Memory Consolidation Effects in Altered States of Consciousness

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Ethical Approval

Full ethical approval was given for the current experiment to be undertaken via the University of Birmingham Sona System (See Appendix A). This included the nature of the experiment as well as the possible deceptions present within the experiment. Approval for the experiment to be conducted on the university grounds was also provided by the University of Birmingham. All participants were kept safe from harm and received an information sheet (Appendix B) as to the tasks they were set to carry out prior to signing consent. A full debrief as to the true nature of the experiment was given to all participant once all of the tasks had been completed. All of the guidelines provided by the university with regard to health and safety procedures were carried out without exception.

Abstract

Memory consolidation is the process by which new experiences are stabilised following their initial acquisition. Current research focuses on the active role sleep, in particular deep (non-REM) sleep has in the consolidation process. Previous studies have shown that promoting consolidation via cueing during non-REM sleep is effective in boosting memory retrieval, while cued reactivation during waking states is often linked to detrimental or non-significant effects. To further research into this area, cued reactivation amidst an artificially generated delta brainwave state (commonly found in non-REM sleep) was examined with regard to its effect memory retrieval when compared to an ‘Awake’ state. In order to achieve this ‘Altered’ state of consciousness, techniques used in brainwave entrainment research, specifically Binaural Beats were employed. These audio tracks involve a low frequency pulsation played in both ears, triggering a delta brain wave state that matches with the frequency of the pulsing. Memory retrieval was examined using both explicit recollection and an implicit recognition memory task in an attempt to examine any differential effects on hippocampus dependent and hippocampus independent memories. During the control experiment involving an ‘Awake’ state, memory retrieval was not significantly reduced by cueing as expected when examining previous research. Similarly, during an ‘Altered’ state, no significant effect of cueing on memory was observed in either the explicit and implicit memory retrieval tasks. However, the depth of encoding appeared to greatly increase the memory recall throughout and so the possible explanations for these findings are discussed. Finally, the lack of effects found during the both ‘Altered’ and ‘Awake’ state are discussed with regards to the methodological issues present. Future iterations and improvements are outlined in an attempt to expand research into this subtle and often elusive phenomenon.

Introduction

General Memory

Memory in Psychology refers to the process in which information is maintained (encoded, stored and retrieved) over time (Matlin, 2005). One of the most commonly researched areas in memory is that of retrieval. Retrieval is divided into two main categories that draw a distinction between *Explicit Memory*, involving conscious recollection of information and *Implicit Memory,* defined as an improvement in task performance due to previous unconscious experience (Schacter, 1987). The former is often divided into two distinct subsets: *Semantic Memory* and *Episodic Memory*. Semantic memories involve the articulation of general world knowledge such as facts, concepts and ideas (McRae & Jones, 2013), whereas episodic memory is the distinct recollection of previously experienced scenarios that are mentally re-creatable at any given time (Tulving, 2002). The general consensus is that the Hippocampus is involved in the acquisition and formation of episodic memories (Squire & Zola-Morgan, 1991; Eichenbaum & Cohen, 2001; Kinsbourne & Wood, 1975). The formation of these new autobiographical memories appears to require the medial temporal lobe (which includes the hippocampus) as a whole. This is demonstrated by the impairment to these memories during progressive neurodegenerative diseases such as Alzheimer's disease when affecting the medial temporal lobe (Kolb & Wishaw, 1996). Similarly, patients suffering from amnesia generally appear to demonstrate explicit memory impairments, while implicit recall often appears to remain relatively intact (Stickgold, Malia, Maguire, Roddenberry, & O'Connor, 2000), suggesting a different mechanism of formation. These implicit memories are fundamental different to explicit memories as they often occur without conscious awareness and so alternative methods are required to research these elusive forms of information retrieval.

Implicit memory is distinguishable from other forms of memory by its ability to be presented seemingly without conscious recognition. Supporting evidence of implicit memory arises in priming experiments involving measured improvements in task performance when participants have been unconsciously prepared. For example, recognition for the word 'Banana' will be faster if participants have previously been primed with the word 'Yellow' (demonstrating priming). Tulving, Schacter, and Stark (1982) found that priming effects have the potential to be longer lasting than explicit recognition. Tulving et al. (1982) demonstrated this during research into the long term storage of implicit and explicit memories. They found that of the 24 participants studied, priming effects (implicit memory) remained consistent over a period of a few hours to several days, at which point explicit retrieval was highly inhibited. This research therefor appears to provide support for a multiple-systems theory of memory as priming was present without explicit recognition. This theory states that priming effects and explicit recognition are mediated independently of one another and so information recalled implicitly does not rely on conscious recollection (Squire, 2004). Despite this, many years of research into memory (see Mulligan, 2003; Roediger & McDermott, 1993; Schacter, 1987 for a review), has failed to provide conclusive evidence to support the notion of a 'pure' implicit memory in which conscious recollection is truly absent (Butler & Berry, 2001; Shanks & St John, 1994). This lack of repeatability has led to the notion of a single-system model of memory.

A single-system model of memory implies that both explicit and implicit methods of recollection rely on the same processes, so priming effects are ultimately not possible without recognition (Kinder & Shanks, 2001, 2003). Supporting evidence for this single-system based theory of memory is provided by Berry, Shanks, Li, Sheridan Rains, and Henson (2010) who attempted to replicate the findings of a 'pure' implicit memory found by Vuilleumier, Schwartz, Duhoux, Dolan, and Driver (2005). Berry et al. (2010) conducted three rapid-serial visual presentation (RSVP) experiments. During experimentation, participants were presented with stimuli at such a speed that it would bypass conscious awareness, leading to base-rate explicit recollection. Priming effects were only found to be significant when explicit recollection was also found. Similarly, no evidence of priming without recognition was found furthermore supporting a single-system model of memory. Berry et al. (2010) did however note that a lack of supporting evidence for the multiple-systems theory is what supports the single-system model, rather than direct experimentation of this theory. Research involving amnesia patients (For examples see Riley & Venn, 2015; Berry, Kessels, Wester, & Shanks, 2014) addresses this limitation. Berry et al. (2014) primed participants then proceeded to show fragmented images involving previously viewed images and new ones. Participants reported whether they could recognise what the image was at that particular level of fragmentation (providing an implicit measure if the image is 'old') and had they been unsuccessful, the level of fragmentation was reduced. Following this, a non-fragmented version of the image was judged as old or new (giving a conscious recognition response). A deficit in both priming and recognition was found amongst amnesiacs, supporting the hypothesis that amnesia led to reductions in a single aspect of memory (affecting both explicit and implicit memory) and so supporting a single-system model. One of the areas that studies looking at implicit memory retrieval often fail to consider is how implicit retrieval may differ in altered states of consciousness.

Altered States of Consciousness

Sleep and 'Awake' states are not the only states of consciousness accessible to the human mind. Using a non-invasive technique known as Electroencephalography (EEG), a recording of the electrical activity of the brain can be examined and can be attributed to various brainwave states

(Niedermeyer & da Silva, 2004). General observations of EEG findings suggest that slower brainwave frequencies may have profound effects on unconscious processes and so on implicit forms of memory. This is demonstrated by the fact that slower frequency brainwaves seemingly coincide with increased access to unconscious processes and stores (Sanei & Chambers, 2007). It should be noted however that throughout daily life all brain wave frequencies are present, however the prominence of specific frequencies increase during various activities. Sanei & Chambers (2007) describe Beta wave (electrical activity ranges from around 14 - 26Hz) as the most common brain wave frequency and these occur during regular waking activity. These brainwave states are typically associated with active thinking, focus on the outside world (Sanei & Chambers, 2007) and active concentration (Baumeister, Barthel, Geiss, & Weiss, 2008). Due to the engaging nature of experimental tasks, a strong Beta frequency is present in most participants carrying out psychological experimentation. The next slower frequency wave is the Alpha wave (around 7.5 -12.5Hz; Klimesch, 1999) and is characterised by a relaxed awareness and high levels of creativity (Fink & Benedek, 2014). At the next deeper level of relaxation and even slower a frequency than Alpha waves, Theta waves (around 4 – 7.5Hz, Sanei & Chambers, 2007) occur during deep relaxation and often are prominent during REM sleep. Finally, Delta waves (0.5 - 4Hz; Sanei & Chambers, 2007) are often regarded as the slowest brain wave state and it most present during Non-REM deep sleep. Despite there being multiple brainwave states, implicit memory research usually involves testing memory in normal waking (beta) states, however research into slower brainwaves suggest that these can have profound effects on implicit memory.

Alpha brainwaves are often characterized with higher levels of creativity and relaxation. This is supported by Haarmann, George, Smaliy, and Dien (2012) who used Remote Association tasks (a human creativity test) to examine the effects of Alpha waves on creativity. They found that an increase in Alpha waves generated through neurofeedback (teaches self-regulation of brain function) led participants to find solutions to the problems posed by the Remote Association Task they failed to answer previously. It was suggested that an unconscious activation may be related to the effect they experienced. This increase in creativity has been hypothesised to be generated by an unconscious process (Andreasen, 2011) and so, due to the unconscious basis of implicit memories, alpha brainwaves may influence not only creativity but also unconscious processes. Berntsen (1998) provided evidence of this by examining the connection between implicit memories and creativity using voluntary (explicit) and involuntary (debatably implicit) autobiographical memories in a qualitative, diary- based study. Berntsen (1998) discovered increased levels of specificity amongst the involuntary memories described by participants, as well as containing more emotionally positive content when compared to the voluntary memories. Using similar methodologies, similar findings were also found by Berntsen & Jacobsen (2008) who demonstrated that imaginations of future events were reported as more vivid when they were involuntarily generated when compared to their voluntary counterparts. Although there appears to be a connection with creativity and implicit processes, other evidence suggests that an increase in even slower frequency waves may have stronger effects.

Theta and delta waves have been long associated with access to unconscious material, sleep and deep meditation (Sanei & Chambers, 2007). An often stated phenomenon demonstrating the connection between these slow frequencies and unconscious processes is that of hypnosis. Williams and Gruzelier (2001) examined high or low hypnotically suggestible participants and found that the EEG readings given by highly suggestible participants exhibited increased Theta waves which appeared to indicate high levels of relaxation. Although future experimentation should replicate the findings with more than 16 participants, it does appear to show a link between hypnosis (and so in turn unconscious processes and retrieval), hypnotic suggestibility and Theta activity. This is supported by Sebastiani, Simoni, Gemignani, Ghelarducci, and Santarcangelo (2005) who found higher Alpha and Theta frequency waves in highly hypnotically suggestable participants. Hypnosis is not however without its downfalls as hypnotic retrieval of memories induces false memory production (Spanos, Burgess, Burgess, Samuels, & Blois, 1999) and so as a method to examine implicit memory, hypnosis is ill-advised. Overall, the slower brain wave states appear to be beneficial to the retrieval of involuntary implicit memories and so appear to influence some form of unconscious processing. Due to the implications altered states have for implicit memory retrieval, examining these states in relation to memory consolidation may help to uncover the true effects of consolidation and mechanism by which this phenomenon takes place.

Memory Consolidation

Memory consolidation is the process by which new experiences are stabilised following their initial acquisition (Dudai, 2004). The consolidation process is usually sub-divided into two processes known as *Synaptic Consolidation* and *Systems Consolidation*. In Neuroscience, memories are thought to be stored in the synapses between neurons and the connections between these neurons can be strengthened by learning and repetition, effectively strengthening the memory (Clopath, 2011). However, as these synaptic connections change so regularly, the formation of new memories would ‘overwrite’ old ones. Therefore, synaptic consolidation (utilising long term potentiation) is required to consolidate the memories at a synaptic level. This leads to the long-term storage of these experiences within the synapse of certain brain regions such as the hippocampus (Clopath, 2011).This ‘long-term potentiation’ is the strengthening of the synapse due to an increased rate of transmissions being sent by two neurons (Tronson &Taylor, 2007). This long-term potentiation process has been suggested to be influenced by protein synthesis as the administration of protein synthesis inhibitors has been found to inhibit this consolidation process (Gold, 2008). However, it has been noted that this effect may only occur under certain conditions as protein synthesis inhibitors are unable to entirely inhibit memory consolidation, leaving room for other factors to be influential (Gold, 2008). Once this long-term potentiation occurs, eventually neurons ‘learn’ to fire synchronously with each other and so form more stable long-term connections, thereby strengthening pre-existing memories (Spencer, 2008). This form of consolidation has been suggested to occur within minutes to an hour of the memory being encoded (Dudai, 2004) making it much faster than its systems consolidation counterpart.

Systems consolidation is roughly described as the process by which the memories encoded during synaptic consolidation processes (in the hippocampal region) are reorganized to the neo-cortex to be even more permanently stored (Roediger, Dudai & Fitzpatrick, 2007). This slow process can take years to take place whereas the synaptic consolidation of new experiences can occur within minutes (Roediger et al., 2007). There are two main theories as to how system consolidation takes place (Standard Model and the Multiple Trace Theory), each with their own explanations as to the steps required for the reorganisation of the memories from the hippocampal region to the neo-cortex. The standard model of systems consolidation (for a summary, see Squire & Alvarez, 1995) states that when information is encoded, it is retained in the Hippocampus and cortical regions (Frankland & Bontempi, 2005). This phase is known as the hippocampal-dependent phase, in which the memories are retained after initial acquisition (Frankland & Bontempi, 2005). This lasts around one week, during which recollection strengthens the connection between the hippocampus and the neo-cortex (Dudai, 2004). Finally, beyond this phase the memory becomes hippocampus independent by being slowly transferred to the neo-cortex to remain permanently stored (Dudai, 2004). Consolidation under this model is the process by which the hippocampus activates, and in turn strengthens connections with the neo-cortex. Research supporting the standard model generally utilises brain injury patients suffering from retrograde amnesia.

Squire and Alvarez (1995) support the standard model by stating that patients suffering from retrograde amnesia (failure to recall events before the onset of the amnesia) often report being temporally graded. Temporally graded amnesia involves patients experiencing greater memory impairment for experiences acquired closer to the onset of the amnesia than the more remote memories (Clark, Broadbent, Zola, & Squire, 2002). The nature of this phenomenon suggests that once the hippocampus forms a connection with the neo-cortex, it is no longer required and so the memories must be hippocampus independent. Despite this support, Winocur and Moscovitch

(2011) are quick to point out that the model fails to fully predict the role of the hippocampus in the retrieval of semantic memories. The authors also report that the hippocampus is required for episodic memories to be retained, while semantic memory retrieval is independent of the hippocampus. Finally, there are also often ethical issues with using amnesia or brain damaged patients in research utilising neuroimaging (for overview on ethical issues of neuroimaging post-brain injury, see Weijer et al., 2014). Even with these issues, the standard model of the strength of connection between the hippocampus and neo-cortex is widely supported and generally highly regarded. However, the Multiple Trace Theory attempts to address these shortcomings by expanding on the distinction between episodic and semantic memory encoding and retrieval with regard to their dependence on the hippocampus.

The Multiple Trace Theory (MTT) is distinct from the previous model as it states the hippocampus is always involved with retaining and retrieving remote memories no matter the age. This differs from the standard model which states that, after many years the memories become hippocampus independent (Nadel & Moscovitch, 1997). The MTT also suggests that the hippocampus is required for the storage and retrieval of episodic memories, but not necessarily for semantic memories (Nadel & Moscovitch, 1997). These semantic memories can be encoded in areas such as the neo-cortex during the consolidation process making them somewhat hippocampus independent (Nadel & Moscovitch, 1997). Supporting evidence (by Nadel & Moscovitch, 1997) demonstrated that retrograde amnesia patients experienced hippocampal activation while recollecting old autobiographical memories (up to 45 years old). However, although the positron emission tomography (PET) scan showed hippocampal activation, the authors admitted that establishing a baseline is difficult as the hippocampus is required for the encoding of new experiences. This would mean that any activation recorded could simply be the consequence of patients encoding the study as a new event and memory. Other criticisms by Haist, Gore, and Mao (2001) come from using function magnetic resonance imaging (fMRI) to test the standard theory against the MTT. The study used a ‘famous faces’ remote memory test (tests facial recall for people who were famous years ago) to investigated the regions responsible for retrieval in temporally graded amnesiacs. The study found that the entorhinal cortex is required to activate remote memories for retrieval, and the hippocampus was only marginally responsible. They proposed that due to the advancement of technology, we can distinguish the two brain regions to a greater degree. Overall, both theories as they stand suffer from various flaws such as the use of mostly amnesiacs as subjects, which are limited in numbers. To further develop a unified theory for the consolidation process at a systems level, a general consensus on the definitions of semantic and episodic memory (reported to be lacking by Meeter & Murre, 2004) is fundamental.

In an attempt to further understanding into the consolidation process, researchers have begun focusing on the consolidation effects present in sleep.

Sleep consolidation has been found to play a pivotal role in establishing information in the hippocampal and cortical regions (Walker, Stickgold, Alsop, Gaab, & Schlaug, 2005). This systems consolidation process involves an increase in neural activity during Rapid-Eye Movement (REM) sleep, which in turn improves neural connections between the hippocampus and neo-cortex, strengthening memory (Ribeiro, 1999). Walker et al. (2005) examined procedural memory using a motor related task (involving finger tapping accuracy). Participants were tested post-training with or without sleep in between the sessions. Results indicated increased activation in the hippocampal and cortical regions in the ‘sleep’ group as well as improvements in performance in the speed and accuracy tasks compared to the ‘non-sleep’ group. This has been noted as potentially being related to synaptic consolidation as it occurs over a short-term period (Vertes, 2004). Vertes (2004) also found that consolidation also occurs during wakefulness over a period of 4-6 hours, so sleep may not be critical for this process. Other studies have examined the process of memory reconsolidation and the reactivation of neural pathways as an explanation to perceived consolidation effects found in sleep and wakefulness.

Memory reconsolidation occurs during the reactivation of the neural pathways (by the act of recollection) of already consolidated memories, causing them to be further consolidated, strengthened and maintained (Tronson &Taylor, 2007). The act of retrieval however, puts the memories into a state referred to as a ‘labile state’, in which the memories are prone to alterations should they not be reconsolidated (Tronson &Taylor, 2007). Due to this, the reconsolidation theory views reactivation of the neural pathways during an ‘Awake’ state as detrimental to memory retrieval (Diekelmann, Buchel, Born, & Rasch, 2011). Previous research (see Rodriguez, Horne, & Padilla, 1999; Pedreira, Perez-Cuesta, & Maldonado, 2002) has demonstrated that upon reactivation of a memory trace during wakefulness, the memory reaches a labile state and so becomes prone to alterations and destabilization. However, this only occurs during a small time window of a few minutes to hours (Rodriguez et al., 1999). Diekelmann et al. (2011) provide supporting evidence for this by examining the destabilization effects produced by reactivation in wakefulness when compared to slow wave sleep. The study focused on using odour cues to reactivate memories in participants then providing them with an interference task designed to test the memory stability. Findings suggest that reactivation during wakefulness led to activation of the prefrontal cortical regions (found using fMRI) and ultimately the destabilization of the memory trace. Other research on primates and rats has demonstrated that it is the hippocampal region that reactivates during retrieval at an 'Awake' state (Vertes, 2004). However it was noted by the author that perceived reactivation could simply be residual firing of the neurons from the learning phase. So although reactivation appears to have detrimental effects to the stability of a memory trace during 'Awake' states, Diekelmann et al. (2011) and others have seemingly found supporting evidence that reactivation positively facilitates the stability of a memory when it occurs during slow wave sleep.

Although reactivation (caused by retrieval) is thought to be the cause of the destabilisation of a memory during a wakeful state, it is however theorised as the mechanism by which sleep consolidates memory (for a review see Rasch & Born, 2007; Sara, 2000). In order to test this controversial phenomenon, Rasch, Buchel, Gais, and Born (2007) cued participants to odours during a learning phase then re-exposed the odours during slow-wave (Delta) sleep. Using fMRI, reactivation in the hippocampus during the re-exposure to the odours was found, seemingly supporting the reconsolidation theory. These effects were not found during wakefulness or REM sleep states suggesting that reconsolidation is primarily an effect of slow-wave sleep. Using odours and a similar set-up Diekelmann et al. (2011) found (using an fMRI) that reactivation in the hippocampal regions led to immediate stabilisation of memories and so increased their durability against interference. Despite this, these studies only examined odours as a mechanism for reactivation and so further evidence in the form of other stimuli is required. Rudoy, Voss, Westerberg, and Paller (2009) examined the reconsolidation theory using sounds instead of odours in an attempt to boost memory performance. During slow-wave sleep, participants were presented with sounds that had previously been associated with objects and their spatial location. The cueing during sleep was found to increase correct recollection of the spatial locations of objects during the post-sleep test. Overall, cueing during a deep sleep state appears to demonstrate a beneficial effect upon memory retrieval. To further research into this fairly new and controversial topic, the current research will seek to examine whether an artificially generated delta (slow wave sleep) brainwave state also has a beneficial effect on memory retrieval (both implicit and explicit) through the use of various brainwave entrainment techniques.

Current Study

The primary focus of the current research involved the attempt to examine how providing reminders (cueing) during an offline period may affect episodic memories. To do this, a similar methodology to previous memory consolidation research was carried out (see Diekelmann et al., 2011). Here we primarily examined how cueing affects episodic recall amongst wakefulness, with the added measure of implicit memory. This was utilised in an attempt to further the memory consolidation theory by examining whether cueing effects hold true for other forms of memory retrieval. Following this, to better mimic previous research in the area, the addition of an altered state was included. Unlike previous sleep consolidation studies which utilise a sleep state, this current study examined consolidation effects when this ‘non-REM state’ (delta brainwave state) is artificially generated. To do this, it utilised the use of brainwave entrainment technology. Discovered in 1893 by Heinrich Wilhelm Dove, the pulsating frequency of sounds that match with the frequency of a certain brainwave states actually generate that specific brainwave frequency in the listeners brain (entrainment). General use involves simulating meditational altered states and enhancing meditative focus (Lavallee & Koren, 2011). Brainwave manipulating technologies usually appear in two main forms, *Binaural Beats* (two audio tones of different frequency played in each ear) or Isochronic Tones (evenly spaced tones that turn off and on again). Previous studies using these technologies have demonstrated rather intriguing findings, both with regards to their abilities to alter brainwave states, as well as their effects on memory.

In an attempt to research brainwave entrainment, research examines the effects these technologies have on brainwaves of participants with an EEG-style methodology. A recent study into Binaural Beats conducted by Gao et al. (2014) applied binaural beats for 5 mins at different frequencies, finding alterations in brainwave frequency using EEG at around the 3.5 minute mark. Similar results that support the use of brainwave entrainment in modulating specific brainwave frequency production was found by Becher et al. (2014). However, Lavallee, Koren, and Persinger (2011) found no significant influence of the binaural beats on the control subjects when compared to meditators. However, the authors did note a significant alteration in brainwave frequency amongst the meditators and so concluded that previous experience with altering one’s brainwave frequency (in this case through meditation practice) influenced the effectiveness of the brainwave entrainment techniques. Despite being fairly novel in memory research, these techniques have been used in conjunction with memory research prior to this study. Wahbeh, Calabrese, Zwickey, and Zajdel (2007) examined the recollection for words over multiple trials having been trained with certain frequencies. The authors found a decrease in explicit memory during long periods of brainwave entrainment, however when split up into short sessions participants experienced a significant memory boost. This could be due to the beats being a distraction over longer periods of time and so reducing the efficiency of explicit retrieval. Overall, this fairly under-researched area appears to demonstrate promise as a method of utilising alternative brainwave states and so application to the sleep consolidation paradigm is justifiable.

The paradigm used in this study is a derivative of the traditional sleep consolidation experiments as it that it comprises of a learning/encoding phase, a cueing/offline phase and finally a retrieval phase. However, the 'Altered' states group of this current study involves participants listening to Delta Frequency (2Hz) binaural beats as a substitute for sleep. The encoding phase utilises a similar set-up as Staresina, Alink, Kriegeskorte, and Henson (2013) in which object-scene pairs are encoded together and one item is presented with the participant required to retrieve its pair. This paradigm is advantageous in that it provides the basic outline for future studies to replicate and perhaps employ brain imaging techniques such as fMRI. This could be used to examine whether presentation for the one item of the pair (e.g. object) activates the brain region for the other (e.g. scene) demonstrating the consolidation of the information. In order to cue the stimuli, a sound stimulus matching the objects will be encoded with the objects and later cued in the offline period (for a similar set up see Rudoy et al., 2009). Following cueing, implicit memory was examined using a simple unscrambling mechanism (see Gagnepain, Henson, & Anderson, 2014) involving an item slowly fading into view. This item (e.g. object) was eventually recognised by the participant thereby providing a recordable, implicitly generated reaction-time based response. Following this, a simple recollection task was utilised for the explicit responses.

Rationale and Hypotheses

Evidence from previous literature suggests that cueing during an 'Awake' state will have detrimental effects upon memory due to putting the memory trace into a labile state capable of alterations (Diekelmann et al., 2011). The first hypothesis therefor was that cueing during an 'Awake' state will have a significantly detrimental effect upon episodic memory retrieval. Despite cueing during this state being found to be detrimental to memory generally (see Diekelmann et al., 2011), research into slow-wave sleep (and so in turn delta frequency brainwaves) has found beneficial effects upon explicit recognition (see Rudoy et al., 2009). As this line of research is in its infancy, the second hypothesis involved examining whether cueing in an artificially generated slow-wave state would have a significantly beneficial effect on memory retrieval (demonstrating consolidation effects). Finally, one of the unanswered questions by the current literature is whether memory consolidation during altered states of consciousness has any effect on other types of memory recall such as implicit recognition, rather than just explicit recognition. To address this issue, the current research examined consolidation effects on implicit recognition. Due to the single-system theory of implicit memory stating that explicit and implicit memory rely on the same underlying processes (Kinder & Shanks, 2001, 2003), the third and final hypothesis is that any effect cueing has on explicit memory during both 'Altered' and 'Awake' states will also be present amongst implicit memory. In addition to the three previous hypotheses, the levels of encoding reported by participants during the encoding phase will be examined as an additional variable.

Due to literature on visual imagery and memory recall (see Hussey, Smolinsky, Piryatinsky, Budson, & Ally, 2012), higher levels of encoding should have a significantly beneficial effect upon both implicit and explicit recognition. Similarly, previous research by Tse et al. (2007) has demonstrated that systems consolidation occurred significantly faster when the experiences fit within an already established schema (person's current knowledgebase). Should this be the case, schema-consistent stimuli deemed 'plausible' should be better consolidated and so better recalled than their 'implausible' counterparts.

General Methods

Participants

All versions of the experiment were carried out using a Within-Subjects Design. Throughout all experiments, all participants were students at the University of Birmingham and participated in the study as part of compulsory module or for a cash reward. The Exclusions for the study included participants who are unable to speak English as a first language or suffering from neurological disorders. No other biographical data was collected and participants were unaware as to the true nature of the experiment prior to the verbal debriefing stage.

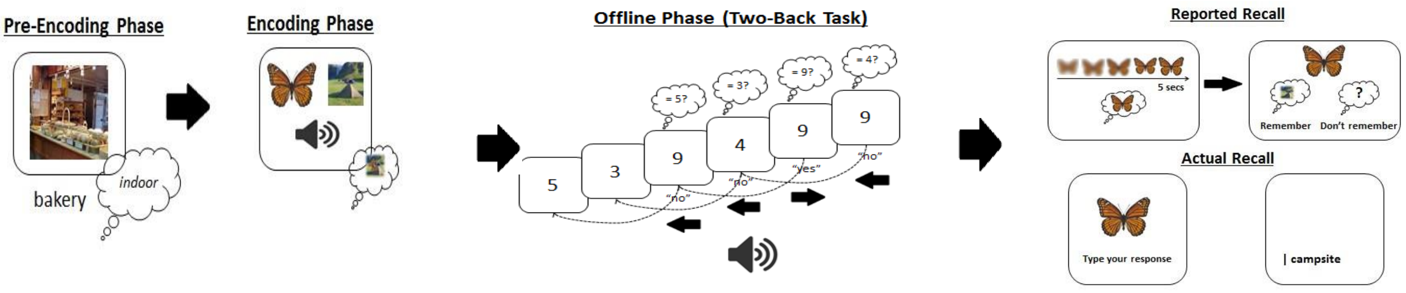
Materials

A brief information sheet with information describing the upcoming experiment (see Appendix B) as well as a consent form allowing participation in the study to take place (see Appendix C) was developed and given to participants, prior to them taking part. A laptop computer (Stone® Model NT310-H) ran the experiment through the use of MATLAB® 2014a. As well as this, Logitech Speakers (z130 Stereo Speakers) were used for the audio stimuli stage which played through the computer program. During each part of the experiment, participants were presented with an instruction sheet explaining the task they would be required to carry out (see *Design and Procedure* section for the outline of these tasks). During these tasks, a series of 100 (7cm x 7cm) colour pictures of common nameable everyday objects (e.g. 'ice cube'), as well as 100 (7cm x 7cm) coloured images of simple nameable scenes (such as 'airport') were presented. These items were chosen from the list of stimuli provided by Brady, Konkle, Alvarez, and Oliva (2008). Short audio tracks that correspond with the sounds the object stimuli make (downloaded from 'http://www.audiomicro.com') were cut to last 4 seconds using the audio-editor 'Audacity'. All of these audio tracks were equalised for volume (to 89.0db) using the audio-editing software 'MP3Gain'. Finally, once the experiment was completed the participants were fully debriefed as to the true nature of the experiment.

Design and Procedure

A Within-Subjects/Repeated Measures Design was used and so all participants took part in all phases of the experiment. The participants were presented with a brief information sheet telling them what the experiment was looking at and how it would be carried out (see Appendix B). Once they agreed to take part in the study, they filled out generic biographical data (such as age, gender and handedness) and signed the consent form (see Appendix C). They proceeded to read computer based instructions for the first part of the experiment (pre-encoding) before carrying out the computer-based, scene-processing task. The instructions consisted of informing participants that they will be presented with images of various common scenes (each for four seconds) and will be required to make a judgement as to whether the presented scene is indoors (press the Left-Arrow key) or outdoors (press the Right-Arrow key). Following this, they proceeded to complete an encoding phase involving an object-scene imagery task, in which an object and a scene image were presented side by side. During this task, sounds representing the object (e.g. Dog & 'Woof' sounds) were played in order to familiarise the participants with the corresponding sounds for each image. The task required them to report whether they can (Left-Arrow) or cannot (Right-Arrow) form a vivid mental image that incorporates both the object and the scene. Having finished with this encoding task they then proceeded to take part in an offline period. During this offline period they took part in an *n*-back task in which a string of numbers are presented one at a time for two seconds each (for outline see Gazzaniga, Ivry, & Mangun, 2009). The participants were required to make a judgement for each number as to whether the number being presented was the same (Left-Arrow) or different (Right-Arrow) as the number two digits prior. Simultaneously to this task, participants were cued for half of the objects (for a total of four seconds) through the use of the sounds previously heard. A random presentation of brown noise for four seconds was also presented occasionally throughout to help reduce participant concentration on the cueing.

Following on from the pre-encoding, encoding then offline phases of the experiment, the final stages involve memory retrieval tasks. Participants were presented with instructions informing them that an object will fade into the screen for a maximum of five seconds and their task is to report when they recognise this object (pressing the Down-Arrow key), thereby providing a reaction-time based implicit memory response. These objects were randomly rotated so to avoid simple shape recognition and so report actual object recognition. Once an object had been recognised during the five seconds (or not) the participants would then be asked whether they recall (Left-Arrow) or not (Right-Arrow) the scene previously paired with the object during the encoding phase. Participants then took part in a follow up memory task in which they were presented with an object and were then required to type out the name of the scene they believed to have paired with the object. This was then analysed and the responses were reported as correct, null or incorrect. Responses were reported as correct when the written response by the participant matched the scene paired with the object, while an incorrect score was given when this response given was a scene other than the correct one. Finally, null scores were given for responses that were either deemed too vague to successfully demonstrate correct recollection or when a participant simply reported they 'don't know' the scene. This was conducted so to provide an 'Actual Recall' that could later be compared with the 'Reported Recall' provided in the previous task. Finally, the participants received a full verbal debrief explaining the true nature of the experiment and were informed as to who to contact should they have any queries with the experiment or the way it was conducted.



Analysis of Data

Prior to analysing the data for any cueing effects amongst all experiments, all of the data was analysed for outliers. Upon calculation of the z-score for each participant's data, any data point with a z-score of over +/- 3 was examined as a possible outlier. Multiple paired-samples T-tests were conducted with the significance level of .05 being used as the threshold for significance for all the experiments. For the analysis of *Hypothesis 1 and Hypothesis 2*, the main dependent variable was the percentage of correct scenes recalled by the participants during the retrieval phase of the experiment. However in an attempt to further examine Hypothesis 1 and Hypothesis 2, the incorrect and null scores were lightly analysed. For *Hypothesis 3,* the dependent variable was the speed at which objects were recognised by the participants during the retrieval phase of the experiment. The within-subjects factor was that of 'cueing' in which half of the items were randomly cued, while the other half were not. The mean scores were used throughout all analyses instead of the raw data as they provided a more suitable base to view the findings.

Hypothesis 1: Cueing during an 'Awake' state will have significant detrimental effect to explicit recollection memory when compared to stimuli that remained un-cued. Hypothesis 2: Cueing during an 'Altered' state will have significant beneficial effect to explicit recollection memory when compared to stimuli that remained un-cued. Hypothesis 3a: Cueing during an 'Awake' state will have significant detrimental effect to implicit recognition memory (due to a single-system theory of memory), when compared to stimuli that remained un-cued. Hypothesis 3b: Cueing during an 'Altered' state will have significantly beneficial effects on implicit recognition memory, when compared to stimuli that remained un-cued.

Experiment 1: Methods

Participants

A total of ten (9 females, 1 males; Mean age = 19.1 years; SD = 0.7 years) individuals were recruited via an online participation pool at University of Birmingham. Participants were all psychology students at the University of Birmingham and participated in the study as part of compulsory module.

Materials

The materials used in this experiment are identical to the materials stated in the 'General Methods' section.

Design and Procedure

The design and procedure for this experiment is identical to the design and procedure of the 'General Methods' section.

Analysis of Data

Amongst the data set for the Experiment 1, one outlier was found and removed from the analysis (both explicit and implicit analysis). This was due to a technical error in which the experiment failed to record most of the retrieval responses made during the retrieval phase. Amongst this current experiment, only Hypothesis 1 and Hypothesis 3a are used as Hypothesis 2 requires the use of an 'Altered' state, which was not present here. *Hypothesis 1: Cueing during an 'Awake' state will have significant detrimental effect to explicit recollection memory when compared to stimuli that remained un-cued. Hypothesis 3a: Cueing during an 'Awake' state will have significant detrimental effect to implicit recognition memory (due to a single-system theory of memory), when compared to stimuli that remained un-cued.*

Experiment 1: Results

Explicit Effects

Multiple paired-samples t-tests were conducted to examine the effects cueing has on the recall of scenes post-cue. During this analysis participants were not penalised for incorrect answers, simply scored for the percentage of correct, null and incorrect ones. The average percentage of incorrect, null or correct responses for cued and un-cued stimuli during the retrieval task can be seen below in Figure 1.

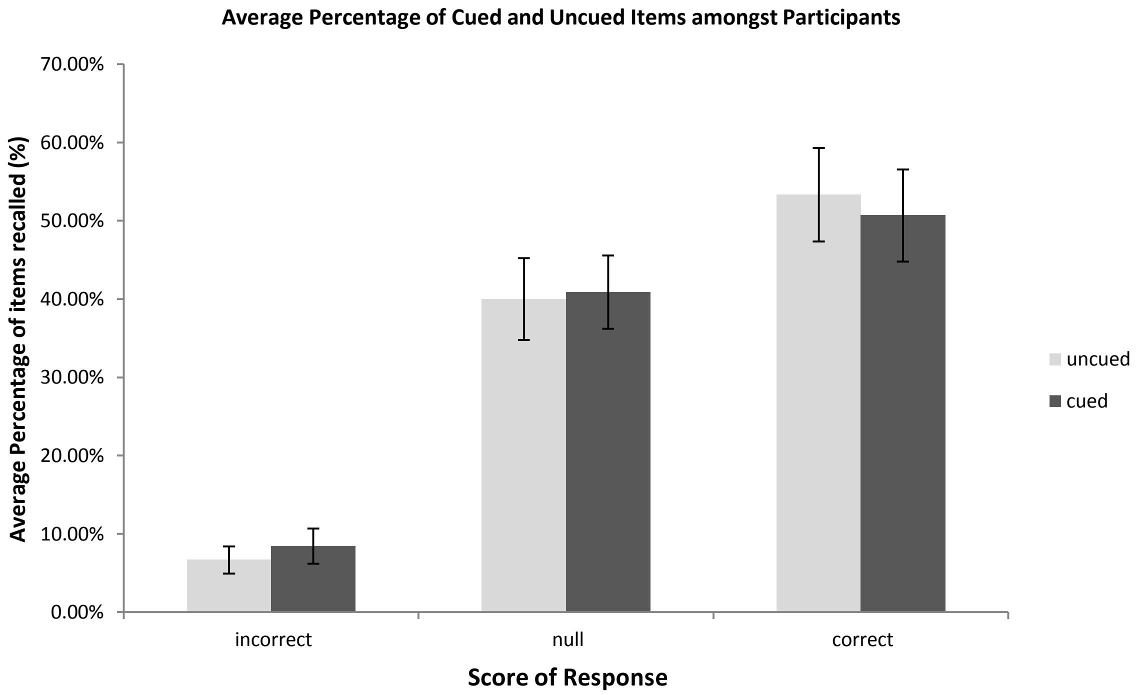


Figure 1. Bar chart showing the relationship between the cueing and the percentage of correct, null or incorrect scores during the retrieval task. The error bars demonstrate the standard error for each variable. The data is compiled from all participants minus the one outlier (n=9).

Hypothesis 1 was not supported. The data appeared to show that, although in the direction predicted, there was not a significant difference in the percentage of incorrect, null or correct responses between cued and un-cued stimuli at a .05 level. The statistical analysis comparing the percentage of responses that were incorrect responses amongst cued (M= 8.44, SD= 6.72) or un-cued (M= 6.67, SD= 5.25) was found to not reach a level of significance; t(8)= 1.15, p= .283. Similarly, there was not a significant difference when looking at the percentage of null responses given during cued (M= 40.89, SD= 14.05) and un-cued stimuli (M= 40, SD= 15.69); t(8)= 0.39, p= .708. Finally, the statistical analysis indicated that the percentage of correct responses given was not significantly different between the cued (M= 50.67, SD= 17.69) and un-cued (M= 53.33, SD= 17.94) groups; t(8)= 1.33, p= .219.

Implicit Effects

The average reaction time for cued and un-cued stimuli across participants (to recognise the objects during the implicit retrieval task) can be seen below in Figure 2.

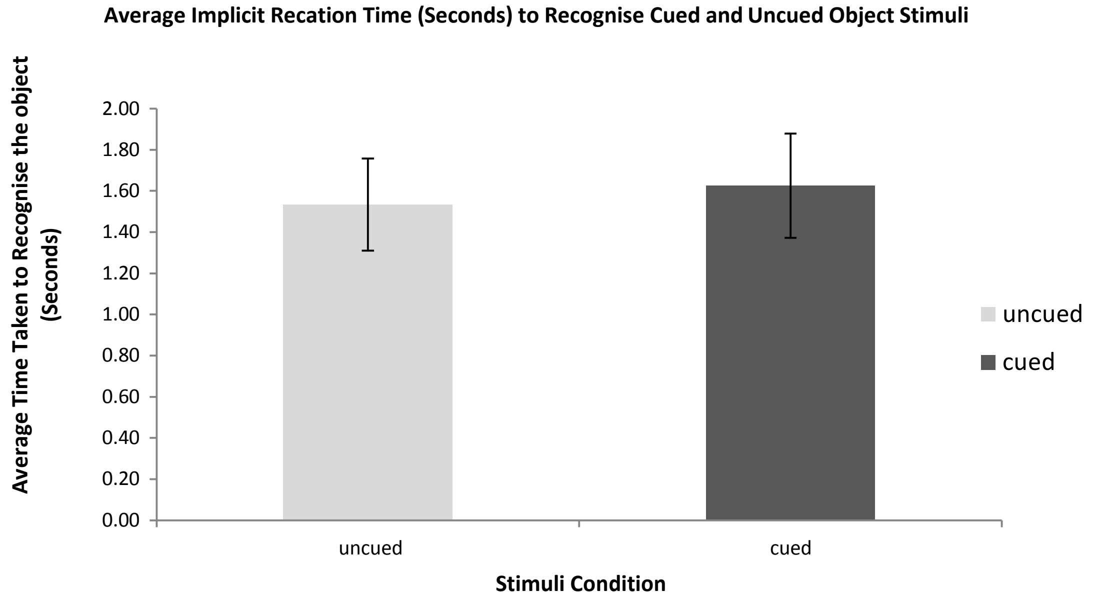


Figure 2. Bar chart showing the average reaction time for cued and un-cued stimuli during the implicit recognition task. The error bars demonstrate the standard error for each variable. The data is compiled from all participants minus the one outlier (n=9).

Hypothesis 3a was not supported. The paired-samples t-test comparing the average reaction time (seconds) for the implicit recognition of cued (M= 1.63, SD= 0.76) or un-cued (M= 1.53, SD= 0.67) stimuli was found to not reach significance; t(8)= 1.35, p= .215.

Experiment 2: Methods

Participants

A total of five (4 females, 1 males; Mean age = 20.6 years; SD = 1.5 years) individuals were recruited via an online participation pool at University of Birmingham. Participants were psychology students at the University of Birmingham and participated in the study for a cash payment of 10 pounds.

Materials

The materials and equipment used in this version remained the same as those stated in the 'General Methods' section. Please re-view this section for further information.

Design and Procedure

The same design and procedure stated in the 'General Methods' section was used in this experiment, however a few changes to the structure of the individual tasks were made in an attempt to further enhance the methodology. One of these changes involves the encoding phase in which participants view object and scenes side by side and form a mental image incorporating them both. During the first version of the experiment, the objects (with sounds) and scenes were presented for four seconds once each pair. However, in this version each pair is presented for three seconds but presented twice in an attempt to strengthen the link between the objects and the scenes. The duration of the presentation of the pairs was reduced in an attempt to counteract any ceiling effects that could occur. Finally, the presentation of the cues during the offline period (n-back task) was doubled and so each sound cue was presented twice. In an attempt to avoid an increase in duration and in turn avoiding fatigue effects for this task, the brown noise was also removed to allow for more cueing time.

Analysis of the Data

Amongst the retrieval task data set for 'Experiment 2', no outliers were found. Amongst this current experiment, only Hypothesis 1 and Hypothesis 3a are used as Hypothesis 2 requires the use of an 'Altered' state, which was not present here. *Hypothesis 1: Cueing during an 'Awake' state will have significant detrimental effect to explicit recollection memory when compared to stimuli that remained un-cued. Hypothesis 3a: Cueing during an 'Awake' state will have significant detrimental effect to implicit recognition memory (due to a single-system theory of memory), when compared to stimuli that remained un-cued.*

Experiment 2: Results

Explicit Effects

Multiple paired-samples t-tests were conducted to examine the effects cueing has on the recall of scenes post-cue in this experiment. During this test participants were not penalised for incorrect answers, simply scored for the percentage of correct, null and incorrect ones. The average percentage of incorrect, null or correct responses for cued and un-cued stimuli during the retrieval task can be seen below in Figure 3.

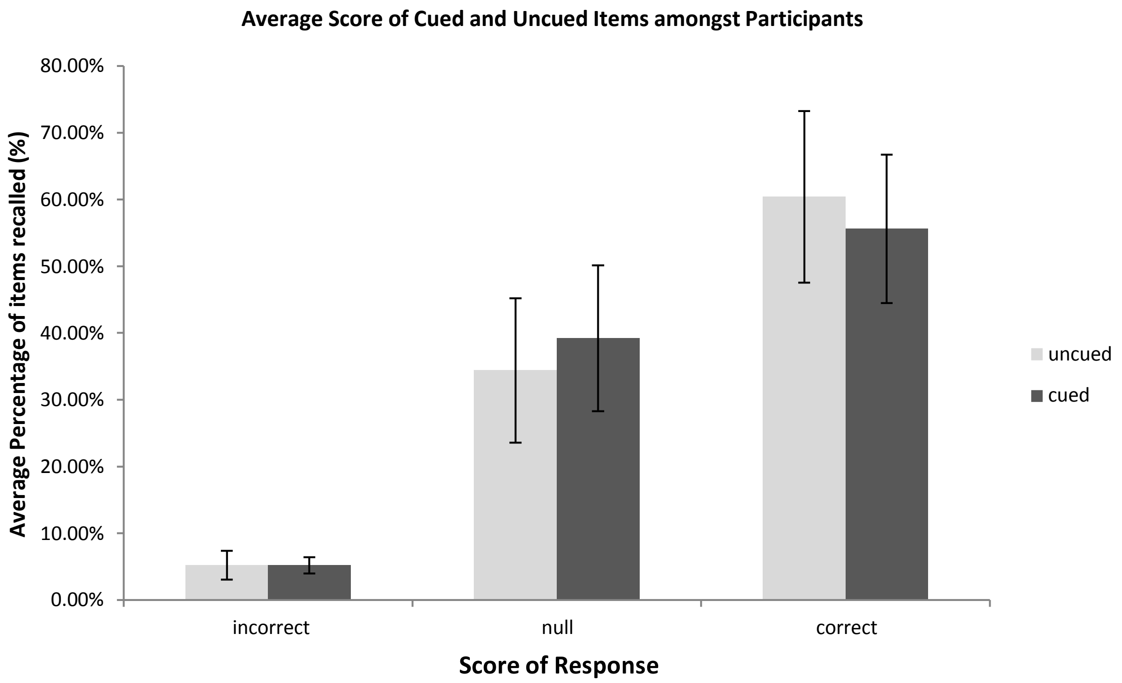


Figure 3. Bar chart showing the relationship between the cueing and the percentage of correct, null or incorrect scores during the retrieval task. The error bars demonstrate the standard error for each variable. The data is compiled from all participants (n=5).

Hypothesis 1 was not supported. The data appeared to show that, although in the direction predicted, there was not a significant difference in the percentage of incorrect, null or correct responses between cued and un-cued stimuli at a .05 level. The paired-samples t-test comparing the percentage of incorrect responses that were either cued (M= 5.20, SD= 2.71) or un-cued (M= 5.20, SD= 4.83) was found to not reach a level of significance; t(4)= 0, p= 1. However, there was nearly a significant difference when looking at the percentage of null responses in terms of cued (M= 39.20, SD= 24.48) and un-cued stimuli (M= 34.40, SD= 24.18); t(4)= 2.45, p= .070. Finally, the statistical analysis indicated that the percentage of correct responses was not significantly different between the cued (M= 55.60, SD= 24.90) and un-cued (M= 60.40, SD= 28.72) groups; t(4)= 1.22, p= .289.

Implicit Effects

The average reaction time (to recognise the objects during the implicit retrieval task) for cued and un-cued stimuli across participants can be seen below in Figure 4.

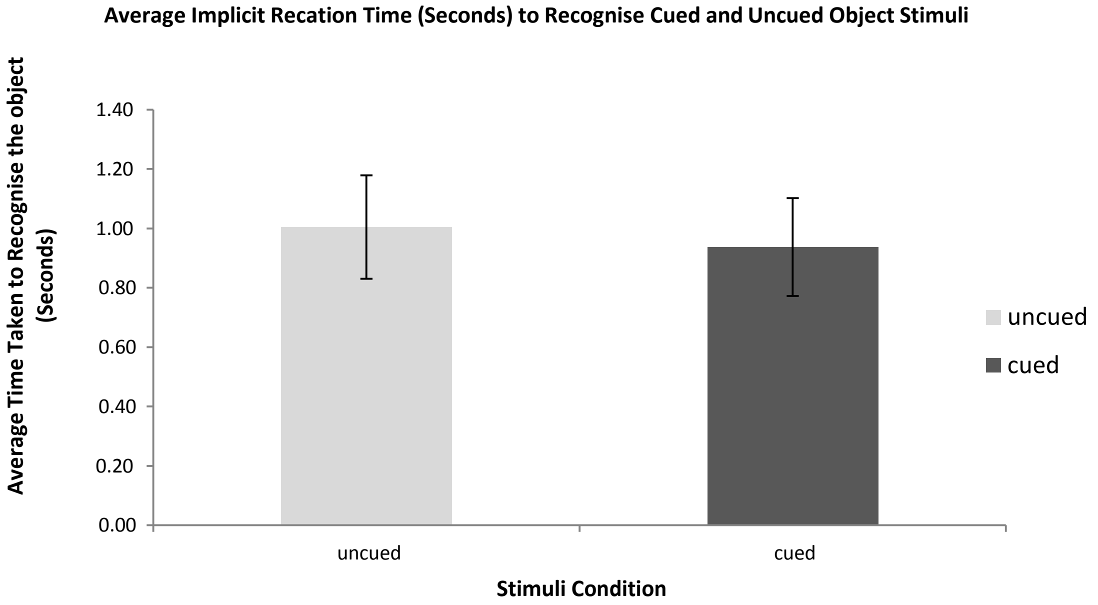


Figure 4. Line chart of the average reaction time for cued and un-cued stimuli during the implicit recognition task. The error bars demonstrate the standard error for each variable. The data is compiled from all participants (n=5).

Hypothesis 3a was not supported. A paired-samples t-test was conducted to compare how cueing affects the reaction time in recognising the object as it fades in during the implicit retrieval task. The statistical analysis comparing the average reaction time (seconds) for the implicit recognition of cued (M= 0.94, SD= 0.33) or un-cued (M= 1.01, SD= 0.35) was found to not reach significance; t(4)= 0.96, p= .392.

Experiment 3: Methods

Participants

A total of 25 (21 females, 4 males; Mean age = 20.8 years; SD = 4.3 years) individuals were recruited via an online participation pool at University of Birmingham. All participants were students at the University of Birmingham and the first nine participated in the study for a cash payment of 10 pounds while the remainder carried out the study as part of a compulsory research module.

Materials

The materials and equipment used in this version remained the same as those stated in the 'General Methods' section.

Design and Procedure

A similar design and procedure to the previous version of the experiment was used, however an additional pre-encoding task was added. As well as this, a few changes were made to the structure of the individual tasks in an attempt to further enhance the experimental methodology. The most prominent alteration involved the addition of the object pre-encoding phase in which, to strengthen the link between the object and the sound, the object was presented along with the sound prior to encoding. During the 'object pre-encoding task', participants were informed to make a size judgement as to whether the object they are presented with could fit within a shoebox. These object-sound pairs were presented twice during this task for a total of three seconds each. Finally, the repetition of the sound cues during the offline period (n-back task) was further increased to strengthen the cueing process and so each cue was presented three times. In an attempt to avoid an increase in duration and in turn avoiding fatigue effects for this task, the n-back task was split into three blocks with each lasting a total of four minutes. This allowed participants to have a short break between each block allowing further concentration at the percentage task once they began again.

Analysis of Data

Amongst the retrieval task data set for 'Experiment 3' one outlier was found amongst the implicit data and was removed from all analysis involving implicit retrieval. Amongst this current experiment, only Hypothesis 1 and Hypothesis 3a are used as Hypothesis 2 requires the use of an 'Altered' state, which was not present here. *Hypothesis 1: Cueing during an 'Awake' state will have significant detrimental effect to explicit recollection memory when compared to stimuli that remained un-cued. Hypothesis 3a: Cueing during an 'Awake' state will have significant detrimental* *effect to implicit recognition memory (due to a single-system theory of memory), when compared to stimuli that remained un-cued.*

Experiment 3: Results

Explicit Effects

Multiple paired-samples t-tests were conducted to examine the effects cueing has on the recall of scenes post-cue in this experiment. During this test participants were not penalised for incorrect answers, simply scored for the percentage of correct, null and incorrect ones. The average percentage of incorrect, null or correct responses for cued and un-cued stimuli during the retrieval task can be seen below in Figure 5.

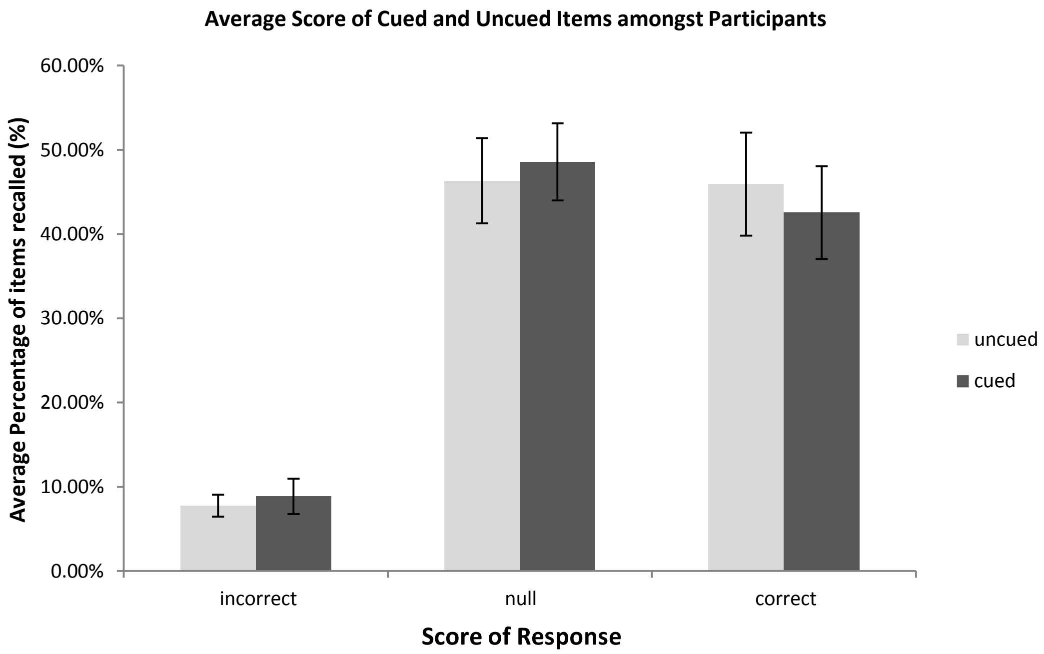


Figure 5. Bar chart showing the relationship between the cueing and the percentage of correct, null or incorrect scores during the retrieval task. The error bars demonstrate the standard error for each variable. The data is compiled from all participants (n=25).

Hypothesis 1 was not supported. Paired-samples t-tests were conducted to compare how cueing affects the percentage of incorrect, null or correct responses given by participants in the retrieval task. The statistical analysis comparing the percentage of incorrect responses given for cued (M= 8.88, SD= 6.30) or un-cued (M= 7.76, SD= 6.51) stimuli was found to not reach a level of significance; t(24)= 1.04, p= .309. Similarly, there was no significant difference when looking at the percentage of null responses in terms of cued (M= 48.56, SD= 13.69) and un-cued stimuli (M= 46.32, SD= 15.23); t(24)= 1.12, p= .272. Finally, the statistical analysis indicated that the percentage of correct responses was also not significantly different between the cued (M= 42.56, SD= 16.51) and un-cued (M= 45.92, SD= 18.35) groups; t(24)= 1.73, p= .096.

Implicit Effects

The average reaction time for cued and un-cued stimuli across participants (to recognise the objects during the implicit retrieval task) can be seen below in Figure 6.

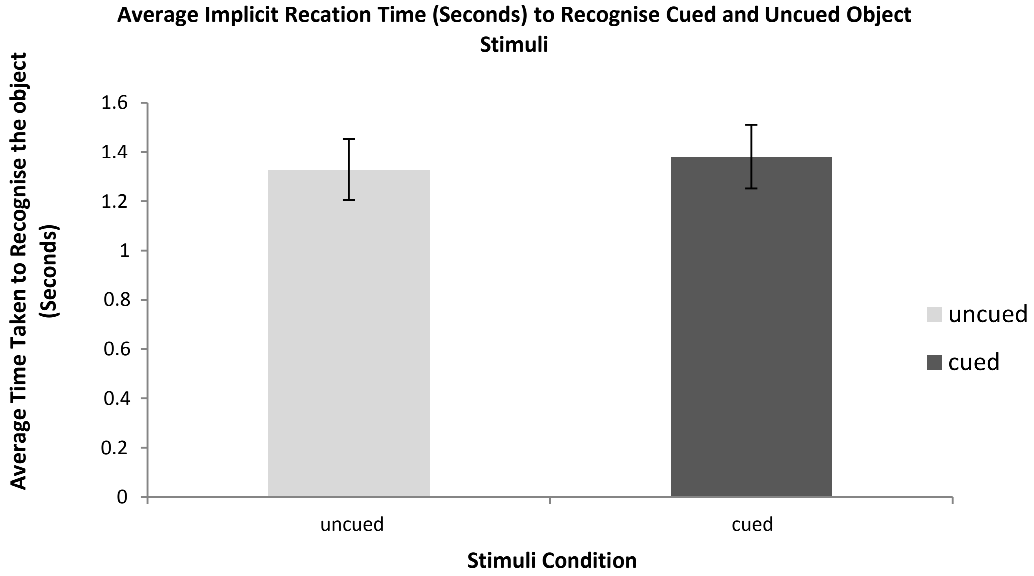


Figure 6. Line chart of the average reaction time for cued and un-cued stimuli during the implicit recognition task. The error bars demonstrate the standard error for each variable. The data is compiled of all participants from Experiment 3 minus one outlier that occurred due to programming error (n=24).

Hypothesis 3a was not supported. A paired-samples t-test was conducted to compare how cueing affects the reaction time in recognising the object as it fades in during the implicit retrieval task. The statistical analysis comparing the average reaction time (seconds) for the implicit recognition of cued (M= 1.38, SD= 0.63) or un-cued (M= 1.33, SD= 0.61) stimuli was found to not reach significance; t(23)= 1.48, p= .153.

Experiment 4: Methods

Participants

A total of 10 (7 females, 3 males; Mean age = 20.4 years; SD = 0.66 years) individuals were recruited via an online participation pool at University of Birmingham. All participants were students at the University of Birmingham and participated in the study for a cash payment of 10 pounds.

Materials

The materials and equipment used in this version are similar to those in the ‘General Methods’ section. However, in an attempt to gain research experience a final year undergraduate conducted this version of the experiment using a desktop computer (Stone® MiniTower PC). She was taught and supervised in how to conduct the experiment in a controlled and ethically sound manner.

Design and Procedure

A similar design and procedure to the previous version of the experiment (Experiment 3) was used. However an additional retrieval task was added, as well as few changes being made to the structure of the individual tasks in an attempt to further enhance the experimental methodology. The main enhancement made to this version involves the addition of a secondary retrieval task based 24-hours after the initial run of the experiment. This ’24 hours later’ retrieval task was added in an attempt to further increase the similarities between the structure of this experiment with other memory consolidation research (see Rasch et al., 2007). Finally, the random rotation of the objects during the implicit reaction-time based task was removed. This was done as any possible shape recognition that might trigger the recognition of the object is in its own right a possible form of implicit recognition. As this is the case, the moment recognition occurs (be it through object or simple shape recognition) the response will be recorded and so will further improve the accuracy of the implicit measure.

Analysis of Data

Amongst both retrieval tasks for ‘Experiment 4’ no outliers were found. Amongst this current experiment, only Hypothesis 1 and Hypothesis 3a are used as Hypothesis 2 requires the use of an ‘Altered’ state, which was not present here. *Hypothesis 1: Cueing during an ‘Awake’ state will have significant detrimental effect to explicit recollection memory when compared to stimuli that remained un-cued. Hypothesis 3a: Cueing during an ‘Awake’ state will have significant detrimental effect to implicit recognition memory (due to a single-system theory of memory), when compared to stimuli that remained un-cued.* Both of these hypotheses were examined with relation to two retrieval tasks, the first occurring post-cueing and the second occurring 24 hours later.

Experiment 4: Results

Explicit Effects

Multiple paired-samples t-tests were conducted to examine the effects cueing has on the recall of scenes ‘post-cue’ (the first retrieval task) and ‘24 hours later’ (second retrieval task) in this experiment. During this test participants were not penalised for incorrect answers, simply scored for the percentage of correct, null and incorrect ones. The average percentage of responses for cued and un-cued stimuli during both retrieval tasks (scored as incorrect, null or correct) can be seen below in Figure 7 below.

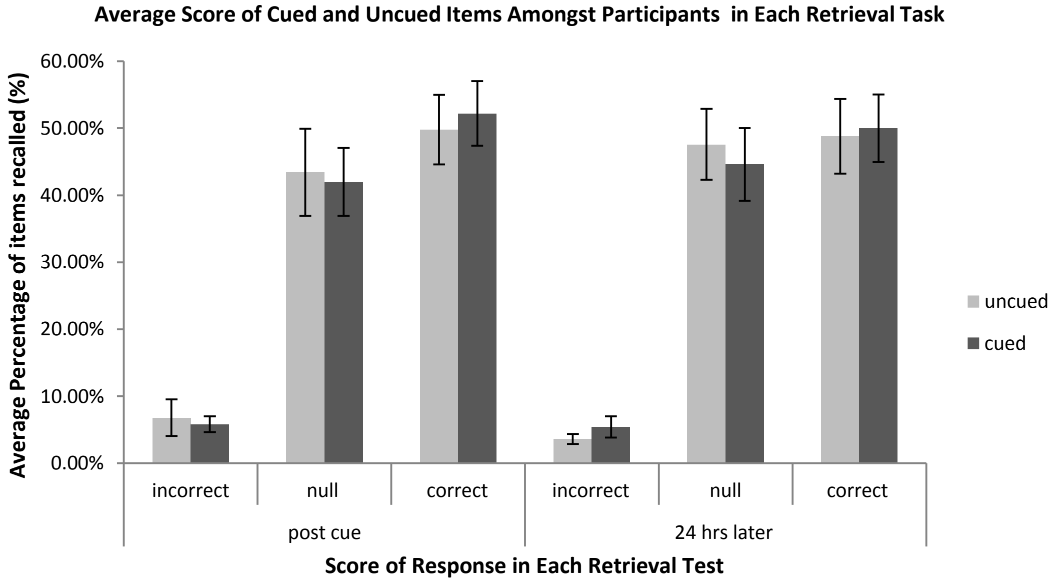


Figure 7. Bar chart showing the relationship between the cueing and the percentage of correct, null or incorrect scores during both the ‘post cue’ and ‘24 hours later’ retrieval tasks. The error bars demonstrate the standard error for each variable. The data is compiled from all participants (n=10).

Analysis of the ‘Post Cue’ test demonstrated that Hypothesis 1 was not supported. The data appeared to show that there was not a significant difference in the percentage of incorrect, null or correct responses between cued and un-cued stimuli at a .05 level. The paired-samples t-test analysis comparing the percentage of incorrect responses that were either cued (M= 5.80, SD= 5.02) or un-cued (M= 6.80, SD= 8.59) was found to not reach significance; t(9)= 4.55, p= .660. Similarly, there was no significant difference when looking at the percentage of null responses that were given in terms of cued (M= 42.00, SD= 17.16) and un-cued (M= 43.40, SD= 20.55) stimuli; t(9)= 0.56, p= .591. Finally, the statistical analysis indicated that the percentage of correct responses was also not significantly different between the cued (M= 52.20, SD= 15.96) and un-cued (M= 49.80, SD= 16.41) groups; t(9)= 0.78, p= .458.

Similar findings were present amongst the ’24 hours later’ test, as here Hypothesis 1 was also not supported. A paired-samples t-test was conducted to examine how cueing affects the percentage of incorrect, null or correct responses given during the ’24 hours later’ retrieval task. The statistical analysis comparing the percentage of incorrect responses that were either cued (M= 5.40, SD= 3.69) or un-cued (M= 3.60, SD= 2.33) was found to not reach significance; t(9)= 1.65, p= .134. Similarly, there was no significant difference when looking at the null responses in terms of cued (M= 44.60, SD= 16.00) and un-cued stimuli (M= 47.60, SD= 16.75); t(9)= 1.02, p= .337. Finally, the statistical analysis indicated that the percentage of correct responses was also not significantly different between the cued (M= 50.00, SD= 15.26) and un-cued (M= 48.80, SD= 17.55) groups; t(9)= 0.36, p= .727.

Following this, the difference between the percentage of correct answers for cued and un-cued stimuli in both retrieval tasks was statistically analysed using a paired-samples t test. Analysis indicated that the percentage of correct answers given for cued and un-cued stimuli was not significantly different between the ‘post cue’ (M= 2.40, SD= 9.29) and the ‘24 hours later’ (M= 1.20, SD= 10.01) retrieval tasks; t(9)= 0.63, p= .546.

Implicit Effects

The average participant reaction time for cued and un-cued stimuli across the two retrieval tasks (‘post cue’ and ’24 hours later’) can be seen below in Figure 8.

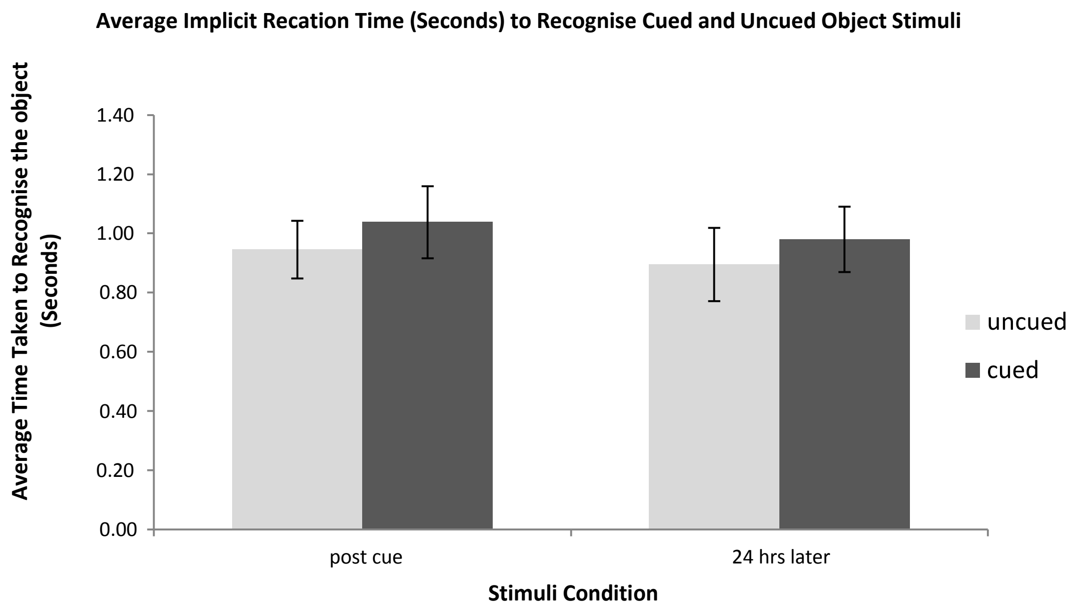


Figure 8. Line chart of the average reaction time for cued and un-cued stimuli during the implicit recognition task across the two tests. The error bars demonstrate the standard error for each variable. The data is compiled from all participants (n=10).

Hypothesis 3a was not supported amongst the ‘Post Cue’ test. Paired-samples t-tests were conducted to compare how cueing affects the reaction time in recognising the object as it fades in during the implicit retrieval task of the ‘post cue’ test. The statistical analysis comparing the average reaction time (seconds) for the implicit recognition of cued (M= 96.1, SD= 0.38) or un-cued (M= 0.90, SD= 0.29) stimuli was found to not reach a level of significance; t(9)= 1.19, p= .262.

Finally, Hypothesis 3a was examined amongst the data from the ’24 hours later’ test and was also not supported. The paired-samples t-test analysis of the average reaction time (seconds) in the ’24 hours later’ test for the implicit recognition of cued (M= 0.98, SD= 0.35) or un-cued (M= 0.90, SD= 0.39) stimuli was also found to not reach significance; t(9)= 1.64, p= .136.

Experiment 5: Methods

Participants

A total of 10 (9 females, 1 males; Mean age = 19.3 years; SD = 0.9 years) individuals were recruited via an online participation pool at University of Birmingham. All participants were students at the University of Birmingham and participated in the study for a cash payment of 10 pounds.

Materials

Most of the materials and equipment used in this version remained the same as those stated in the ‘General Methods’ section. Please re-view this section for further information. However, due to alterations made during this version of the experiment, the use of Sony headphones (Dynamic Stereo Headphones MDR-V150) was necessary. These headphones were required to play a downloaded 2.0Hz Delta Binaural Beat audio track from a credited binaural beat website (http://www.free-binaural-beats.com/). Similarly, to play the binaural beat audio-file, a multimedia player program (VLC Media Player) was utilised. Finally, participants were provided with a sheet of A4 paper with multiple pictures of leaves in which they were required to outline. This sheet can be seen in Appendix D.

Design and Procedure

The design and procedure of this version of the experiment is similar to ‘Experiment 4’ in that there is an additional retrieval task (24-hours after the initial experiment) and there is no rotation of the images during the implicit recognition task. The only alterations involve the use of binaural beat technology during the offline/cueing period (instead of the n-back task) in an attempt to generate an ‘Altered’ state of consciousness in the participants. During this phase (the n-back task in previous versions), participants were required to wear headphones which played the binaural beat audio as well as simultaneously cueing the objects with the cue sounds. However in an attempt to reduce conscious attention to the binaural beat audio and the cueing, participants were given an outlining task. They were instructed to outline the images of leaves provided as accurately as possible. This novel task was chosen as, due its simple nature it does not involve much cognitive processing and so will not inhibit the effects of the brainwave entrainment technology.

Analysis of Data

Amongst both retrieval tasks for 'Experiment 5' two outliers were found amongst the implicit data and so were removed from all implicit analysis. Amongst this current experiment, only Hypothesis 2 and Hypothesis 3 are used as Hypothesis 1 requires the use of an 'Awake' state, which was not present here. *Hypothesis 2: Cueing during an 'Altered' state will have significant beneficial effect to explicit recollection memory when compared to stimuli that remained un-cued. Hypothesis 3b: Cueing during an 'Altered' state will have significantly beneficial effects on implicit recognition memory, when compared to stimuli that remained un-cued.* Both of these hypotheses were examined with relation to two retrieval tasks, the first occurring post-cueing and the second occurring 24 hours later.

Experiment 5: Results

Explicit Effects

Multiple paired-samples t-tests were conducted to examine the effects cueing has on the recall of scenes 'post-cue' (the first retrieval task) and '24 hours later' (second retrieval task) in this experiment. During this test participants were not penalised for incorrect answers, simply scored for the percentage of correct, null and incorrect ones. The average percentage of responses for cued and un-cued stimuli during both retrieval tasks (scored as incorrect, null or correct) can be seen below in Figure 9 below.

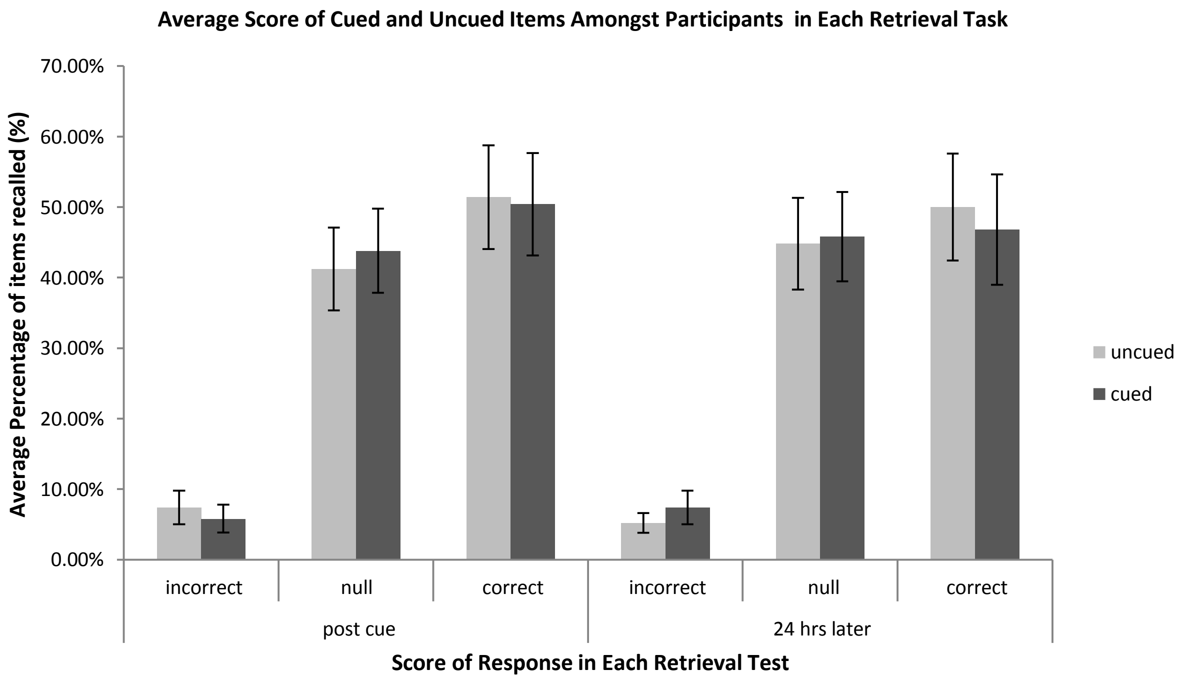


Figure 9. Bar chart showing the relationship between the cueing and the percentage of correct, null and incorrect scores during both the 'post cue' and 24 hours later' retrieval tasks. The error bars demonstrate the standard error for each variable. The data is compiled from all participants (n=10).

Analysis of the ‘Post Cue’ test demonstrated that Hypothesis 2 was not supported. The data appeared to show that there was not a significant difference in the percentage of incorrect, null or correct responses between cued and un-cued stimuli at a .05 level. Paired-samples t-tests were conducted to compare how cueing affects the percentage of incorrect, null or correct responses given by participants in the first retrieval task that occurred ‘post cue’. The statistical analysis comparing the percentage of incorrect responses that were either cued (M= 5.80, SD= 6.23) or un-cued (M= 7.40, SD= 7.54) was found to not reach a level of significance; t(9)= 1.12, p= .290. Similarly, there was no significant difference when looking at the percentage of null responses that were given in terms of cued (M= 43.80, SD= 18.84) and un-cued stimuli (M= 41.20, SD= 18.59); t(9)= 0.83, p= .427. Finally, the statistical analysis indicated that the percentage of correct responses was also not significantly different between the cued (M= 50.40, SD= 22.97) and un-cued (M= 51.40, SD= 23.24) groups; t(9)= 0.29, p= .779.

Similar findings were present amongst the ’24 hours later’ test, as Hypothesis 2 was also not supported here. Following analysis of the first retrieval task (post cue), the second retrieval task that occurred 24 hours after the initial run of the experiment was examined. A paired-samples t-test was conducted to examine how cueing affects the percentage of incorrect, null or correct responses given during the ’24 hours later’ retrieval task. The statistical analysis comparing the percentage of incorrect responses that were either cued (M= 7.40, SD= 7.49) or un-cued (M= 5.20, SD= 4.40) was found to not reach a level of significance at a .05 level; t(9)= 1.49, p= .170. Similarly, there was no significant difference when looking at the null responses in terms of cued (M= 45.80, SD= 19.97) and un-cued stimuli (M= 44.80, SD= 20.61); t(9)= 0.41, p= .694. Finally, the statistical analysis indicated that the percentage of correct responses was also not significantly different between the cued (M= 46.80, SD= 24.77) and un-cued (M= 50.00, SD= 24.00) groups at a .05 level; t(9)= 1.15, p= .280.

Implicit Effects

The average participant reaction time for cued and un-cued stimuli across the two retrieval tasks (‘post cue’ and ’24 hours later’) can be seen below in Figure 10.

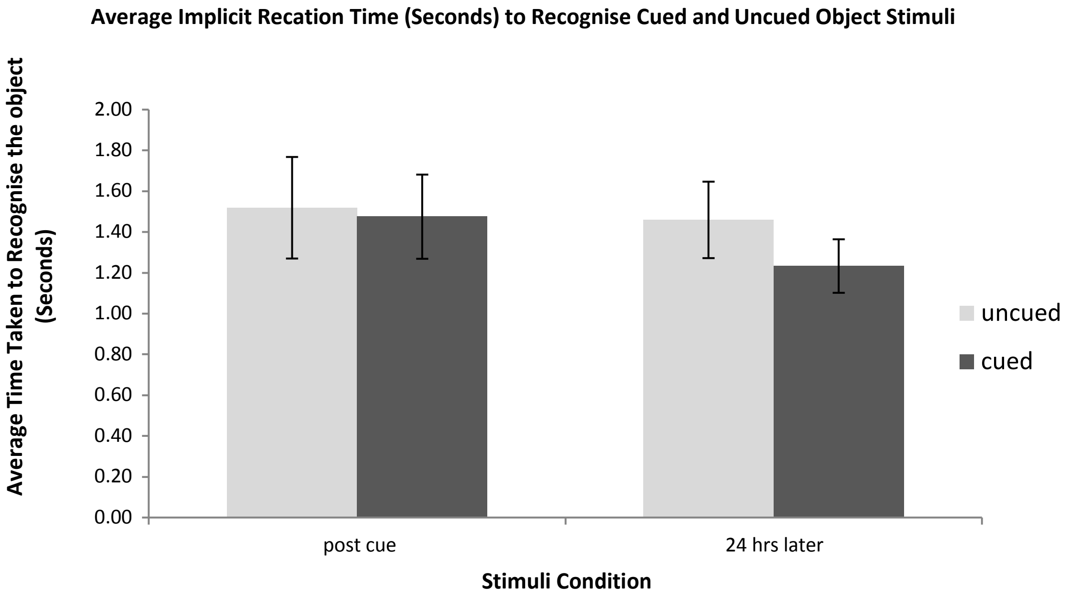


Figure 10. Line chart of the average reaction time for cued and un-cued stimuli during the implicit recognition task across the two retrieval tests. The error bars demonstrate the standard error for each variable. The data is compiled from all participants minus two outliers (n=8).

Hypothesis 3b was not supported amongst the 'Post Cue' test. Paired-samples t-tests were conducted to compare how cueing affects the reaction time in recognising the object as it fades in during the implicit retrieval task of the 'post cue' test. The statistical analysis comparing the average reaction time (seconds) for the implicit recognition of cued (M= 1.47, SD= 0.58) or un-cued (M= 1.52, SD= 0.70) was found to not reach significance; t(7)= 0.47, p= .651.

Finally, Hypothesis 3b was examined amongst the data from the '24 hours later' test and was supported. The average reaction time (seconds) for cued (M= 1.23, SD= 0.37) stimuli was found to be significantly lower than for the un-cued (M= 1.46, SD= 0.53) stimuli; t(7)= 2.36, p= .046.

Experiment 6: Methods

Participants

A total of 10 (7 females, 3 males; Mean age = 20.4 years; SD = 1.8 years) individuals were recruited via an online participation pool at University of Birmingham. All participants were students at the University of Birmingham and participated in the study for a cash payment of 10 pounds.

Materials

All of the materials were the same as 'Experiment 5', including the headphones, multimedia software program and the A4 sheet of leaves.

Design and Procedure

The design and procedure of this version of the experiment is different to that of the previous versions. The first change involved the retrieval task being revised in an attempt to improve its accuracy. The removal of the 'Reported Recall' task was carried out as having an 'Actual Recall' task seemingly undermined the need for the 'Reported Recall' variable. The revised retrieval task only involved recording the implicit response followed by the 'Actual Recall' task (writing the name of the scene paired with the object). The next change to the tasks involved the re-addition of the n-back task, however this time the cueing was been removed from the task as this task simply acted as a delay period task. Additionally to these changes, the actual structure of the experiment was altered.

The structure of the experiment was altered in an attempt to better mimic the set-up of previous memory consolidation research (see Rasch et al., 2007). This experiment begins with the pre-encoding and encoding phases the same as the fifth version of the experiment. Followed by this, participants took part in the n-back task as a delay task and there was no cueing sounds during this task. Once completed, participants took part in the revised version of the retrieval task (implicit reaction time task followed by the 'Actual Recall' task). This task was introduced at this stage of the experiment as it will provide the levels of recollection prior to cueing. Followed by this, participants took part in the binaural beat task in which they are required to outline the leaves while listening to the binaural beat audio and the sound cues. This task acted as a cue for the objects and perhaps scene memories previously formed during the encoding task. Once this cuing had taken place, participants took part in a secondary retrieval task (the new version). This task then provided the data as to the recollection post cueing. Finally, participants were required to return 24-hours post testing to take part in a final retrieval task (once again involving the revised test) further mimicking the structure of previous memory consolidation research.

Analysis of Data

Amongst both retrieval tasks for ‘Experiment 6’ three outliers were found. Two of these outliers were found amongst the explicit retrieval task and one was found amongst the implicit retrieval. These outliers were each removed only from the analysis in which the error occurred. Amongst this current experiment, only Hypothesis 2 and Hypothesis 3 are used as Hypothesis 1 requires the use of an ‘Awake’ state, which was not present here*. Hypothesis 2: Cueing during an ‘Altered’ state will have significant beneficial effect to explicit recollection memory when compared to stimuli that remained un-cued. Hypothesis 3b: Cueing during an ‘Altered’ state will have significantly beneficial effects on implicit recognition memory, when compared to stimuli that remained un-cued.* Both of these hypotheses were examined with relation to the three retrieval tasks, the first occurring pre-cue, then post-cue and finally 24 hours later.

Experiment 6: Results

Explicit Effects

Multiple paired-samples t-tests were conducted to examine the effects cueing has on the recall of scenes during the ‘pre-cue’ test (the first retrieval task), ‘post-cue’ test (the second retrieval task) and ‘24 hours later’ test (final retrieval task) in this experiment. During this test participants were not penalised for incorrect answers, simply scored for the percentage of correct, null and incorrect ones. The average percentage of responses for cued and un-cued stimuli during both retrieval tasks (scored as incorrect, null or correct) can be seen below in Figure 11 below.

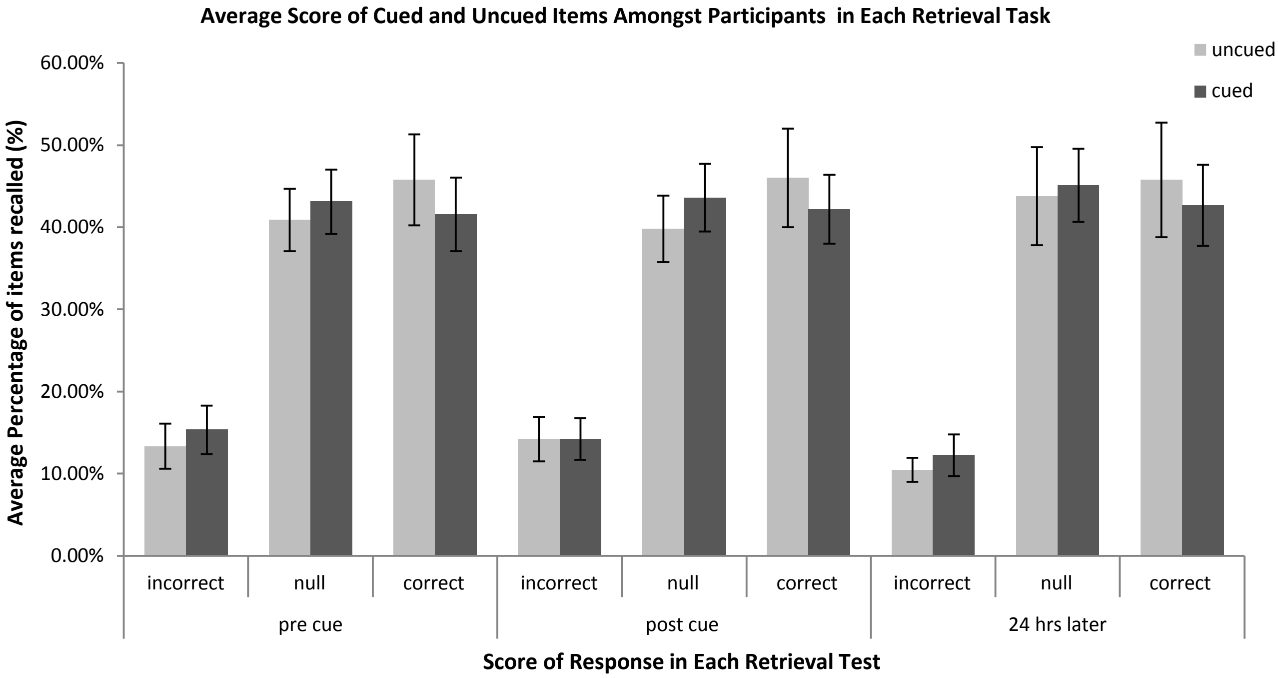


Figure 11. Bar chart showing the relationship between the cueing and the percentage of correct, null or incorrect scores during retrieval tasks occurring ’pre cue’ (n=9), ‘post cue’ (n=10) and ‘24 hours later’ (n=9). The error bars demonstrate the standard error for each variable.

Analysis of the ‘Pre Cue’ test demonstrated that Hypothesis 2 was not supported. The data appeared there was not a significant difference in the percentage of incorrect, null or correct responses between cued and un-cued stimuli at a .05 level. Paired-samples t-tests were conducted to compare how cueing affects the percentage of incorrect, null or correct responses given by participants in the first retrieval task that occurred ‘pre cue’. The statistical analysis comparing the percentage of incorrect responses that were either cued (M= 15.33, SD= 8.84) or un-cued (M= 13.33, SD= 8.22) was found to not reach a level of significance; t(8)= 0.99, p= .353. Similarly, there was no significant difference when looking at the percentage of null responses that were given in terms of cued (M= 42.00, SD= 26.00) and un-cued stimuli (M= 32.00, SD= 28.00); t(8)= 0.67, p= .525. Finally, the statistical analysis indicated that the percentage of correct responses was also not significantly different between the cued (M= 56.00, SD= 50.00) and un-cued (M= 66.00, SD= 58.00) groups; t(8)= 1.60, p= .148.

Similar findings were present amongst the ‘Post Cue’ test, as Hypothesis 2 was also not supported here. A paired-samples t-test was conducted to examine how cueing affects the percentage of incorrect, null or correct responses given during the ‘post cue’ retrieval task. The statistical analysis comparing the percentage of incorrect responses that were either cued (M= 14.20, SD= 8.02) or un-cued (M= 14.20, SD= 8.55) was found to not reach significance; t(9)= 0.00, p= 1. Similarly, there was no significant difference when looking at the null responses in terms of cued (M= 43.60, SD= 12.99) and un-cued stimuli (M= 39.80, SD= 12.82); t(9)= 1.02, p= .338. Finally, the statistical analysis indicated that the percentage of correct responses was also not significantly different between the cued (M= 42.20, SD= 13.31) and un-cued (M= 46.00, SD= 19.02) groups; t(9)= 1.22, p= .256.

Finally, the ’24 Hours Later’ test was analysed and Hypothesis 2 was also not supported here. Paired-samples t-test analysis indicated that the percentage of correct answers given for cued and un-cued stimuli was not significantly different between the ‘pre cue’ (M= 4.22, SD= 7.45) and the ‘post cue’ (M= 3.80, SD= 9.40) tests at a .05 level; t(9)= 0.77, p= .464. Similarly, the percentage difference between cued and un-cued stimuli for correct answers between the ‘pre cue’ (M= 4.22, SD= 7.45) and the ’24 hours later’ (M= 3.11, SD= 8.49) tests were also not significant; t(8)= 0.78, p= .456. Finally, the difference in average score between cued and un-cued stimuli for correct answers between the ‘post cue’ (M= 3.80, SD= 9.40) and the ’24 hours later’ (M= 3.11, SD= 8.49) tests were also not significant; t(8)= 0.59, p= .569.

Implicit Effects

The average participant reaction time for cued and un-cued stimuli across the two retrieval tasks (‘post cue’ and ’24 hours later’) can be seen below in Figure 12.

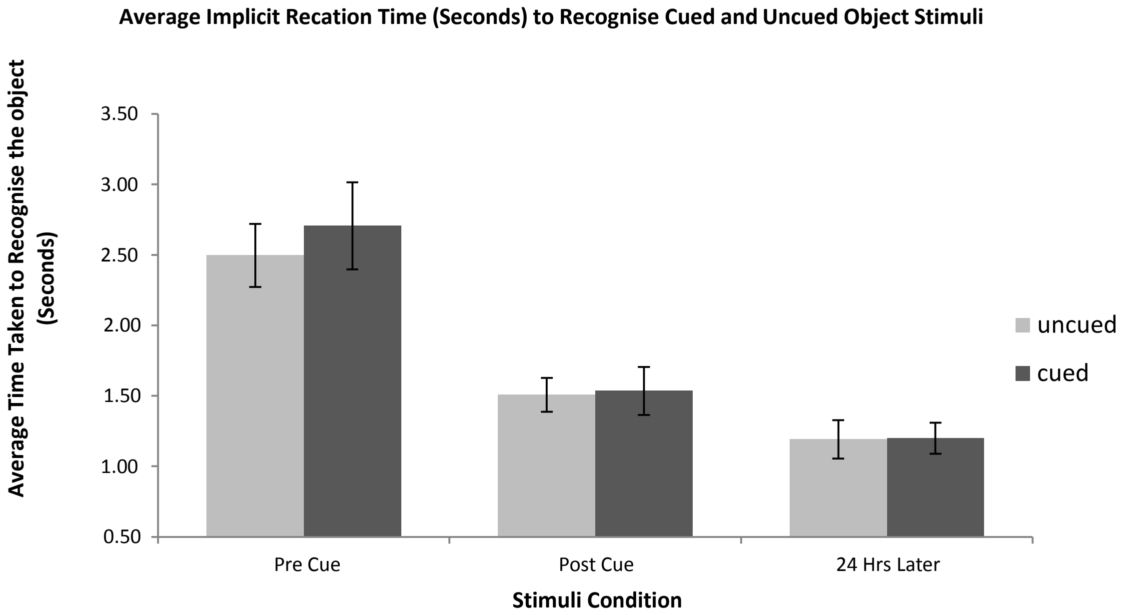


Figure 12. Line chart of the average reaction time for cued and un-cued stimuli in the implicit recognition task during the 'pre cue' (n=9), 'post cue' (n=10) and '24 hours later' (n=9) tests. The error bars demonstrate the standard error for each variable.

Hypothesis 3b was not supported amongst the 'Pre Cue' test. Paired-samples t-tests were conducted to compare how cueing affects the reaction time in recognising the object as it fades in during the implicit retrieval task of the 'pre cue' test. The statistical analysis comparing the average reaction time (seconds) for the implicit recognition of cued (M= 2.71, SD= 0.93) or un-cued (M= 2.50, SD= 0.67) was found to not reach significance; $t(8)= 1.47$, $p= .180$.

Hypothesis 3b was also not supported amongst the 'Post Cue' test. Amongst the 'post cue' retrieval task the average reaction time (seconds) for cued (M= 1.53, SD= 0.54) and un-cued (M= 1.51, SD= 0.38) stimuli was not found to be significantly different; $t(7)= 0.35$, $p= .736$.

Finally, Hypothesis 3b was examined amongst the data from the '24 hours later' test and was not supported. Amongst the '24 hours later' retrieval task the average reaction time (seconds) for cued (M= 1.20, SD= 0.35) and un-cued (M= 1.19, SD= 0.43) stimuli was also not found to be significantly different; $t(7)= 0.15$, $p= .884$.

Cross Experimental Results

Amongst the data collected, programming error led to three participants being classified as outliers for the explicit analysis and five participants being classified as outliers for the implicit analysis. Amongst this analysis, all three Hypotheses were examined. *Hypothesis 1: Cueing during an 'Awake' state will have significant detrimental effect to explicit recollection memory when compared to stimuli that remained un-cued. Hypothesis 2: Cueing during an 'Altered' state will have significant beneficial effect to explicit recollection memory when compared to stimuli that remained un-cued. Hypothesis 3a: Cueing during an 'Awake' state will have significant detrimental effect to implicit recognition memory (due to a single-system theory of memory), when compared to stimuli that remained un-cued. Hypothesis 3b: Cueing during an 'Altered' state will have beneficial effects on implicit recognition memory, when compared to stimuli that remained un-cued.* Finally, an additional analysis to examine any effects the plausibility measure (during the encoding task) has on explicit recollection and implicit recognition.

Explicit Effects

As Hypothesis 1 requires an 'Awake' state, experiment 5 and 6 are exempt from the analysis. As the only experiment to involve a 'pre cue' test was Experiment 6, this test will be omitted from the analysis. For an in depth analysis of this retrieval task, see the results section of the corresponding experiment. Hypothesis 1 was not supported when examining all of the relevant 'Post Cue' data. The paired-samples t-test indicated that the cueing had no significant effect upon the average percentage of incorrect ($t(48)= 0.87$, $p= .387$), null ($t(48)= 1.23$, $p= .226$) or correct ($t(48)= 1.69$, $p= .097$) responses. All other interactions and effects were not significant for this Hypothesis. Following this, Hypothesis 2 was examined.

Hypothesis 2 was also not supported when examining the relevant 'Post Cue' data. Analysis indicated that cueing had no significant effect upon the average percentage of incorrect ($t(19)= 0.56$, $p= .579$), null ($t(19)= 1.34$, $p= .195$) or correct ($t(19)= 1.05$, $p= .308$) responses. Similar findings were present amongst the '24 Hours Later' task as there was no significant effect of cueing on the average percentage of incorrect ($t(18)= 1.70$, $p= .106$), null ($t(18)= 0.63$, $p= .539$) or correct ($t(18)= 1.59$, $p= .129$) responses. All other interactions and effects were not significant for this Hypothesis.

Implicit Effects

Hypothesis 3a was supported using paired-samples t-tests. It was found that amongst the 'Awake' experiments, cued objects ($M= 1.29$, $SD= 0.64$) were significantly slower to be recognised than un-cued objects (M= 1.24, SD= 0.59); t(37)= 2.03, p= .049. However, Hypothesis 3b was not supported. Analysis amongst the ‘Altered’ state experiments indicated that cued objects (M= 1.51, SD= 0.56) were not significantly different in average recognition speed to the un-cued objects (M=1.51, SD= 0.55); t(19)= 0.07, p= .945.

Plausibility Effects

Previous research (Tse et al., 2007) suggests a positive influence upon recollection when object-scene pairs are plausible. In an attempt to examine whether plausibility of the object-scene pairs had an influential effect upon the levels of explicit recall amongst the ‘Post Cue’ and ’24 Hours Later’ retrieval tasks, paired-samples t-tests were conducted. Analysis of the ‘Awake’ states indicated a significant increase in the percentage of correct responses for stimuli reported as ‘plausible’ (M=56.46%, SD= 17.01%) than ‘implausible’ (33.21%, SD= 22.16%); t(48)= 10.69, p< .001. Similarly, amongst the ‘Altered’ state experiments there was significantly more correct responses amongst ‘plausible’ (M= 54.96%, SD= 19.65%) than ‘implausible’ (M=33.80, SD= 24.71%) responses; t(19)= 5.47, p< .001. Finally, amongst all of the experiments regardless of state of consciousness, there were significantly more correct responses for ‘plausible’ (M= 56.03%, SD= 17.83%) than ‘implausible’ (M= 33.38%, SD= 22.93) responses; t(68)= 11.94, p< .001. Following this, the implicit data was examined for any encoding effects that may be present.

In an attempt to examine whether plausibility of the object-scene pairs had an influential effect upon the speed of implicit recognition, paired-samples t-tests were conducted on the ‘Post Cue’ task data. Analysis indicated that ‘plausible’ (M= 1.23, SD= 0.61) objects were significantly faster than ‘implausible’ (M= 1.38, 0.67) objects amongst the ‘Awake’ experiments; t(47)= 3.70, p< .001. Similarly, amongst the ‘Altered’ state experiments ‘plausible’ (M= 1.53, SD= 0.52) objects were recognised significantly faster than ‘implausible’ (M= 1.69, SD= 0.62) objects; t(17)= 3.15, p= .006. Following this, all of the experiments regardless of state of consciousness were examined. This analysis indicated that ‘plausible’ (M= 1.31, SD= 0.60) objects were significantly faster to be recognised than the ‘implausible’ (M= 1.46, SD= 0.67) objects; t(65)= 6.25, p< .001.

Other Effects

In addition to the analyses previously conducted, paired-samples t-tests were conducted to further examine the possibility of cueing effects. Amongst this statistical analysis, multiple paired-samples t-tests were conducted to examine the effects cueing has on the recall of scenes during the ‘pre-cue’ test (the first retrieval task), ‘post-cue’ test (the second retrieval task) and ‘24 hours later’ test (final retrieval task) in all the experiments regardless of state of consciousness. The average percentage of responses for cued and un-cued stimuli during both retrieval tasks (scored as incorrect, null or correct) can be seen below in Figure 13 below.

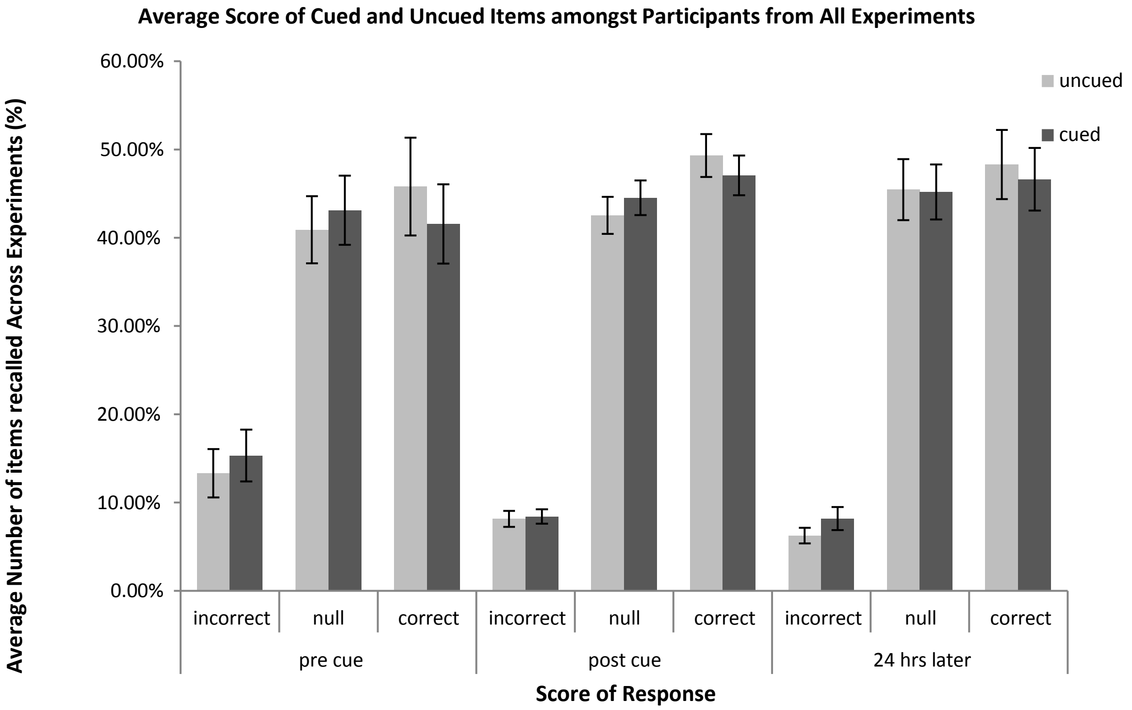


Figure 13. Bar chart showing the relationship between the cueing and the percentage of correct, null or incorrect scores during the ’pre cue’ (n=9), ‘post cue’ (n=69) and ‘24 hours later’ (n=29) retrieval tasks. The error bars demonstrate the standard error for each variable.

As the only experiment to involve a ‘pre cue’ test was Experiment 6, this test will be omitted from the analysis. For an in depth analysis of this retrieval task, see the results section of the corresponding experiment. Paired-samples t-tests were conducted to compare how cueing affects the percentage of incorrect, null or correct responses given by participants in the retrieval tasks that occurred ‘post cue’. The analysis was not significant for incorrect (t(68)= 0.37, p= .709) or null (t(68)= 1.81, p= .075) responses. However, the statistical analysis indicated that the percentage of correct responses was significantly lower amongst the cued (M= 47.04, SD= 18.62) stimuli than un-cued (M= 49.30, SD= 20.27) stimuli, t(68)= 1.99, p= .050. Following analysis of the ‘post cue’ retrieval task, the ’24 hours later’ retrieval task was examined. A paired-samples t-test was conducted to examine how cueing affects the percentage of incorrect, null or correct responses given during the ’24 hours later’ retrieval tasks. The statistical analysis found significantly more incorrect responses for items that were cued (M= 8.21, SD= 7.05) than un-cued (M= 6.28, SD= 4.78), t(28)= 2.29, p= .030. However, there was no significant difference when looking at the null (t(28)= 0.17, p= .864) or correct (t(28)= 0.95, p= .351) responses. Following this, all other analyses examining the effects cueing has on explicit recall were not significant and so are not reported here.

Finally, multiple paired-samples t-tests were conducted to examine the effects cueing has on the average reaction time of object (demonstrating implicit recognition) amongst the ‘pre-cue’ test (the first retrieval task), ‘post-cue’ test (the second retrieval task) and ‘24 hours later’ test (final retrieval task) in all the experiments, regardless of state of consciousness. The average participant reaction time for cued and un-cued stimuli across all experiments can be seen below in Figure 14.

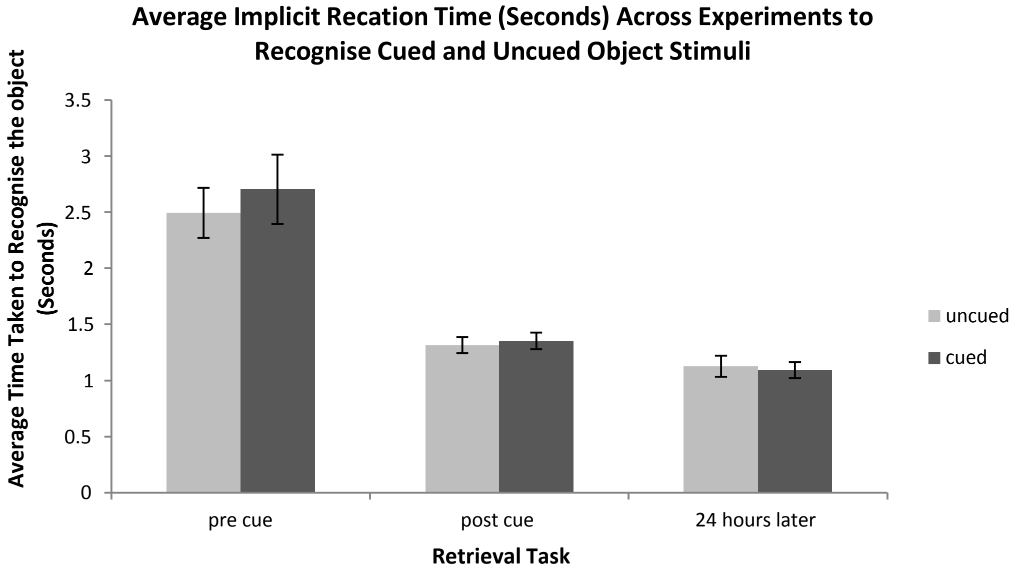


Figure 14. Line chart of the average reaction time for cued and un-cued stimuli in the implicit recognition task during the ’pre cue’ (n=9), ‘post cue’ (n=66) and ‘24 hours later’ (n=29) tests. The error bars demonstrate the standard error for each variable.

As the only experiment to involve a ‘pre cue’ test was Experiment 6, this test will be omitted from the analysis. For an in depth analysis of this retrieval task, see the results section of the corresponding experiment. Paired-samples t-tests were conducted to compare how cueing affects the reaction time in recognising the object as it fades into view. The average reaction time (seconds) for the implicit recognition of cued (M= 1.35, SD= 0.63) or un-cued (M= 1.32, SD= 0.59) objects during the ‘Post Cue’ test was not significant; t(65)= 1.48, p= .144). Similarly, amongst the ’24 hours later’ retrieval task the average reaction time (seconds) for cued (M= 1.09, SD= 0.39) and un-cued (M= 1.13, SD= 0.51) stimuli was also not found to be significantly different at a .05 level; t(28)= 0.80, p= .432. Following this, the average reaction time for each participant (regardless of cueing) was compared between the ‘post cue’ and the ’24 hours later’ retrieval tasks of experiments 4, 5 and 6. The average reaction time for each participant (regardless of cueing) was found to be significantly slower during the ‘post cue’ (M= 1.33, SD= 0.61) test than the ’24 hours later’ (M= 1.11, SD= 0.45) test; t(28)= 4.58, p< .001. All other analyses examining the effects cueing has on implicit recognition were not significant and so are not reported here.

Discussion

This study investigated memory consolidation and the effects of cueing at an 'Awake' state or an artificially generated 'Altered' state of consciousness on memory retrieval. The research examined the consolidation effects upon explicit recollection and implicit recognition as evidence for the beneficial effects on memory that cueing has during an 'Altered' state (Rudoy et al., 2009), or the detrimental effects often cited during 'Awake' states (Diekelmann et al., 2011). The first hypothesis (cueing during an 'Awake' state is detrimental to explicit memory recall) was only partially supported as the overall trend was in the expected direction. Findings from the 'Cross Experimental' analysis seemingly demonstrate this as there were fewer correct and more incorrect responses amongst cued than un-cued stimuli overall, whereby most studies involved an 'Awake' state. However, when examining the 'Awake' state solely this effect does not remain, indicating that the addition of the 'Altered' state seemingly is responsible for this result. The second hypothesis (cueing during 'Altered' states will have a beneficial effect on explicit memory) involved replicating the findings of previous sleep consolidation research (see Diekelmann et al., 2011). This hypothesis however could not be supported at any level as none of the analyses indicated the expected effect. The third and final hypothesis (cueing will have beneficial effects to implicit recognition in 'Altered' states and detrimental effects in 'Awake' states) was partially supported. 'Cross Experimental' analysis indicated significantly slower recognition for cued objects amongst the 'Awake' state experiments. However, this effect was not found to be beneficial for the 'Altered' states as expected and so the hypothesis can only be supported so far. Finally, additional analyses found that objects-scene pairs reported as plausible would be significantly better recalled than implausible pairs. This was supported across both states of consciousness however was not found to have a significant effect upon implicit recognition speed. This seems to suggest that encoding strength is highly beneficial for explicit recollection (as reported by Hussey, Smolinsky, Piryatinsky, Budson, & Ally, 2012), however it may be less effective for implicit recognition. Despite the general lack of hypothesis support, examining previous literature and methodologies gives a clearer explanation as the possible reason for these mostly null findings.

Explanation of Findings

Previous literature suggests that cueing during an 'Awake' state is detrimental to explicit memory retrieval (Diekelmann et al., 2011); however this was not the case here. In contrast to Diekelmann et al. (2011), this research used an n-back task as the offline period in which the cueing was presented. Cueing during such a complex, cognitively demanding task such as the n-back task is a fairly novel addition to this research area. The findings appear to demonstrate that cueing during such a demanding task not only reduces the effects of cueing, but in tern may actively inhibit the effects of memory consolidation. Similarly, the current experiment utilised the use of 'scene' images as opposed to a simple special-location exercises (see Rudoy et al., 2009) to examine explicit recall. The difference in the results of the studies suggests a possible difference between the two memory types in terms of encoding and perhaps consolidation processes, despite both being episodic memories. This difference is likely due to higher levels of encoding amongst the current research when compared to previous research (see Rasch et al., 2007; Rudoy et al., 2009). This potentially resulted in participants being more likely to recall scenes for plausible pairs regardless of cueing, weakening the perceived cueing effect. However, this weakening of the cueing effect was not present amongst the implicit data, as when examining all the 'Awake' studies, cued objects were significantly slower to be recognised than un-cued objects. As the level of encoding was not reported to be a significant influence upon implicit recognition, the argument for encoding being the influential factor for the null cueing effects present amongst the explicit retrieval is further strengthened. However, the detrimental effect found on implicit recognition was only amongst the 'Awake' state, whereas the 'Altered' state version contained different findings.

Altered states (predominantly sleep) are often stated amongst memory consolidation research to be beneficial to memory when examining cueing effects (Rudoy et al., 2009). However, the current research was unable to demonstrate such an effect as almost all of the 'Altered' state hypotheses failed to demonstrate a significant difference. One possible explanation for this is that the 'Altered' state utilised within this experiment involved the use of binaural beats. These beats involve a constant noise and have the ability to be highly distracting, effectively reducing the ability to recollect the scenes within the required significance levels (despite no obvious floor or ceiling effect). Similarly, as the use of the binaural beats is a new and interesting way of manipulating brainwave states, it has never been combined with memory consolidation prior to this study. Therefor the lack of a beneficial effect on memory could be due to the use of this technique rather than the experimental methodologies. These findings overall appear to suggest a weak trend in expected direction however the strength of the effect was not significant. This may be due to multiple limitations in the methodological structure of this experiment. However with future improvements and iterations, this could lead to a better understanding of the consolidation process generally.

Limitations and Improvements

One of the primary limitations of this study was the lack of access to an EEG system. Due to this, the use of the binaural beats cannot verifiably be stated to have altered participant brainwave states enough for an effect to be demonstrated. To improve upon this, a future study utilising an

EEG style set up with the use of the binaural beats is recommended. Similarly, the use of binaural beats may have been for too short a duration as previous research in the area suggests that prolonged use may have more of a beneficial effect on manipulating brainwaves (Wahbeh, Calabrese, & Zwickey, 2007). In order to improve upon this, the use of binaural beats for a few days prior to experimentation could lead to the participants entering the correct brainwave state at a faster, more reliably pace. Alternatively improvements could be based on providing a set breathing method such as 'Diaphragmatic Breathing' (outlined by Farhi, 1996) to increase relaxation and in turn generating slower frequency brainwaves naturally. As well as technical limitations, some methodological issues were also present that future studies should seek to avoid. One of the first issues involves the object pre-encoding task amongst most of the experiments. During this task, participants were required to report whether the object they are presented with would generally fit within a shoebox. At encoding, elements have been stated to be predominantly sorted into three types (people, objects/animals or locations; see Horner, Bisby, Bush, Lin, & Burgess, 2015). Although a shoebox is often seen as an object, the act of envisioning an object within a shoebox is debatably similar to encoding the inside of the shoebox as scene/location. This is demonstrated within the raw data as some participants were found to report that the object was paired with a shoebox during the 'Actual Recall' retrieval task. To improve this, an alternative pre-encoding task in which participants judge the object based on its characteristics (e.g. smooth vs rough texture) may be more appropriate. Finally, the use of the n-back task has been known to reduce memory retention and encoding generally (Naveh-Benjamin & Guez, 2000; Hicks & Marsh, 2000), making it possible that it also affects the impact of memory cueing effects. Although a novel task amongst memory consolidation research, the null findings suggest that the task may have been too cognitively complex to allow for the effects of cueing. To improve this, future research should seek to utilise a similar delay period present in other memory consolidation research (Oudiette, Antony, Creery, & Paller, 2013; Diekelmann et al., 2011). Despite these limitations, the addition of the previously stated novel variables has many implications for current research in the field.

Implications for Current Research

The current study has multiple implications for various aspects of the memory consolidation topic area. The findings presented here provide a valued contrast to the current findings within the memory consolidation field. Primarily, evidence here appears to demonstrate that the effects of cueing are fairly weak when examining episodic memory recall. The use of episodic memories allows for further research into the Multiple Trace Theory of memory which states that the hippocampus is required for the encoding and retrieval of these types of memory, but not semantic memories (Nadel & Moscovitch, 1997). Combining brain imaging technologies such as fMRI to such a study could potentially validate or contradict this theory. Should this brain imaging research demonstrate that these episodic memories become hippocampus independent after a few years, supporting evidence for the Standard Theory of consolidation could be provided. This current study's findings suggest that an artificially generated 'Altered' state does not have an impact on cueing effects and memory consolidation. When combining this with findings that both wakefulness and REM sleep also do not generate consolidation effects from cueing (Rasch et al., 2007), it suggests slow wave sleep is the specific and crucial state for this phenomenon. This research could therefore open up interesting possibilities about the differences between artificially generated brainwave states and the real altered states. Finally, most memory consolidation research as of yet has avoided the use of the n-back task utilised amongst this study. The findings appear to suggest that this task is very cognitively demanding and in turn potentially reduces the consolidation process (as seen by the null findings amongst the studies with such a task). The implications of this are vast as perhaps the reason for deep sleep being the perfect state for memory consolidation to occur is due to the almost complete lack of cognition. This opens up future research possibilities in which different levels of cognitive attention during the cueing phase are examined, with deep sleep being the least cognitively demanding stage. The implications of this study do not stop with memory consolidation as it has implications for research into altered states of consciousness and memory research as a whole.

Memory research suggests that implicit and explicit memories are retained and processed independently and so implicit recall is possible without explicit knowledge (Tulving et al., 1982). Upon initial viewing of the results, it appears as though cueing has an impact upon implicit memory but not on explicit memory, suggesting support for the multiple-systems theory of memory. This can be seen by how cued stimuli are significantly slower to be recognised amongst the implicit recognition task, while the explicit task failed to demonstrate any such effect. However, due to the fact that explicit recall was overall fairly strong, a 'pure' implicit memory (whereby explicit recall is truly absent) was not demonstrated and so the current study provides support for a sings-system approach to implicit memory overall. There also appears to be implications for research into altered states of consciousness. As mentioned previously, one of the issues with the current study involves the use of the binaural beats which are a fairly understudied technique amongst psychological research. One of the main implications of this is that, due to the overall null effect these beats had, further research is required to examine how best to utilise this technology. Despite other research stating the use of the beats for 30 minutes over multiple days is effective (Wahbeh, Calabrese, & Zwickey, 2007), others state that using the beats a few seconds at a time (Becher, Höhne, Axmacher, Chaieb, Elger, & Fell, 2014) was beneficial. This opens the possibility that the effectiveness of such a technique is based on the individuals being tested. So examining the individual difference amongst the effectiveness of binaural beats could lead to breakthrough uses of such techniques. Overall, research into the use of binaural beat technology to study memory consolidation phenomena is an easy practical application to the future of the topic area, opening up the potential for future study.

Future Studies

As briefly mentioned previously, future research should seek to further this current study by utilising brain imaging technology such as an EEG system to further examine whether the binaural beats do in fact alter brainwave frequency. Should this be demonstrated, the use of them would be much more valid in conjunction with memory consolidation. One method of utilising these technologies would be to examine the consolidation effects amidst other brainwave frequencies, besides the slow wave (delta) frequency often studied for sleep consolidation. One interesting area this opens up to examination is that of daydreaming, as promoting slower brainwave states increases the likelihood of daydreaming (Zhao, Wu, & Ou, 2013), allowing any consolidation processes occurring here to be examined. Despite research into this area having already been conducted (see Deuker et al., 2013), experiments are far from common and the use of binaural beats could simplify the process greatly. Similarly, binaural beat technology could be used in conjunction with implicit recall studies as the prominence of slower frequency brainwaves seemingly coincide with increased access to unconscious processes and stores (Sanei & Chambers, 2007). The use of such techniques during the retrieval phase (as opposed to the delay period) may therefore have profound effects. Should this have beneficial impacts upon memory, the potential to use this technology in a clinical setting such as an aid for amnesia patients, becomes more plausible. Finally, recognition amongst the implicit task was significantly slower for cued objects when examining cross studies suggesting a relationship between cueing, consolidation and implicit processes. Future research should therefore consider utilising implicit recognition tasks in conjunction with explicit retrieval tasks to provide a larger scope for study amongst this fairly young topic.

Conclusion

Previous literature states that memory consolidation effects are influenced by the act of cueing in which, cueing during an ‘Awake’ state has detrimental effects upon explicit retrieval (Diekelmann et al., 2011), while cueing during an ‘Altered’ state has beneficial effects (Rudoy et al., 2009). In an attempt to advance the current field, the use of an artificially generated ‘Altered’ state was utilised with the addition of an implicit recognition task. Despite the overall findings failing to reach statistical significance, the fact that implicit recognition was significantly affected by cueing suggests an important link between the consolidation process and implicit memory. To expand our understanding of such an often illusive phenomenon, it is vital that the addition of brain imaging technology by used. Similarly, the use of binaural beat technology has the potential to be a key component for further study into the consolidation effects at these ‘Altered’ states. Finally, as the current theories addressing memory consolidation include semantic and episodic memories only, further amendments are required in light of the implicit findings provided here. Should these theories therefor not be compatible with the implicit consolidation findings, revision of the current state of the field are required with perhaps new theories being necessary. Overall, the memory consolidation process is a new and intriguing field of study, making further research into human memory and human learning systems a welcome sight.

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