurs when one’s attention fails at being drawn to observe a change that is taking place; the type of change that once pointed out, appears as something obvious and easy to notice (Simons & Rensink, 2005). An interruption or brief transitional blank period, also known as masking, acts as a blocking agent preventing the perception of the change when it occurs (Tse, 2004). This process is known as ‘failures of selection in space’ (Simons & Levin, 1998), and the absence of adequately noticing the physical changes within the scene is the process of CB (Simons & Rensink, 2005). There is evidence that researchers have been investigating this phenomenon since the 1950’s, but interest surged in the mid 1990’s with the introduction of CB task paradigms; over time, more recent studies using the paradigm approach have increased emphasis regarding the necessity for resembling more real-world perceptual scenarios (Simons & Ambinder, 2005).

Inducing CB using a flicker paradigm task is the foremost approach taken by researchers investigating this phenomenon (Scholl, 2000). This paradigm consists of a spot the difference style procedure whereby two images are presented one after the other in a flickering sequence. The images are identical except for one feature, with a brief transitional blank period interrupting their presentation. This forms a four-part loop; image 1/blank/image2/blank, and this same loop repeats itself until the change has been observed, or until the sequence times out, if a time limit has been imposed (Turatto, Bettella, Umilta & Bridgeman, 2003). This type of CB flicker paradigm task is often devised and replicated for experimental purposes, and although it is a falsified procedure, it is widely used as a verified method for examining attention, as findings are transferable to real-world scenarios (Scholl, 2000).

One of the most well-known experiments relating to failures of selection in space was carried out by Simons & Levin (1998), who set up a test involving a person asking for directions. Two people engaged in a verbal exchange are interrupted by workers walking between them carrying large white board, and as this interruption occurs the person asking for directions swaps places with a new person. The study revealed that only half of the test subjects noticed that the person had changed. Studies like this provide evidence that it is not possible for our attention to process and attend to all the information that is constantly flooding our senses vying for attention. These authors discuss how this may be partly due to evolutionary features ensuring that the most pertinent information at any moment in time is the one that will be given attention, and hence reducing the intake of information that is deemed secondary and less important.

Highlighting CB is important is because it challenges the incorrect common consensus that surrounds how the visual system operates; many people are under the impression that what we see when observing visual surroundings is a true representation of what is actually there, but this is not always the case (Rensink, O' Regan & Clark, 2000). Often, the level of consciousness a person has about their surrounding environment is far more meagre than they instinctively believe (Simons & Ambinder, 2005). Therefore, the CB flicker task paradigm is useful for illustrating how our attention system often fails with perceiving, remembering and attending to every detail within a scene at once, even though we may be trying hard to do so

(Rensink, O' Regan & Clark, 1997). Furthermore, the implications of CB are very significant considering that this masking effect can and does occur frequently, during the brief transitional period induced by the blink of an eye (O'Regan, Deubel, Clark & Rensink, 2000).

CB task experiments are formulated whereby participants complete several tasks in succession. During this process there are times when the changes will be easily detected, but also times when the change goes undetected altogether (Rensink, O' Regan & Clark, 2000). A real-life application of CB concerns the fact that people tend to wrongly assume that their attention will be automatically drawn to critical events as they happen, such as a pedestrian stepping out in front of their car while driving, but CB confirms that this may not necessarily be true. Hence, CB has the potential to create catastrophic consequences for tasks that require high levels of vigilance, such as driving (Simons & Ambinder, 2005). Moreover, this difficulty with detecting all environmental changes as they are occurring is further exacerbated if the change was unexpected, or of secondary importance to the task already being undertaken by the observer (Levin, Momen, Drivdahl & Simons, 2000). In relation to driving, this observation provides one explanation for the dangers of doing other tasks while driving, such as speaking on the phone, because if the phone conversation is taking the primary attention focus of the driver, then the road becomes of secondary importance, hence greatly increasing driver susceptibility to CB. However, it is worth noting that CB can also have an advantageous role. Firstly, this filtering process prevents our visual and attention systems from becoming overwhelmed by the constant sensory input that it is subjected to (Cavanagh, 1992), and from an applied viewpoint it is also beneficial in the entertainment industry, often relied upon by television and filmmakers, as a perceptive flaw that allows for mistakes to go unnoticed by the majority of audiences (Levin et al., 2000).

1.3 ***The Impact of sleep deprivation***

Sleep is a vital component for health, and consequently ensuring survival of the human body. Research widely acknowledges the detrimental effects of sleep deprivation on human functioning, specifically in relation to cognitive ability, motor performance and subjective experiences (Pilcher & Huffcutt, 1996; Lim & Dinges, 2010). From a medical viewpoint, sleep deprivation occurs when too little sleep prevents a person feeling fully awake and alert, to an extent that impacts their physical and cognitive abilities (Davis, 2018). Scientific guidelines assert that the average adult requires 7-9 hours' sleep per night (National Sleep Foundation, 2007). These guidelines were recently re-examined by the institute, with rigorous testing and analysis leading the foundation to reiterate that it strongly endorses 7-9 hours' sleep as being the necessary and appropriate amount of sleep needed by adults (Hirshkowitz et al., 2015).

Literature appears to present numerous definitions for sleep deprivation, but it can commonly be broken down into acute (<4 hours/24 hours) or partial (<7 hours/24 hours) categories, and can occur as a once-off incidence, or be a more chronic longer-term condition (Durmer & Dinges, 2005). It is noted that a substantial amount of literature tends to focus on the effects of acute sleep deprivation, even though chronic partial sleep deprivation is a more regular occurrence in everyday life (Alhola & Polo-Kantola, 2007). Therefore, the current study will investigate the effects of the latter, looking at partial sleep deprivation defined as <7 hours sleep in the preceding 24-hour period. Furthermore, the terms sleep deprivation and fatigue will be used interchangeably throughout the paper, but both terms are in fact referring to this prior-defined definition of partial sleep deprivation. Partial sleep deprivation is of specific interest for the current research because it has been shown to bear substantial influence on attention (Alhola & Polo-Kantola, 2007).

It is recognised that the amount of sleep an individual requires differs significantly between individuals, depending on personal attributes, and research also suggests that some individuals are more vulnerable to the negative effects of sleep deprivation than others (Van Dongen, Vitellaro & Dinges, 2005). However, although some twin studies may suggest sleep requirements are determined by genetic predispositions for between 31% – 55% of individuals (Watson, Buchwald, Vitiello, Noonan & Goldberg, 2010), the basal amount of sleep required for adequate physical and cognitive functioning rarely falls below the seven-hour threshold (Alhola & Polo-Kantola, 2007). Furthermore, a meta-analysis review of literature by Pilcher & Huffcutt (1996) concluded that sleep deprivation and its consequences are too often underestimated by researchers.

Detrimental effects of reducing sleep by 1.5 hours per night for a one-week period, were shown via significant impacts on cognitive performance in research conducted by Bonnet & Arand (1996), which also highlighted that the effect was evident from day after one of the study. Similarly, another study that reduced participant sleep from 8 to 6 hours per night revealed a 32% reduction in cognitive abilities the next day (Rosenthal, Roehrs, Rosen & Roth, 1993). Examples of cognitive deficits resulting from fatigue include decreased ability in speed of processing (Leproult et al., 1997), lapses of ability to sustain attention levels (Dinges et al, 1997), along with deterioration of working memory function, specifically the capacity to encode, manipulate and retrieve information (Chee & Choo, 2004; Durmer & Dinges, 2005). An argument refuting this has shown that there may be times when the sleep deprived brain is able to temporarily perform at a similar level to a rested brain, if the task in question is complex and engaging (Linde, Edland & Bergstrom, 1999; Harrison & Horne, 2000). This suggests that the mind may have the potential capability to overcome fatigue effects temporarily, when it desires to do so.

One study that linked the effect of fatigue and age differences on work productivity, found that participants under the age of 25 displayed no significant correlation between RT and productivity when fatigued, but showed an evident correlation between subjective feeling of fatigue and productivity. However, for the over 25 age category that same influence was not evident; there was a significant correlation between RT and work productivity when fatigued, but subjective feeling of fatigue did not further impact productivity (Setyawati, 1995). This demonstrates two things in relation to fatigue, reaction time and work productivity. Firstly, fatigue appears to have a greater negative influence on performance as age increases. Secondly, the research suggests a connection between the role of subjective experience in relation to feeling fatigued. The first observation is explicable in terms of cognitive function as there is an expectation of the slowing down of cognitive ability with age (Owsley, Sekular & Siemsen, 1983), and it is unsurprising to see that this factor was further impacted by fatigue. The second observation is less anticipated but might be explained by culture and work ethic; perhaps older people have a different mindset after a greater number of years working, whereby there is an understanding that the work must be done regardless of feeling tired.

One explanation for reductions in attentional processing abilities because of fatigue has been described by the 'Lapse Hypothesis'. This hypothesis, put forward by Dinges & Kribbs (1991) highlights how attention declines in irregular stages that occur as intermittent blips in consciousness, as opposed to a continuous loss of focus. As the brain becomes more and more fatigued the frequency and duration of periods where attentional awareness is switched off increases. In terms of a CB task this would explain how being fatigued can cause a person to achieve fewer correct responses, if their attention goes through bouts of being on and off during the task. However, research by Dinges et al. (1997) found the hypothesis to be an insufficient explanation for the prolonged neurological changes which occur in participants exposed to chronic fatigue. Therefore, although there is some support for the hypothesis, research now suggests it may only be of any relevance in instances where fatigue is caused by an acute sleep deprivation state.

Numerous research studies indicate that there are just as many dangers associated with driving while sleep deprived, as there are with drink driving. One such study by Williamson & Feyer (2000) compared a group of sleep deprived participants with another group who had consumed alcohol, and used a variety of tasks to measure cognitive functions via RT. They found that performance levels of the fatigued group were comparable to that of the alcohol group, with a progressive element that suggested as fatigue level increased the resulting effects corresponded with effects of having consumed higher doses of alcohol. The fatigued group even displayed up to 50% slower RT scores than the alcohol group, during some tasks. Overall, sleep deprivation was reported as equivalent to, or in some instances worse than, having a blood alcohol concentration level (BAC) of 0.05%. Similar observations were also revealed by an experiment using a simulated driving procedure, where ability of the participant to keep in their own lane when sleep deprived was akin to that of a person with BAC of 0.07% (Fairclough & Graham, 1999). Currently, in Ireland the legal alcohol limit for driving is BAC 0.05 for unrestricted fully licenced drivers, and 0.02 for learner drivers (Road Safety Authority [RSA], 2018). It is estimated that at any one time approximately 20% of all adults are functioning in a sleep deprived state (Hublin, Kaprio, Partinen & Koskenvuo, 2001), and this statistic suggests that perhaps it is time due diligence is given to the serious consequences that may arise from the attentional lapses that go hand in hand with fatigue and sleep deprivation.

1.4 *Effects of the presence of music on cognitive performance*

Older research tended to primarily focus on assessing music as a distractor during reading tasks. One such study found pop music to be a significant distractor (Henderson, Crews & Barlow, 1945), but both this study and another similar study found no evidence that listening to classical music had a distracting influence on the tasks (Freeburne & Fleisher, 1952). However, recent research is a lot more complex in its methodologies, and thus shows different results; the distraction of music presence was measured via tracking eye movements during a reading task involving word recognition. Results showed that the music did cause significant distraction as participants needed to re-read words more often to comprehend them and needed to gaze at the words for longer (Zhang, Miller, Cleveland & Cortina, 2018). This study also stated that music presence resulted in less efficient and perhaps even worsened comprehension, and performance further deteriorated when the material was difficult. However, these authors then conclude by stating that the impact on word recognition did not appear detrimental overall, as it was usually compensated for by the re-reading. Upon reading this research, the reader is left with some confusion as to the actual extent of the effects of music presence as a distractor.

Alternative research appears to suggest that music presence has either no effect or a positive effect on performance. A study by Consiglio, Driscoll, Witte and Berg (2003) found that listening to music whilst driving had no effect on braking reaction time, during a laboratory-controlled driving simulation experiment. Disputing this, however, research assessing the impact of music presence on recall performance found that it had the effect of significantly impairing performance, but that unfamiliar music was less impairing (Perham & Sykora, 2012). Furthermore, another study suggested that only music with lyrics significantly impacted on attention and performance (Shih, Huang & Chiang, 2012). In relation to the current study, the chosen background music is of a classical style, with no lyrics.

Specifically looking at the type of music, one study revealed classical music had a slightly negative effect on performance, compared to the control group, but the effect was minimal in comparison to the effects of other types of music, such as high intensity hip-hop which was found to be highly distracting (Chou, 2010). Contrary to this, another study assessing cognitive performance of older adults, found classical music had a positive effect and increased working memory performance (Mammarella, Fairfield & Cornoldi, 2007). In addition to these findings, the concept that music presence may enhance RT was proposed by Turner, Fernandez and Nelson (1996) whose findings asserted that music being played at a level comfortable to the individual had the effect of decreasing RT, thus actually enhancing the performance levels of the individual. However, this is disputed by Banbury, Macken, Tremblay & Jones (2001) whose study concluded that quiet backgrounds are optimal and have a markedly positive effect on increasing efficiency for cognitively demanding tasks. A different approach was taken by Pacheco-Unguetti & Parmentier (2014) who examined emotive connections and found sad music was more distracting, and increased RT for cognitive tasks.

Thus, the effect of music presence is recognised as being a very complex issue. Almost all research suggests the effects are multi-factorial, and that it is difficult to draw conclusions due to the numerous confounding variables that may also bear influence, such as the type of music, the type of task being undertaken, and the personal characteristics of the individual (Furnham & Allass, 1999; Banbury et al., 2001). Overall, literature discussing the topic is very mixed in its findings, with lots of conflicting evidence as to whether the effects are positive, negative or in fact non-existent.

1.5 *Influences of sex and age on cognitive performance*

When assessing reaction times for visual tasks, sex differences tend to follow a pattern whereby RT tends to be longer for females than males. Blough & Slavin (1987) found this to be true, but their study also noted that female accuracy outweighed their male counterparts and emphasized that this appears to be another common theme that emerges in studies. Another such study, which also revealed a speed-accuracy trade-off, was conducted by Der & Deary (2006) and found women to have a slower Mean RT, but better accuracy results and more correct answers (Der & Deary, 2006). This was disputed by more recent research that examined saccadic RT in infants and adults and found gender differences for infants but no differences for adults (Kenward et al., 2017). Abilities related to cognitive tasks appear to be influenced by age in ways which follow an overall pattern, suggesting a period of rapid development and improvement throughout childhood, with a peaking of performance in the late teens and early twenties, followed by a consistent but gradual decline of cognitive functioning as age progresses (Owsley, Sekuler & Siemsen, 1983).

Much research denoting differences between age groups agree that older adults are significantly slower than their younger counterparts at visual search tasks and change detection

(Pringle, Irwin, Kramer & Atchley, 2001; Rensink, 2000; Humphrey & Kramer, 1997). One longitudinal study revealed a consistent slowing of RT with increased age, that was more prominent in females than males. More pronounced changes occur in the later decades than the earlier years, with very visible further decreased RT between age seventy and age eighty, than occurred between age twenty and thirty, for example (Fozard, Vercruyssen, Reynolds, Hancock & Quilter, 1994). The link between this deterioration in RT and age is further supported in a study by Veiel, Storandt & Abrams (2006) who also found older adults to be markedly slower at noticing changes within a visual stimuli paradigm. These authors hypothesised that an explanation for this may relate to the likelihood that older persons may be more cautious and careful when completing RT tasks, and this factor may be of significance during their performance of tasks.

1.6 *Gaps in current research literature*

Although there is plentiful research concerning sleep deprivation and fatigue, as previously mentioned much of the literature tends to focus on acute sleep deprivation only. Therefore, it was intended that the current study findings could complement the research on partial sleep deprivation. Another research gap concerns the link between age and RT and is criticized by Der & Deary (2006) who claim that most RT research contains participant samples consisting entirely of an older population, and that there are few studies that are inclusive of a range of different ages within the one study, and so allow for comparison of age differences. Therefore, as the current study encompasses participants of varying ages, it was hoped that it would contribute towards addressing this gap within the research also.

Regarding the impact of music presence on tasks requiring attention, literature seems to be somewhat mismatched, inconclusive and often contradictory. Much of the literature seems to focus on music as a distractor during study related aspects such as reading. Although study related topics are of importance, it is suggested that there is a gap in the literature in relation to the effects of music presence on other types of attentively demanding tasks. There is research that examines the possible link between music presence and driving, but even that is sparse and at times inconclusive in its findings, due to the influence of confounding variables that tend to be difficult to control for. Overall, a general rhetoric appears time and time again throughout the literature stating that the effect of music presence on tasks requiring attention is a difficult concept to address. Therefore, the current study hopes to add to the literature, specifically in relation to the effects of classical music presence on performance during a CB task, of which there does currently seem to be a similar existing study available.

1.7 *Aims, objectives & rationale for the current study*

Investigation of the link between fatigue and RT is pertinent to many areas of life. Research in America suggests that fatigue is a major causal factor of up to sixty percent of road traffic accidents (Horne & Reyner, 1995), and fatigue is also thought to greatly increase the risk of all accidents that can occur because of human error (Dinges, 1995). As previously discussed, there are also studies which suggest that sleep deprivation effects performance to a level on par with the effects seen when an individual has consumed varying amounts of alcohol (Williamson & Feyer, 2000; Fairclough & Graham, 1999). Hence, it is discernible that the relationship between fatigue and attention is one that requires investigation. The CB task paradigm relates specifically to visual scene perception and is a proven method for measuring

RT performance. Visual scene perception tasks are relevant in real-life scenarios such as driving and providing eye witness testimony, or any other multiple scenarios where there is an ever-present need to be alert and notice change, especially minor detail changes.

Regarding the detrimental effects of fatigue, it has been noted that the prevalence of persons conducting their lives in a manner pertaining to being regularly fatigued only continues to increase year on year. This was highlighted by a study examining sleep trends in American adults between the years of 1985 – 2012, which found that the number of adults regularly sleeping for less than six hours in a 24-hour period had almost doubled during that time frame (Ford, Cunningham & Croft, 2015). It is realised that this substantial shift is mainly caused by environmental factors, such as work and family demands (Basner et al., 2007). However, having rational reasons for being sleep deprived doesn't subtract from the negative consequences it may cause, at both an individual and societal level. Therefore, as psychologists it is important to continue to research and highlight the importance of this topic.

The current study aimed to investigate RT in relation to completion of a series of CB tasks, focusing on assessing the impact of different levels of fatigue on performance, alongside the effects of the presence of music, and the potential influences of the demographic variables of age and sex. In conclusion, there does not appear to be a similar study examining the effects of partial sleep deprivation and fatigue, also incorporating the potential effects of the presence of music on RT, using the CB task paradigm. Therefore, it was hoped that this research could be a valuable addition to this field of research within psychology.

1.8 *Research hypotheses*

- (H1) Hours of sleep will influence RT during performance of a CB task.
- (H2) Participant sex will influence RT during performance of a CB task.
- (H3) Participant age will influence RT during performance of a CB task.
- (H4) The presence of music will influence RT during performance of a CB task.

  (4a) There will be an interaction effect between music presence and hours of sleep gained the previous night.

  (4b) There will be an interaction effect between music presence and subjective perception of fatigue.

2. Methodology

2.1 *Participants*

The research comprised of a sample of sixty participants, recruited using combined methods of convenience and snowball sampling. Participant inclusion criteria required persons to be age eighteen and over & have no history of any medical issues which may have been affected by the flashing images that occurred during the experiment. Upon completion of the experimental component, participants were asked to complete a basic demographical questionnaire relaying information about their sex, age and fatigue levels. To ensure external validity it was necessary to gain participants representative varying demographical categories. Therefore, participants included male and female (m=29, f=31), and fell into one of three age categories: 18-34 (n=32), 35-54 (n=18) & 55+ (n=10).

2.2 *Design*

The study is a quantitative quasi-cross-sectional experiment, denoting that data will be collected one time only, and that some of the independent variables being examined are innate to the participant and cannot be randomly assigned by the researcher (Harris, 2008, p.230). Furthermore, the between-subject method was chosen, which symbolizes that each participant completed only one of the two possible conditions for the experimental procedure; music or no-music. This was deemed appropriate to facilitate comparison and subsequent analysis between the two different experimental conditions. Random assignment of participants to either the music or no-music condition depended on their subject number, and allocation was conducted this way as a control measure. The type of music used in the with-music condition consisted of a selection of classical tracks with no lyrics. However, it should be noted that music presence was only one independent variable, and not a relevant component of all hypotheses. Therefore, the two conditions were grouped together to form an overall sample for all analysis of variables unrelated to music presence.

The experiment consisted of two components; firstly, a uniquely designed experiment conducted via the OpenSesame psychology platform on the researchers own laptop, followed by a short demographic questionnaire set up on google drive (or else hand written, i.e. in instances where Wi-Fi was unavailable, and later entered to Google Drive by the researcher). The demographic questionnaire requested information about participant sex, age category, number of hours of sleep gained the previous night, and a subjective question about whether or not they perceived themselves to be feeling more fatigued than usual (see Appendix A for sample questionnaire).

The dependent variable was RT & the independent variables were hours of sleep the previous night, presence of music, age, sex and subjective fatigue. Measuring RT is a well-established method used in experiments in cognitive psychological research, and is often considered one of the most pervasive of dependent variables within psychology, as it has the ability to adequately reflect potential differences within the structure of the mind (Luce, 1986). There are two types of reaction time; simple reaction time occurs when there is a singular stimulus and only one possible form of response, whereas choice reaction time applies when there are two or more stimuli demanding a variety of responses (Colman, 2009, p. 638). The experiment for this research involves measurement of simple reaction time.

One possible issue that concerns using a CB task to measure RT relates to the possibility of a practice effect occurring. However, research by Donovan & Radosevich (1999) asserts that tasks with spaced practice conditions are more susceptible to the practice effect, than tasks that are completed as part of a once- off design, whereby the participant starts and finishes the task continuously without rest. Therefore, due to the design of the current study, it was hoped that this practice effect would not bear any influence, as participants only completed one set of trials continuously, during a once-off event. Another potential problem with the CB task procedure, also relating to design, concerns one study that provided evidence suggesting that using fictitious unnatural scenes, or scenes with only a small number of easily distinguishable objects, has the effect of increasing ease of the task, and therefore, substantially decreasing RT scores (Intriligator, He & Barton, 1998). However, the current study aims to avoid this issue by using verified CB task images, that are of natural scenes, and are very detailed in their design.

2.3 ***Materials & Apparatus***

The OpenSesame platform (version 3.1) was downloaded on the researchers own laptop (Toshiba, Windows 10) and utilised to create the experiment. The files used for the CB task trials (Wolfe, 2015), and the music that accompanied the with-music condition (“Free Music Archive,” n.d.) were all accessed online by searching for freely available and copyright free content (see Appendix B for the list of music tracks that accompanied the with-music condition). Data for each participant was saved in Microsoft Excel (2016 version). The automatic data saved by the programme was set up to consist of several elements including correctness of response & RT for each trial. Upon completion of data collection, all relevant information was examined and formulated using excel features, to gain average scores, and then exported to the Statistical Package for the Social Sciences (SPSS) programme. Information from the questionnaires was also formulated and inputted into SPSS.

2.3.1 *Statistical analysis*

Inferential and descriptive statistics were analysed using SPSS-24 on a Toshiba (Windows 10) laptop. SPSS is a recommended and popular analysis tool amongst psychologists and was deemed suitable for the current study because it facilitates a large variety of techniques for analyses, data conversions, and formulae of outputs (Arkkelin, 2014, p.2). Significance level for all tests was set at .05% as this is deemed the minimum appropriate level to be able to reject the null hypothesis within psychological research (Harris, 2008, p.184). Within SPSS, the tests that were chosen for analysis were one-way and two-way between groups mixed Analysis of Variance (ANOVA). ANOVA analysis is appropriate for comparing the mean RT scores of two or more groups, using post-hoc comparisons to assess for significance, and two-way ANOVA has the added advantage of being able to decipher if there is an interaction effect between the independent variables being tested (Pallant, 2007, p.103-104).

2.4 *Procedure*

The experiment was conducted in a variety of locations. However, it was ensured that the room was quiet, and the only persons present during the experiment were the participant and the researcher. This ensured each participant had no distractions that would affect their ability to concentrate. The room consisted of a height appropriate table and chair to ensure comfort while completing the laptop-based experiment, and adequate lighting to aid the process. Upon entering the room, the participant was first given a brief verbal explanation of the study and what the experimental process would entail. Once the researcher assigned the participant a subject number, the laptop was handed over to the participant, and from here on in the experimental design via OpenSesame provided detailed step-by-step instructions which guided the participant through the experiment. For participants who were assigned to the with-music condition the volume level was set at 60 decibels on the laptop.

Ethics were considered, with reference to guidelines provided by Dublin Business School and the Psychological Society of Ireland. The experiment involved limited ethical issues. The primary issue related to consent, and this was addressed via the information page at the beginning of the OpenSesame programme, which was set up so as the experiment could not have continued unless consent had been agreed. The experiment was considered low risk regarding the possibility of causing harm or distress to participants. A potential health risk issue relating to the fact that the flashing images may cause problems for individuals who suffer with migraine headaches or have sensory issues, was highlighted as part of the initial information and consent form. Participants were informed of their right to withdraw at any time. Participants were given a subject number, and all responses were anonymised.

2.4.1 *Experimental Protocol*

Upon handing the laptop over to the participant, the initial aspect they encountered consisted of a participant information and consent page (see Appendix C). This page included information about anonymity, possible health risks, the right to withdraw at any time, the inclusion of a questionnaire component, and asked the participant to voice any queries they may have had at this stage. There was a box which needed to be ticked signifying that the information had been read and understood, followed by a consent agreed and participate feature that allowed the experiment to continue to the next step. Once consent is agreed, the next page provided detailed instructions about how the experiment was formulated, and what the participant needed to do during it (see Appendix D).

Each condition consisted of 23 trials. Three of these were practice trials completed before the core trials commenced. These practice trials followed the exact same process as the core trials, only the answers were more obvious and easier to answer, and this was to ensure participants gained a good understanding of the procedure before commencing with the core trials. The researcher decided to assist participants during the practice trials, to help them get familiar with the process. Therefore, the practice trials were considered invalid as answers, and later removed from data set prior to analysis.

Each trial included a pair of images of a visual scene with an intermittent blank grey image displayed between the two images, and again after the second image. The pair of images were identical except for one feature, which was absent from the second scene image (see Appendix E for sample images). The four images together made up one loop sequence. Each of the four images were presented for 250 milliseconds, making each loop sequence one second long in completion time. Each trial continued for a maximum of fifteen loops, after which it then timed out if no attempt to answer has been initiated by the participant. During each trial participants had been instructed to click the space bar, as soon as they noticed the change that was occurring as the images were flickering. Upon clicking the space bar, the computer programme stored the data relating to the RT and immediately took the participant to an answer page. The answer page consisted of a multiple-choice question (MCQ) scenario with four options to choose from (see Appendix F for sample MCQ). The participant chose what they deemed to be the correct answer and clicked continue, and the next trial commenced straight away. On the occasions when timeout occurred, the screen instructed the participant that the trial had timed out, before immediately commencing with the next trial once they followed the onscreen advice telling them to press any key to continue.

3. Results

This section will provide descriptive and inferential results relating to analysis of the SPSS data, which comprised both the experiment and questionnaire results. Only data pertaining to correct participant responses was used for analysis. All results are reported in milliseconds, and to two decimal places. Significance levels are determined and reported at the .05 level.

Prior to commencing analysis, assumption checks were carried out which revealed a normal distribution for correct responses. Assessing normality, the overall mean RT (6696.94) and the 5% trimmed mean RT (6655.69) were close enough together in score to indicate that there were no extreme scores or outliers bearing influence on the data set. Furthermore, the Skewness (.466) and Kurtosis (-.140) were both below 5, aiding the decision to use parametric tests to test the hypotheses.

3.1 *Descriptive Statistics*

The sample consisted of 60 participants, 52% were female (*n*=31) and 48% were male (*n*=29). The range of mean RT varied from a minimum time of 3635.44 to a maximum mean RT of 10481.75, with an overall mean RT score of 6696.94 (*M* = 6696.94) and standard deviation of 1631.58 (*SD* = 1631.58) for all participants combined. Participant age was divided into three categories; 18-34 (*n*=32), 35-54 (*n*=18) and 55+ (*n*=10). A trend emerged suggesting that females tended to present with better overall mean RT scores than males; females were slightly faster at 6686.99 (*SD* = 1840.83), compared to males (*M* = 6707.57, *SD* = 1406.55). Also, females in the 18-34 age category showed the lowest mean RT for any group overall (*M* = 5718.09, *SD* = 1299.10), whereas males in the 55+ category had the highest overall group mean RT (*M* = 9260.59, *SD* = 1726.98).

Mean RT scores revealed that younger persons performed better overall at the experimental task than older persons, with greatest differences observed between the over 55's age group and both of the other two categories. A smaller difference was detected between the other younger and middle age group. Mean RT and SD scores in relation to age categories are displayed via Table 1.

Table 1. Mean RT and Standard deviations for different age categories.

Age Category	Mean RT	Std. Deviation
18-34	6060.85	1273.38
35-54	6688.89	1315.10
55+	8746.91	1578.32
Total	6696.94	1631.58

Each participant was randomly assigned to one of two conditions based on their subject number. An even subject number partook in the no-music condition (*n*=29) whereas an odd subject number denoted that background music was present during the experiment (*n*=31). A clear pattern emerged throughout the age categories revealing that those in the audio category showed overall faster reaction times, than those in the no-music category for each of the age groups. These differences are demonstrated via Figure 1.

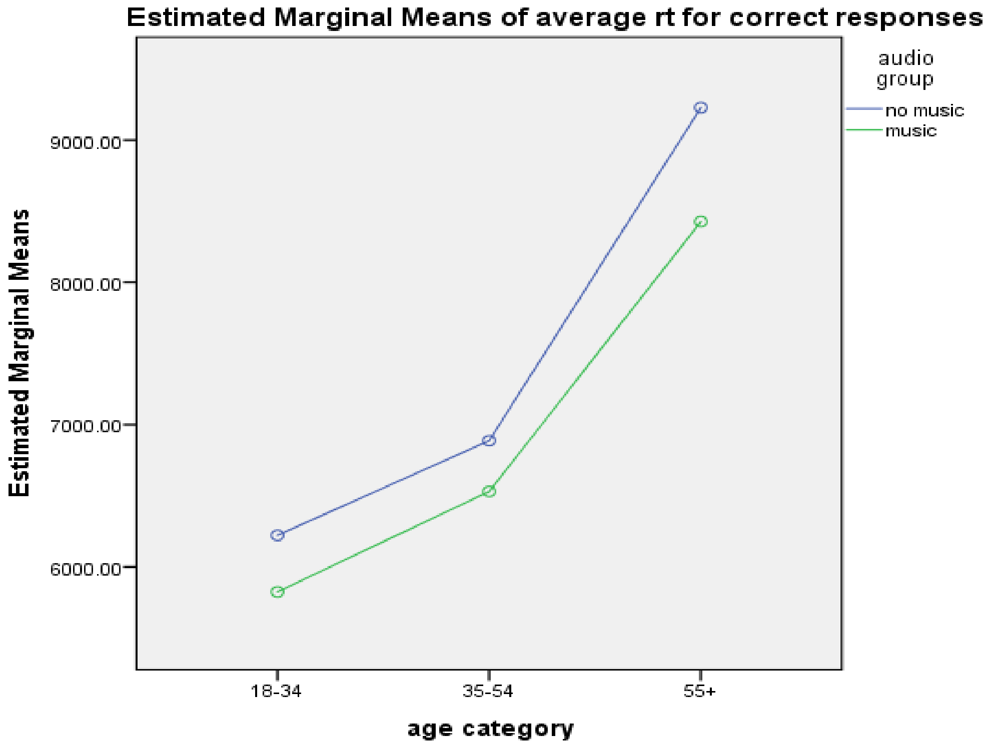

Figure 1. Graph illustrating effects of music/no-music on age categories.

Participants were asked to provide information regarding how many hours they had slept the previous night. There were 4 categories; 0-4 (*n*=12), 5-6 (*n*=26), 7-8 (*n*=17) and 9+ (*n*=5). Participants who had 7-8 hours' sleep the previous night performed best overall, followed by those who had 9+ hours, then the 5-6 hours group, and finally those in 0-4 hours category had the lowest mean RT score. This information is provided in Table 2.

Table 2. Mean RT and Standard deviation in relation to hours of sleep the previous night.

Hours of sleep	Mean RT	Std. Deviation
0-4	7644.93	1831.59
5-6	7028.23	1542.23
7-8	5598.57	1045.97
9+	6433.48	1474.60

Participants were also asked whether they felt more fatigued than usual. This subjective perception of fatigue had little difference on overall reaction times. The mean RT score for participants who answered yes to being more fatigued than usual (*n*=35) was 6960.76 (*SD* = 1624.67), compared with those who answered no (*n*=25) having a mean RT of 6327.59 (*SD* = 1600.38).

3.2 *Inferential Statistics*

Hypothesis 1: Effect of number of hours sleep on RT

A one-way ANOVA showed that mean RT was significantly impacted by the number of hours sleep gained by the participant the previous night ($F (3, 56) = 5.25$, $p = .003$). More specifically Tukey HSD post hoc analysis revealed significant results between the 0-4 & 7-8 hours of sleep categories (Mean difference = 2046.36, p= .003, CI [95%] 569.38, 3523.34) and between the 5-6 & 7-8 categories (Mean difference = 1429.67, p= .016, [CI] 207.83, 2651.51). Thus, highlighting that hours of sleep significantly influence performance. Scores showed best mean RT results for the 7-8 hours' sleep category (*M* = 5598.57, *SD* = 1045.97), and the category denoting the least amount of sleep at 0-4 hours showed the highest mean RT of 7644.93 (*SD* = 1831.59).

Hypothesis 2: Effect of sex on RT

Mean RT for male participants was 6707.57 (*SD* = 1406.55), and 6686.99 (*SD* = 1840.83) for females. Although female mean RT scores were faster overall in all categories the differences were minimal. A one-way ANOVA showed the results were not significant (F (1.58) = .002, p = .962). Therefore, proving the null hypothesis to be correct for this hypothesis.

Hypothesis 3: Effect of age on RT

A one-way ANOVA showed that mean RT performance was affected by age, as the scores differed significantly between the age categories (F (2, 57) = 15.34, P = <.001). More specifically Tukey HSD post hoc analysis revealed significant differences between the older age category of 55+ and the youngest age category of 18-34 (Mean difference = -2686.06, p = <.001, [CI] -3852.79, -1519.33), and between the 55+ and 35-54 age categories (Mean difference = -2058.02, p = .001, [CI] -3328.20, -787.85). These results highlight that younger participants performed better than older participants during the experiment. Further analysis of this is presented in Table 3.

Table 3. Mean differences between age categories

(I) Age Category	(J) Age Category	Mean Difference (I-J)	Sig.
18-34	35-54	-628.04	.205
	55+	-2686.06*	.000
35-54	18-34	628.04	.205
	55+	-2058.02*	.000
55+	18-34	2686.06*	.000
	55+	2058.02*	.000

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

Hypothesis 4: Effect of the presence of music on RT

The Mean RT score for the music group was 6606.44 (*SD* = 1691.37), and for the no-music group it was 6781.60 (*SD* = 1596.88). A one-way ANOVA was conducted to investigate if there was an overall effect of music presence on mean RT scores, but the results were not significant ($F(1, 58) = .170$, $p = .681$). Therefore, the null hypothesis is accepted for the effect of the presence of music on RT.

*Hypothesis 4(a)***:** Interaction between music presence and hours of sleep

A two-way ANOVA was used to analyse the interaction between music presence and hours of sleep. Although results show that those in the music category scored better mean RT than those in the no-music group, the differences were not strong enough to be significant ($F(3, 52) = 1.63$, $p = .193$). Regardless of music presence or not, hours of sleep the previous night was the overriding influencing factor, as the same pattern of mean RT results prevailed with or without music, whereby 7-8 hours' sleep showed the best RT scores, and 0-4 hours' sleep the worst mean RT. This is further demonstrated via Table 4.

Table 4. Mean RT & Standard Deviation in relation hours of sleep and music presence

	Music		No Music	
Hours of Sleep	Mean RT	Std. Deviation	Mean RT	Std. Deviation
0-4	6737.62	2377.84	8293.00	1097.69
5-6	7385.59	1487.52	6721.92	1575.68
7-8	5396.05	886.36	5778.58	1192.99
9+	6525.77	1685.97	6064.33	n/a
Total	6606.44	1691.37	6781.60	1596.88

*Hypothesis 4(b)****:*** Interaction between music presence and subjective perception of fatigue

A two-way between-groups ANOVA examined the interaction between subjective perception of fatigue and music presence on RT and found there to be a significant result ($F (1,56) = 6.08$, $p = .017$). Participants who reported feeling more fatigued than usual scored better mean RT in the music group (*M* = 7325.06, *SD* = 1546.40), compared with the opposite as true for participants not feeling more fatigued than usual, who scored a better mean RT in the no-music group (*M* = 5640.31, *SD* = 1024.48). This was an interesting result considering that music presence was not significant overall, and neither was it significant in comparison to fatigue levels as measured by hours of sleep the previous night. This implies that music presence only has a role in determining mean RT for participant performance when the participant is feeling fatigued, supporting the notion that subjective feelings can also impact on performance. This finding will be further discussed in the discussion section.

4. Discussion

The aim of the current study was to explore the effects of fatigue and music presence on performance levels, via analysis of mean RT scores for correct responses during completion of a CB task experiment, while also looking at the potential influences of age, sex and subjective feeling of fatigue. To the researchers' knowledge, there is also no other study that specifically focuses on examining the effects of fatigue and music presence using the CB flicker task paradigm. Therefore, it was hoped that the current study may contribute towards filling this gap in the literature.

4.1 ***Further analysis of findings***

Research suggests that the necessary amount of sleep for an adult is 7-9 hours (Hirshkowitz et al., 2015), and that getting less than this amount significantly negatively impacts on cognitive performance (Rosenthal et al., 1993; Bonnet & Arand, 1996; Chee & Choo, 2004; Lim & Dinges, 2010;). Results from the current study support these previous findings as they revealed that optimal mean RT scores were consistently obtained by participants who reported gaining 7-8 hours' sleep the night before participation, and highlighted that the worst mean RT performances occurred for the category of people who had less than 4 hours sleep the previous night. Therefore, results revealed that regardless of age or other potential influencing factors, performance was significantly aided or hindered by the number of hours of sleep gained by the participant the previous night.

Previous literature suggested a consensus amongst the research that males have faster mean RT than females (Blough & Slavin, 1987; Der & Deary, 2006; Fozard et al., 1994). However, the findings of the current study refute this consensus, as females showed a lower mean RT than males. However, although differences between the sexes in the current study were observed, there was not enough variance between them to be significant. Therefore, the current study findings are more in line with findings by Kenward et al. (2017) whom reported no sex differences in mean RT scores. Regarding age, literature suggests that getting older is strongly linked with a significant decrease of performance in cognitive tasks; increase in age correlates with increase of mean RT (Pringle et al., 2001; Rensink, 2000; Humphrey & Kramer, 1997). Results of the current study further support this argument, as significant differences were observed between age groups, with the older 55+ age category showing the greatest differences, compared to less notable variances between the younger and middle age groups. Current study results also support the notion of a gradual decline as suggested by Owsley, Sekuler & Siemsen (1983), and concur with the findings that suggested there to be a more profound effect as the decades go by, which is portrayed by a speeding up of the declining process in the later years of life (Fozard et al., 1994).

It was previously recognised that findings related to the effects of the presence of music on performance were often inconclusive and contradictory. The current study concurs with research denoting that music presence has little or no effect on RT (Consiglio et al., 2003), as music presence overall did not result in any significant findings in this instance. However, a two-way ANOVA did reveal a positive significant finding in relation to the presence of music and subjective fatigue, whereby participants who reported feeling more fatigued than usual performed better in the with-music condition than the no-music condition. It might be inferred that when feeling fatigued these participants found the music presence to be uplifting and aided their performance. Previous mentioned research investigating work performance found that persons under the age of 25 were significantly negatively affected by subjective feelings of fatigue, but the same was not true for persons over the age of 25 (Setyawati, 1995). Although it is difficult to make comparisons between this study and the current research, due to differing age categories, overall the current study findings would refute this idea, as our findings suggest that all ages combined were not affected by feeling fatigued, and for the result involving subjective feeling of fatigue that was significant, the effect showed the music as being a positive influence. Furthermore, building upon the previous research, our findings also support the findings of Turner, Fernandez & Nelson (1996) who concluded that if music presence did influence performance, it was likely to be a positive one.

4.2 *Strengths, limitations & recommendations for future research*

Some of the current study strengths are directly related to the methodology; the CB experiment is one which few people are familiar with, and this novel aspect seemed to make it appealing. It was observed that most participants enjoyed completing the task. This encouraged participation and was used to the advantage of the researcher, as it enabled the snowball sampling effect to occur whereby more people heard about the experiment and became interested and so presented themselves as willing participants. Also, participation time was kept short, taking a maximum of fifteen minutes to complete the entire experiment, and this aspect also aided encouraging participation. Another strength of the current study is that it has further highlighted the usefulness of using the CB task paradigm for research purposes.

However, the current study also encountered several weaknesses and limitations. Firstly, the sample size was relatively small due to the limited resources available to the researcher; time constraints presented as an issue for both the researcher and the participant; due to the nature of the experiment the researcher needed to be physically present during each experiment making data collection a very time-consuming process. Also, as participants were giving generously of their time without any form of payment or reimbursement it was necessary to limit the experiment completion time to encourage participation. This was a factor which also influenced the designing of the demographic questionnaire. For analysis purposes it may have been helpful to include more demographical questions, but it was necessary to keep the questionnaire concise, as adding extra variables was beyond the scope of the current study. Therefore, it is proposed that similar future research could expand to also include other variables such as educational, employment, marital and socio-economic status, alongside potentially exploring the possible influences of personality and/or cultural differences.

Another limitation relates specifically to hypothesis 1 (effect of hours of sleep). As previously discussed, sleep deprivation can occur as either a once-off incidence or be a longer term chronic ailment (Durmer & Dinges, 2005). As this study only measures sleep deprivation in consideration of the previous night's sleep, and the subjective feeling of fatigue, it is unknown as to whether the fatigued participant was suffering from short-term or chronic fatigue. It is suggested that future research could discriminate between these two categories, exploring if there are any explicit differences that are solely dependent on the type of sleep deprivation experienced by the participant.

Furthermore, the researcher made several observations while conducting the experiment, which may have impacted on participant performance, and should be noted. Firstly, the trials occur in a random order decided by the OpenSesame programme, and some trials would be considered easier than others, due to the complexity of the scenes. On numerous occasions, it was observed that if a participant happened upon the easier trials at the beginning, it appeared to instil confidence and boost their enthusiasm. Likewise, if a participant found the first few core trials difficult, this appeared to cause them to fret and to question their ability to perform well. Therefore, it is plausible that these subjective emotion-related experiences may have impacted performance for these participants, and this influence may have lasted throughout the entire experiment. Hence, it is recommended that future replication of the current study could include a control for this potential effect, by ensuring each participant encounters the trials in the same order.

The researcher also observed that the competitive nature of the task appealed to many participants, who were keen to find out their scores in comparison to others. It is proposed that this competitive element might be a useful addition for future experimental procedures, by specifically designing the experiments to include a competitive element, and perhaps using this as a feature which may encourage participation. However, this competitive component does present its own issues and led to another key limitation of the study concerning the difficulty of controlling for guessing. It remains unknown how many people chose to hit the spacebar, to prevent timeout, before actually seeing where the change was occurring between the two images. Some participants may have chosen this option on occasion if they were getting frustrated with not seeing the difference and wanted the opportunity to guess instead. If any participant chose to do this, they had a 25% chance of guessing correctly, which would have negatively impacted on the validity of the data. However, for the current study, because the researcher was present for all trials it is unlikely that there were a high number of guessed answers. However, future replications with a larger sample size might not always have the researcher present during participation, and so a suggested control measure for this would be to increase the number of possible answers on the MCQ, thus decreasing the likelihood of a guessed answer being correct.

Another observation relates to the fact that younger participants seemed to enjoy the task much more than older participants. This is relevant in relation to hypothesis 3 (effects of age). There are a couple of reasons that might explain this; younger people may have enjoyed it more because they found it easier, as the results have shown, and equally, older people may have thought it a less enjoyable experience because they found it to be more difficult. Also, the role of technology might play a part in explaining this observation; younger people are likely to be more familiar and more at ease using the experimental apparatus, whereas many older people remain unaccustomed to regular use of technology and so this discomfort may have been off-putting for them. These factors may then relate back to the previously discussed issues about feeling confident in one's ability to perform well, and how these subjective experiences could subsequently inadvertently impact on performance. Future research might further investigate these notions and could also consider ways by which it might be possible to control for these age-related issues.

4.3 *Concluding remarks*

The automatic and unconscious processes of our visual system involve complex innate functions that we, as humans, tend to take for granted. The current study looked at one visual error phenomenon known as CB and investigated some of the factors which may increase susceptibility to this error. This exploration was carried out using a CB task paradigm experiment, whereby performance was measured via analysis of correct response RT scores. Results showed that sleep deprivation and age were significant influencing factors for CB, and presence of music also revealed as being positively significant, but only in instances where participants reported to be feeling more fatigued than usual. Findings were only partially consistent with previously reviewed literature, leading for a conclusion to be drawn suggesting that the current study will serve as a valuable addition to available research on the topic, but further future research is recommended. Real-life applications of the CB phenomenon are evident throughout many domains of everyday life and are particularly pertinent in situations where attention and vigilance are indispensable, such as driving. Therefore, continued research of the topic is both advised and justified, in consideration of the potential implications for real-world scenarios that may result from the CB visual error phenomenon.

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Appendix A

Experiment Questionnaire (sample)

*Required

Subject Number *

Your answer

Sex: *

Male

Female

Age: *

18 - 24

25 - 34

35 - 44

45 - 54

55 - 64

65 +

Hours of Sleep last night: *

0 - 4

5 - 6

7 - 8

9 +

Number of hours sleep that is your norm: *

0 - 4

5 - 6

7 - 8

9 +

Do you perceive yourself as being more fatigued than is normal for you today? *

Yes

No

Other:

Appendix B

List of tracks used during the with-music condition:

Bach : Brandenburg Concerto No. 1 in F Major

Beethoven : Piano Concerto No. 1 in C Major

Chopin : Nocturne No. 1 in B minor

Mendelssohn : Hebrides Overture

Mozart : violin Concerto No. 1 in B flat Major

Appendix C

Experiment Information and Consent Page (sample)

You are about to participate in an experiment.

Answers are anonymous, and your name will not be associated with the findings.

This experiment poses no known risks to your health. However, the experiment does involve flashing images, and this may cause discomfort for persons who suffer with migraine, or any other sensory issues. It is also advised that persons with epilepsy refrain from participating for this reason.

You can stop the experiment at any time, if you feel uncomfortable.

After this experimental stage, you will be asked to fill out a short questionnaire. Upon completion of your participation in the study you will be provided with a brief explanation of the research.

If you have any questions not addressed by this consent form, please do not hesitate to ask before commencing.

I have read and understood the information shown above (tick the box)

Participate (tick the box)　　　　　　　　Do not Participate (tick the box)

Appendix D

Experiment instruction page (sample)

You will be presented with pairs of images, one after the other & repeated in a loop. In each pair both images are identical, except for one small change. When you notice what the change is you will press the spacebar on the keyboard. You will then answer an onscreen question asking you to identify what the change was. When you have answered the question, the experiment will continue with the next pair of images. There is a time limit for answering, and the trial will timeout if you do not react quickly enough. If timeout occurs, the experiment will move on to the next pair of images after you press the continue button. The trials are timed, so please answer as quickly as possible. But at other times during the experiment, such as when timeout occurs, feel free to take a breather before continuing. Press any key to begin.

Appendix E

Sample images from the CB task experiment

Figure 1.1

Figure 1.2

Note: There is a picture on the top left-hand side of the wall in figure 1.2 that is not present in figure 1.1 and this is the change which occurred when the images were flickering.

Appendix F

MCQ (sample)

What changed?

What was different between the two images? (tick the appropriate box)

Lamp

Rug

Plant

Table

Press any key to continue