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Conscious Perception and Implicit Memory Formation of a Narrative Presented During Sleep

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Abstract

The present study sought to determine the extent of conscious awareness and implicit memory formation of a narrative presented during sleep. Participants were played an excerpt of J.D. Salinger's Pretty Mouth and Green My Eyes while napping. Afterwards, participants completed a task designed to assess implicit memory to determine if they had formed any memories about words that were either directly stated in the story, or directly related to the plot. Participants who heard the story while asleep responded more quickly to words that had appeared in the story than to words from another story they had not heard. Exactly the same pattern of results was observed in a second group of participants who heard the same story while fully awake. These findings suggest that sleepers are capable of higher-level processing of complex naturalistic stimuli and can form implicit memories of this information like wakeful participants, despite lacking explicit awareness.

Keywords

Sleep; Consciousness; Implicit memory; Electroencephalography; Naturalistic auditory stimuli; Animacy Decision Task

Summary for Lay Audience

Although sleepers show low levels of arousal, this does not mean that they are completely unaware of their surroundings. Some awareness during sleep is vital in case something important or dangerous happens in our surroundings. However, we don't know *how much* information can be processed by the sleeping brain.

Awareness is often accompanied by memory formation (of the information being experienced). We often think of this as *explicit memory*; that is the conscious laying down and subsequent recall of information. However, much of what is remembered during normal awareness results from *implicit memory*. To test for implicit memories, we usually look for a facilitation of performance on tasks that contain the remembered information, rather than explicit recall. Evidence exists to suggest that sleep helps to consolidate implicit memories, resulting in better subsequent task performance, even if the person isn't aware of this improvement. What is less clear, is whether implicit memories can be formed while a person is sleeping, rather than just strengthened.

We investigated implicit memory formation of an engaging narrative (J.D. Salinger's Pretty Mouth and Green My Eyes) while people were sleeping. An Experimental group were played Pretty Mouth and Green My Eyes while sleeping. A Story Control group were played Pretty Mouth and Green My Eyes while awake. A No-Story control group did not hear Pretty Mouth and Green My Eyes at all. Afterwards, all groups completed a test of implicit memory for words that were either directly stated in Pretty Mouth and Green My Eyes or related to words or concepts that occurred in the narrative. The Experimental and Story Control groups responded significantly faster to these words than control words that neither appeared directly nor were related to the narrative. The No-Story control group did not show this effect, confirming that the improvement observed in the other two groups was the result of implicit memory. These results show that people are capable for forming new implicit memories of complex narrative information while sleeping, in the absence of explicit awareness.

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List of Abbreviations

EEG	Electroencephalography
ERP	Event Related Potential
fMRI	Functional Magnetic Resonance Imaging
GME	Green My Eyes
MMN	Mismatch Negativity
NREM	Non-Rapid Eye Movement
REM	Rapid Eye Movement
RT	Reaction Time
SD	Standard Deviation
SWA	Slow Wave Activity
SWS	Slow Wave Sleep
TMR	Targeted Memory Reactivation

Chapter 1

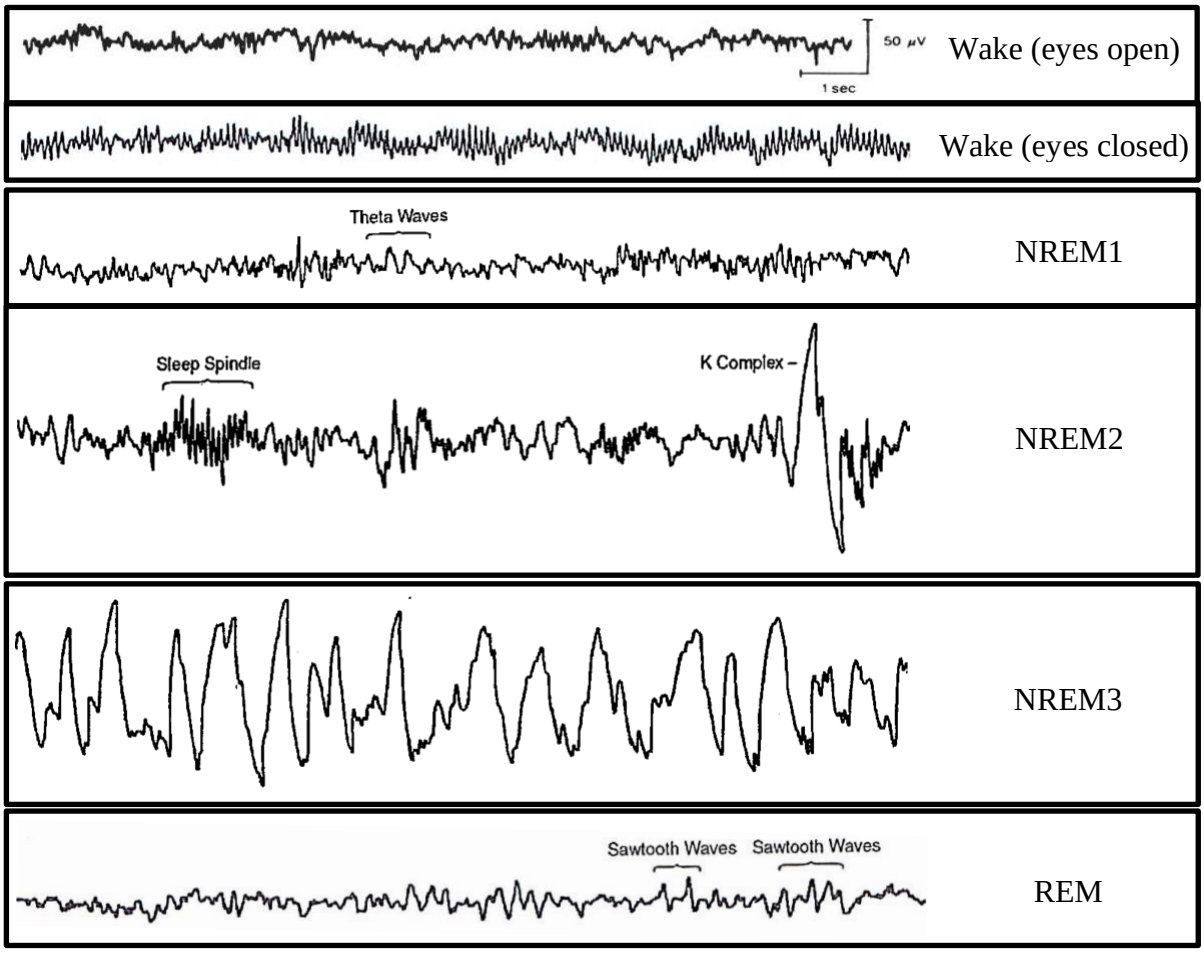
1 Introduction

Sleep can be defined as a state of consciousness that is characterized by a reversible reduction of conscious awareness and behavioural responsiveness (Rasch & Born, 2013). Though sleepers show minimal behavioural activity, sleep is not a passive state – rather, research now suggests that sleep is an altered state of consciousness in which various biological processes such as cardiovascular function (Wolk, Gami, Garcia-Touchard & Somers, 2005), neuroendocrine function, and glucose metabolism (Beccuti & Pannain, 2011) are actively supported. Despite our understanding of sleep's role in a number of critical biological processes, the purpose of sleep is not fully understood. In addition, despite reduced levels of awareness, the sleeping brain continues to monitor the external environment for important and salient events occurring in a person's surroundings, such as a baby crying, while suppressing events that are not considered relevant (Formby, 1967). However, the extent of information processing of our external environment during sleep is not well understood. To address this gap in knowledge, this thesis will address sleep architecture, altered awareness during sleep, and implicit memory formation in sleeping subjects.

1.1 Sleep Architecture

Sleep can be broadly classified into rapid eye movement sleep (REM) and non-rapid eye movement (NREM) sleep. NREM sleep can further be divided into three stages: stage 1 (NREM1), stage 2 (NREM2), and stage 3 (NREM3), which can also be referred to as slow wave sleep (SWS). Each stage of sleep is marked by different EEG waveforms that are characteristic of each stage (see Figure 1a). Throughout a night of sleep, the brain will transition across the 3 stages of NREM sleep and into REM in a sequential cycle that lasts approximately 90 minutes. However, the amount of time spent in each stage of sleep varies depending on the time of night. For instance, deeper stages are predominant in the first half of the night, while REM sleep predominates in the second half of a night of sleep (see Figure 1b).

A



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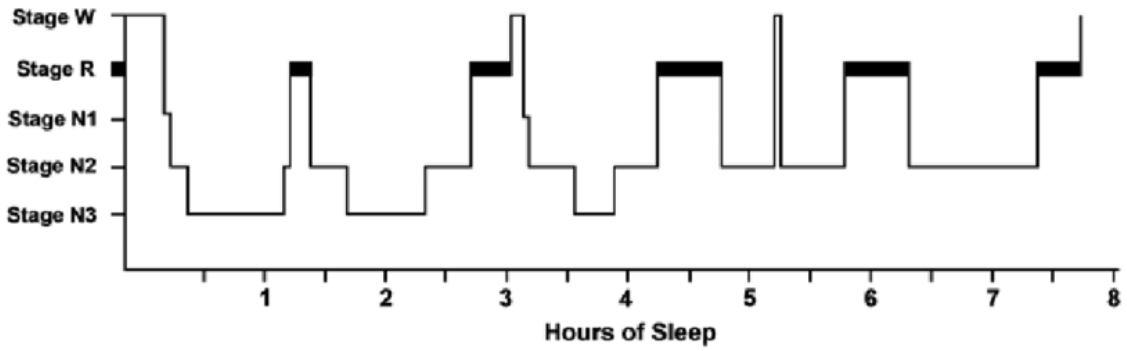

Figure 1. EEG characteristics of sleep

A) EEG characteristics of wakefulness, NREM and REM sleep, where time is represented on the x axis and amplitude on the y axis (from Rechtschaffen & Kales, 1968); B) Hypnogram demonstrating normal distribution of sleep stages during nocturnal sleep (from Bahammam *et al.*, 2016).

1.1.1 NREM1

The first stage of NREM sleep is NREM1, which is the lightest stage of sleep following wakefulness. NREM1 is marked by a decrease in 8- to 13-Hz EEG activity, called alpha activity, with less than 50% of a 30 second epoch containing alpha waves. In addition, characteristic EEG features of NREM1 emerge such as theta waves, which are 4- to 8-Hz waves that are sawtooth-shaped in appearance (Malhotra & Avidan, 2013). Despite the distinct changes in EEG activity from wake to NREM1, the subjective experience of NREM1 does not differ significantly from wakefulness. Subjects who are woken from this stage often report that they were not asleep at all (Stenstrom, Fox, Solomonova, & Nielsen, 2012).

1.1.2 NREM2

The second stage of NREM sleep (NREM2) is considered to be an intermediate stage of sleep. In adults, approximately 50% of nocturnal sleep is spent in NREM2 (Carskadon & Dement, 2011; Malhotra & Avidan, 2013). Physiological changes that occur during NREM2 include decreases in blood pressure, cardiac activity, and cerebral glucose metabolism (Boyle *et al.,* 1994; Malhotra & Avidan, 2013). In this stage, EEG becomes more synchronized, electromyogram activity decreases, and there is an increased arousal threshold (Malhotra & Avidan, 2013). In terms of EEG activity, the majority of NREM2 consists of theta activity (4- to 7-Hz), with bursts of faster activity. These characteristic bursts of activity consist of two types of sleep-waveforms: sleep spindles and K-complexes.

Sleep spindles are short bursts of phasic activity with a frequency of 11- to 16-Hz, and last between 0.5 – 1.5 seconds (Foret *et al.*, 2011; Malhotra & Avidan, 2013). There are two variants of sleep spindles that have been reported in humans: slow spindles, and fast spindles (Foret *et al.,* 2011; Schabus *et al.,* 2007; Zeitlhofer *et al.,* 1997). Slow spindles (<13Hz) mainly appear in frontal regions while fast spindles (>13Hz) tend to preside in central and parietal regions (Foret *et al.,* 2011). The different topographic distributions of fast and slow spindles may be indicative of separate brain regions generating different types of spindles (Anderer *et al.,* 2001; Lu, Kajola, Joutsiniemi, Knuutila & Hari, 1992; Zeitlhofer *et al.,* 1997). Past research has found evidence of sleep spindle involvement in learning potential (Fogel, Nader, Cote & Smith, 2007), motor procedural memory (Fogel

& Smith, 2006), verbal memory consolidation (Clemens, Fabó & Halász, 2005) and as an inhibitory mechanism to protect sleep from arousal (Cote, Epps, & Campbell, 2000; Elton *et al.*, 1997).

K-complexes consist of a fast, negative sharp wave (> 100 μV) which is immediately followed by a slower positive deflection, with the event duration totaling at least 0.5 seconds (Malhotra & Avidan, 2013; Roth, Shaw, & Green, 1956). K-complexes are typically large in amplitude, the largest generally being seen in frontal regions. However, there is no minimum amplitude criterion to score a K-complex. Research suggests that K-complexes are generated in the thalamus (Caporro *et al.*, 2012; Halász, 2005), and they can either be evoked by an external stimulus, or arise spontaneously from endogenous brain activity. (Amzica & Steriade, 1998; Carskadon & Dement, 2011; Malhotra & Avidan, 2013). The function of K-complexes is not well understood; however, there is evidence to suggest that they act as an inhibitory mechanism to protect sleep from arousal caused by external stimuli (Forget, Morin, & Bastien, 2011; Halász, 2005; Nicholas, Trinder, & Colrain, 2002; Wauquier, Aloe, & Declerck, 1995)

1.1.3 NREM3

The third stage of NREM sleep (NREM3) is considered to be the deepest and most restorative stage of sleep (Malhotra & Avidan, 2013). Approximately 15% to 20% of nocturnal sleep is spent in NREM3, and the majority of NREM3 occurs during the first half of the night (Carskadon & Dement, 2011; Malhotra & Avidan, 2013). Slow Wave Activity (SWA) is characteristic of NREM3, with EEG waveforms typically having a frequency in the delta range (1- to 4-Hz) and large amplitudes (≥ 75 μV), making slow waves distinct from other characteristic sleep waveforms. These slow oscillations have been recorded in all major types of neurons, and they often synchronize in large neuronal populations (Foret *et al.*, 2011). Slow oscillations are typically generated in frontal regions (Steriade, McCormick, & Sejnowski, 1993), and the waves tend to travel to more posterior parts of the brain (Massimini, Huber, Ferrarelli, Hill, & Tononi, 2004). There is evidence to suggest that large scale slow wave synchrony seen in NREM3 supports re-activation of memories dependent on the hippocampus, and the redistribution of them to neocortical sites (Diekelmann & Born, 2010). In addition, sleep inertia is strong in NREM3, and sleepers have a high threshold of waking (Malhotra & Avidan, 2013). If awoken from NREM3, a person will likely be confused and disoriented.

1.1.4 REM

The final stage of sleep is REM, or paradoxical sleep, which was first described by Aserinsky and Kleitman in 1953. Approximately 20% of nocturnal sleep is composed of REM, with the majority of REM occurring in the final third of a night (Carskadon & Dement, 2011). The EEG signal that appears in REM differs from NREM sleep because the pattern of neural activity increases to a level comparable to EEG seen in conscious wakefulness (Hobson, Pace-Schott, & Stickgold, 2000; Siegel, 2008). EEG characteristics of REM include low-amplitude, desynchronized oscillations that typically include mixed-frequency theta waves with some alpha activity intermixed (Malhotra & Avidan, 2013). However, the main characteristic of REM sleep is the rapid eye movements that appear as irregular, conjugate, horizontal eye movements that are sharply peaked and typically last less than 500 milliseconds. Rapid eye movements are often observed when people are dreaming. Studies suggest that rapid eye movements are at least in part associated with ponto-geniculo-occipital (PGO) waves, which involve phasic activity in the pons, lateral geniculate bodies, and occipital cortex (Fernández-Mendoza *et al.,* 2009; Lim *et al.,* 2007; Peigneux *et al.,* 2001).

1.2 Consciousness

There is no universally accepted definition of consciousness, nor agreement about the full extent of its role in human behaviour. However, it is generally accepted that consciousness is multifaceted, and in this thesis my working definition of consciousness is that it emerges from two discrete psychological dimensions: arousal and awareness (Zeman, Grayling, & Cowey, 1997).

Arousal can be most simply described as wakefulness, or vigilance (Laureys, Boly, Moonen, & Maquet, 2009; Laureys, Owen, & Schiff, 2004). Observable behaviour (e.g. eyes open or closed, lack of arousal) can easily be used to identify wakefulness. However, as discussed in the previous section, there is a significant body of research detailing EEG protocols that are used to identify sleep and wakefulness accurately. Neural structures that are critical for maintaining wakefulness are the reticular activating system of the brainstem, and its projections to thalamic and basal forebrain regions

(Saper, Chou, & Scammell, 2001; Saper, Scammell, & Lu, 2005). When these regions are damaged, disruptions in sleep-wake function can occur (Laureys *et al.*, 2009).

Awareness can be broadly defined as one's subjective experience of themselves and their surroundings (Laureys *et al.,* 2009). The underlying neural pathways that support awareness are not fully understood; however, it is hypothesized that awareness relies on the integration of information in the cerebral cortex and its reciprocal subcortical connections (Laureys *et al.,* 2009; Massimini *et al.,* 2005). Unlike its counterpart, awareness cannot be directly measured. While some aspects of awareness (e.g. attention) can be assessed using carefully controlled experiments, most aspects of awareness can only be probed by measuring verbal or behavioural responses to stimuli (e.g. command following) (Laureys *et al.,* 2004).

There is a strong relationship between arousal and awareness in healthy adults; for instance, arousal and awareness disappear when under general anesthesia, and reappear upon awakening (Laureys *et al.,* 2009; MacDonald, Naci, MacDonald, & Owen, 2015). Despite sleep being a state where, by definition, participants display little to no wakefulness, that is not necessarily indicative that they have no awareness. For instance, during REM, sleepers have very low levels of arousal, despite having higher levels of awareness as evidenced through dreaming (Hobson, 2009). Referring to Figure 2, it is clear that sleep is a state that traverses through a wide range of wakefulness and awareness. This would suggest that the extent of conscious awareness may also shift through other stages of sleep. In the following section, I will discuss research that has demonstrated some level of awareness during sleep, from basic awareness of the loudness of sounds, to more complex processing of emotionally relevant stimuli.

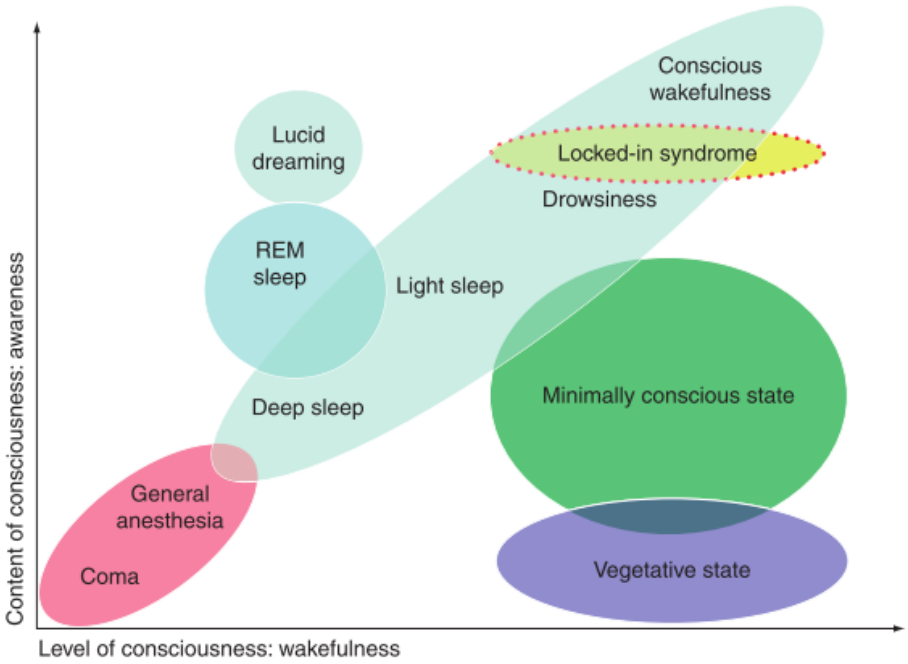

Figure 2. States of consciousness

States of consciousness at different levels of wakefulness and awareness (from Laureys *et al.*, 2004).

1.2.1 Low level auditory processing during sleep

Sleep was once considered to be a passive state, where the brain was devoid of any ability to process the external world. However, it is now known that the sleeping brain can process external information, and the extent to which we process our external environments during sleep has been investigated since as early as the 1950s.

Early studies probed the extent of very basic processing of auditory stimuli after sleep onset. Some of these early studies found that auditory awakening thresholds increase in deeper stages of NREM sleep (Dement & Kleitman, 1957; Rechtschaffen, Hauri & Zeitlin, 1966), and participants in deeper stages of sleep required louder stimuli in order to wake (Williams, Hammack, Daly, Dement, & Lubin, 1964). Additionally, Williams, Tepas & Morlock (1962) used EEG to determine that measurable evoked responses to clicks continue to occur in subjects throughout the various stages of sleep. Furthermore, K-complexes have been found to be significantly more likely to be evoked by the

subject's own name versus other names in sleeping participants (Oswald, Taylor, and Treisman, 1960).

As sleep research progressed, different methods such as oddball paradigms were used to probe awareness in sleepers. Bastuji, García-Larrea, Franc, & Mauguière (1995), played participants tones throughout a full night of nocturnal sleep, and 90% of the tones played were the same (frequent), and 10% of the tones were different (deviant). They found that auditory evoked potentials (closely resembling K-complexes) were elicited to both frequent and deviant tones during sleep, but the potentials elicited by deviant tones were nearly five times larger than those elicited by frequent tones. They also noted that the topography of these potentials differed depending on the stage of sleep that the participant was in. The potentials evoked during NREM1 and REM had similar topographies to those evoked in wakefulness. The authors concluded that the brain is capable of detecting stimulus deviance in all stages of sleep.

In a similar study using an oddball paradigm, mismatch negativity in response to deviant tones was investigated (Ruby, Caclin, Boulet, Delpuech & Morlet, 2008). Mismatch negativity is the negative going deflection in the difference wave, which is generated by subtracting the response produced by a frequent stimulus from that of a deviant stimulus. It was found that in each sleep stage, participants demonstrated significantly stronger negativities to deviant tones compared to frequent tones, suggesting that mismatch negativity can be elicited in all stages of sleep. Additionally, Event Related Potentials (ERPs) were analyzed. ERPs are reliable deviances in the EEG signal seen in response to an event (for review see Sur & Sinha, 2009). In oddball paradigms, the ERP component that is typically seen is the P300, or a positive voltage occurring 300 milliseconds after stimulus onset. A P300 elicited by a deviant tone will be larger than that produced by a frequent tone. Ruby *et al.* (2008) found that during NREM2 and REM, a subcomponent of the P300 called the P3b was elicited in response to deviant tones. The P3b component has a later onset than the P3a subcomponent of the P300, and the largest amplitudes are typically seen in parietal regions. Interestingly, this P3b response to deviant tones was not present in NREM1, NREM3, or in wakefulness.

Portas *et al.* (2000) investigated whether the sleeping brain is capable of discriminating between a name and a beep using simultaneous EEG and fMRI. As previously discussed, evidence from oddball paradigms suggests that the sleeping brain is capable of discriminating between common and uncommon sounds. However, the use of names as a stimulus added a new degree of complexity. Names are not merely a combination of syllables – they carry additional emotional meaning, allowing for investigation into the salience of self-relevant stimuli. Participants were played their own names and beeps, both while they were awake, and while they were sleeping. Participants' brains would respond differentially when they heard their own name in comparison to beeps. Specifically, names elicited higher activation bilaterally in the orbitofrontal cortex as well as the middle temporal gyrus in both sleep and wakefulness, which the authors interpreted as being that more complex semantic processing is required for names. Interestingly, they also found that when participants were presented with names, there was increased activation in the left amygdala and left prefrontal cortex only during sleep. They hypothesized that this wasn't to do with the physical differences between beeps and names, as this effect only occurred during sleep, but rather that there may be a network of regions that are more responsive to emotionally relevant stimuli during sleep.

1.2.2 Processing emotionally salient stimuli during sleep

Further research sought to extend the findings of early sleep studies by adding additional salience to the stimuli presented to sleepers. One study used auditory evoked potentials to probe how participants' brains responded to their own names versus other names in both wakefulness and during sleep (Perrin, García-Larrea, Mauguière & Bastuji, 1999). During wakefulness, participants demonstrated an enhanced P300-like response to their own names, both in a passive and active listening task. While sleeping, they demonstrated a similar P300 response (peaking about 100ms later than during wakefulness), with the response evoked being enhanced specifically to the subject's own name (Perrin *et al.*, 1999). These results may indicate that the sleeping brain is capable of both detecting stimuli and has an enhanced response to that stimulus based on personal significance.

As mentioned previously, stimulus characteristics such as personal salience appear to be important during sleep, with greater stimulus salience being more likely to elicit a larger

EEG response. Blume *et al.* (2016) sought to replicate previous findings demonstrating that sleepers show an enhanced response to their own name versus unfamiliar names. However, they also added a condition where the names were read in both neutral and in angry voices, to determine if emotional salience in the way a word was spoken showed the same degree of increased response during sleep as emotionally relevant words themselves. During wakefulness, Event Related Synchronization (ERS) in the delta frequency band was stronger for participant's own name and for angry voices, indicating that the stimuli were sufficiently salient. During NREM2, they found that both the participant's own name and angry voices elicited stronger delta ERS than unfamiliar names or neutral voices. However, the topographies in sleep and wakefulness differed, with a more distributed topography seen in NREM2. They concluded that the brain is capable of preferentially processing self-relevant and emotionally salient stimuli during NREM2. However, it remains unclear whether this salience would extend to the sentence level, and not just single words.

In a follow-up study, Blume, del Giudice, Wislowska, Heib, & Schabus (2018) investigated whether an additional element of salience (namely, stimuli being spoken by a familiar or unfamiliar voice) would render a stimulus significant enough to be processed by the sleeping brain. They once again replicated previous findings that sleepers show a stronger ERS response in the delta frequency band to their own names versus unfamiliar names. In addition, they also found that sleepers display a stronger delta ERS response to unfamiliar voices compared to familiar voices during all stages of sleep. This study suggests that some characteristic sleep waveforms, such as spindles and slow waves, are tuned to stimulus salience and allow for continued processing of important stimuli.

Kouider, Andrillon, Barbosa, Goupil & Bekinschtein (2014) investigated whether sleepers are capable of preparing an appropriate motor response for a task that they learned prior to falling asleep. The task involved participants pressing a button with their left hand when they heard a word and pressing a different button with their right hand when they heard a pseudoword (which hand was used for words and pseudowrords was counterbalanced across participants). When participants slept, they were played a new list

of words and pseudowords, and the Lateralized Readiness Potential (LRP) was measured as a neural index of response preparation. LRPs are a sensitive measure of motor preparation, with the largest amplitude potentials occurring on the scalp over the motor and premotor cortices. Sleeping subjects continued to prepare the appropriate motor response for the task that they had practiced prior to sleeping, suggesting that they were processing the meaning of the spoken words. The authors suggested that during early NREM stages, environmental information is processed, but action execution is suppressed.

The studies thus far have provided evidence that the brain is capable of processing single words while sleeping. A study performed by Ibáñez, López & Cornejo (2006) investigated whether the sleeping brain is able to discriminate semantic congruency at the sentence level. The sentences were presented to sleeping subjects (e.g. "Something that flies and has a motor is…"), and the final word in the sentence could render the sentence as congruous (e.g. airplane), partly incongruous (e.g. bird), or completely incongruous (e.g. television). The amplitude of the N400 response to these sentences was used as a measure of discriminating semantic congruency. The results suggest that regardless of sleep stage, the brain is able to discriminate semantic congruency at the sentence level. Though this response was diminished in sleeping compared to wakeful participants, it was present nonetheless.

Legendre, Andrillon, Koroma, & Kouider (2019) investigated whether they could detect a difference in how the sleeping brain processes meaningful and non-meaningful stories. Because the sleepers were unable to report whether they were following the stories being presented, the authors developed a modified cocktail party paradigm. They created a passive version of the task involving two competing streams of audio that were played to the listener diotically. One stream was composed of meaningful stories, and the other stream was jabberwocky, which are sounds that are semantically correct, but do not form meaningful words. Using EEG and a technique called stimulus reconstruction, they used the acquired EEG to re-create the auditory signal, which was then correlated to the original sound envelopes of both the meaningful and jabberwocky stories. Sleepers were significantly more likely to follow the meaningful stream of speech over the

jabberwocky, suggesting that even during sleep, the brain can detect and track meaningful stories. This evidence suggests that the sleeping brain is capable of differentiating between relevant and irrelevant speech, and amplifying the signal for meaningful stimuli. However, it remains unclear whether sleepers would be capable of amplifying speech for longer periods of time – for instance, in a narrative – in order to understand what is being communicated in a plotline.

The studies discussed in this section provide strong evidence that the sleeping brain is not only capable of low-level auditory processing, but also higher-level semantic processing. This research suggests that even when lacking arousal, some level of awareness is maintained, even in the deepest stages of sleep. However, this awareness does not necessarily mean that a sleeper will be capable of recalling the information that was presented to them while they were sleeping. In the following section, I will review the evidence for memory formation during sleep.

1.3 Cognition and memory in sleep

Several different memory systems have been described in human beings, such as long term memory (for review see Baddeley, 2004) and working memory (for review see Baddeley, 1992). For the purposes of this thesis, I am interested in two broad categories within long term memory: explicit and implicit memory (Graf & Schacter, 1985; Schacter, 1987). Explicit memory is described as memories of previously learned information that are consciously recalled (Schacter & Church, 1992). Methods used to probe explicit memory formation include recognition and recall tasks (Schacter, 1992; Schacter & Church, 1992). Implicit memory, however, is an unconscious and unintentional form of memory retention (Schacter, 1992) that is not amenable to explicit recall. To probe implicit memory formation, indirect measures such as reaction time (RT) must be used. Implicit and explicit memory function independently of each other (Graf & Schacter, 1985), as evidenced by some types of amnesic patient who have one preserved while the other is not (e.g. Gabrieli, Fleischman, Keane, Reminger, & Morrell, 1995). The following sections will discuss methods used to probe implicit memory, sleep's role in memory consolidation, and evidence of implicit memory formation in sleepers.

1.3.1 Probing implicit memory formation

Implicit memory is expressed as a facilitation of task performance that can be demonstrated in the form of priming effects (Schacter, 1987). Thus, methods used to probe implicit memory formation involve testing whether people have facilitated responses (e.g. respond more quickly) to stimuli based on past experiences (Graf & Schacter, 1985; Schacter, 1987). As a general example of how implicit memory is often investigated, Rajaram and Roediger (1993) compared the efficacy of four different tasks, in addition to examining if cross-modality presentation and testing (e.g. auditory stimulus presentation and visual memory task) impacts subsequent performance. The implicit memory tests used in this study involved a "study" and a "test" task. In the study task, participants were presented with different words in various modalities (e.g. visual, auditory, picture), and they were asked to rate the pleasantness of the word from 1 (least pleasant) to 5 (most pleasant). After a short distractor task, participants completed one of four implicit memory tasks. The goal of all four tasks was to correctly identify a target word (e.g. basket). The tasks were fragment completion (e.g. b__ke_), stem completion (e.g. bas___), anagram solution (e.g. asbekt), and word identification (e.g. word presentation followed by a mask). They found priming effects were greatest in within-modality conditions – for example, when both the study and test material were presented visually. Cross-modality (e.g. auditory study task and visual test) priming effects were also reliably seen; however these effects were not as strong as within-modality conditions. Additionally, they found that all four tasks were effective in detecting priming effects.

Bowers & Schacter (1990) examined whether implicit memories could be formed independently of explicit test awareness. Test awareness was defined as a participant knowing that items from the study task were also included in the test task. Participants studied a list of single words, and after a delay period they completed a stem completion task. Before starting the stem completion task, half of the participants were informed that some of the words in the task included words they had studied earlier, and half were uninformed. After the stem completion task, participants were probed about their test awareness with a questionnaire. They found that among the test-uniformed group, 50%

were unaware that the words in the test were also present in the study list. No difference in the amount of single word priming was found between the test aware and unaware groups. This demonstrates that implicit memory can be formed even when a person is not aware that they had seen the primed word before.

Rugg *et al.* (1998) investigated the differences between the neural correlates of implicit and explicit memory. Words were encoded in either a "shallow" or "deep" study task. The shallow encoding task involved indicating whether the first and last letters of a word were in alphabetical order. The deep encoding task required participants to create a short sentence that included the target word. Then, ERPs were measured while participants were presented with both old and new words, and they were asked to classify which words they had seen previously in the encoding task. ERPs in parietal electrode sites occurring 300-500ms after stimulus onset were significantly more positive for old words compared to new. This effect was still seen in old words that people misclassified as new, suggesting that at the neural level, participants had formed an implicit memory for those old words despite no explicit recollection.

1.3.2 Sleep's role in facilitating implicit memory consolidation

It is well documented that sleep facilitates memory formation (Diekelmann, Wilhelm, & Born, 2009; Stickgold, Whidbee, Schirmer, Patel, & Hobson, 2000; Stickgold, 2005; Walker & Stickgold, 2004) and strengthens memory traces (Schreiner, Göldi, & Rasch, 2015). Recent research has investigated sleep's role in implicit memory consolidation.

Geyer, Mueller, Assumpcao, & Gais (2013) investigated the impact of sleep on a repeated visual search task. Prior to sleeping, participants completed a visual search task in which they were required to find a target letter (i.e. "T") amongst distractor letters (i.e. "L"). Half of these displays were repeated (i.e. target remained in the same location, distractors changed locations) and half were non-repeated (i.e. target and distractors changed locations). After completing this task in the morning, half of the participants napped while the others rested quietly. Afterwards, participants completed the visual search task again. Participants in the "nap" group had faster RTs finding the target letter

in the repeated displays compared to the “rest” group. This suggests that the nap session consolidated the implicit memory of the target location for the repeated display.

Further research about sleep’s role in implicit memory has come in the form of Targeted Memory Reactivation (TMR). In TMR studies, implicit associations are formed by presenting pairs of cues and targets to participants. Later, only the cues are presented in order to covertly activate the associations learned previously (Oudiette & Paller, 2013). Batterink, Creery & Paller (2016) investigated the role of slow oscillations in memory reactivation. Participants were tasked with learning spatial locations of objects, each of which was paired with a sound. Afterwards, participants were given the opportunity to nap. While sleeping, they were covertly cued with half of the sounds they had heard during the task in order to produce TMR. After awakening, they were tested again on their spatial memory in a recall task, and they were found to be significantly more accurate finding the objects whose associated sound had been played to them while sleeping. Additionally, this finding was even more apparent when the cued sounds were played in conjunction with the first half of the downstate of a slow oscillation (i.e. phase angle of 180°-270°).

TMR has also been used to investigate emotional memory consolidation (Cairney, Durrant, Hulleman, & Lewis, 2014). During the encoding phase, participants were presented with either emotionally-neutral or negative pictures, each of which was paired with a unique sound and a specific location on the screen. Participants were instructed to memorize the pictures and their associated locations. Upon completing the encoding task, they performed a retrieval task to test their memory of the photo locations. After completing this task, participants slept for approximately 90 minutes. When participants entered SWS, they were covertly presented with half of the sound cues from the encoding task. Upon waking, they completed the memory retrieval task a final time. For the cued items, increased time spent in SWS was predictive of faster RTs to emotional, but not neutral, photos. Additionally, this effect was also predicted by sleep spindles, suggesting that SWS and spindle activity are involved in TMR.

The evidence thus far suggests that sleep supports the consolidation of implicit memories. However, as previously noted, implicit memory functions independently of explicit knowledge or awareness. With this understanding, the next step in this line of research was to determine if implicit memories could be created while someone was asleep.

1.3.3 Implicit memory formation in sleepers

Arzi *et al.* (2012) investigated whether participants could form implicit memories of pairs of odors and tones presented during sleep. When presented with smells, humans demonstrate a sniff response, and will inhale more deeply to pleasant odors than unpleasant. Different odors were presented to sleepers, and the presentation of these odors was paired with unique tones. Later the same night and again upon awakening, only the tones were played to the participants. They found an increased sniff response to tones that had been paired with pleasant odors both later in the same night and when they woke up, and participants reported they were unaware of this association. In addition, they found that participants demonstrated stronger sniff responses during REM, but evidence of learning was stronger for pairings presented during SWS. This suggests that awareness during REM differs compared to NREM sleep, and that SWS assists in memory consolidation.

Andrillon & Kouider (2016) investigated whether participants could form implicit memories of words heard while sleeping. While falling asleep, participants performed a Lexical Decision Task (LDT), where they indicated with a button press if the words they heard were words or pseudowords. When participants entered NREM2, words and pseudowords from a new list were played. Once they woke up, participants performed a memory task. The items included in this task were either from the original wordlist they had heard while they were awake, the wordlist presented to them while sleeping, or from a brand new list they had not heard before. They were instructed to categorize the words/pseudowords as either “new” (i.e. had not heard before) or “old” (i.e. had heard before). In addition, they were asked to indicate how confident they were with this choice on a 1–7 scale. Participants were able to categorize the words they had heard while they were awake as “old” with a high degree of accuracy. However, items from the new and sleep lists were generally categorized as “new”, indicating a lack of explicit recollection.

Yet when participants labeled words from the sleep list as “old”, they were significantly more confident in their choice compared to words from the new list that they labeled as “old”. In addition, electrophysiological responses to words from the “sleep” and “new” lists were not the same, as sleep words elicited a significantly larger centro-parietal negativity, even for the items participants had misclassified. Although this study showed that single words can be remembered by sleeping participants, it did not reveal whether higher-level semantic concepts such as word meaning could be similarly encoded

Züst, Ruch, Wiest & Henke (2019) presented sleepers with word pairs including a pseudoword (e.g. aryl) and an object (e.g. cork) during SWS to determine if they could form implicit associations. Since the peaks of slow oscillations are periods of neural excitability, they predicted that if a word was presented with a coinciding slow wave, it was more likely to form a semantic association. When participants awoke, they were presented the pseudowords and asked to classify whether the meaning of the pseudowords referred to an object that could fit inside a shoebox. The participants performed above chance on this task, indicating that implicit memory associations for these word pairs had been formed. An additional analysis found that when the presentation of word-pairs repeatedly coincided with a slow wave peak, performance on the memory task improved significantly. Although this study revealed that word meanings can be encoded during sleep, it remains unclear whether high-level concepts, such as those that are conveyed by entire sentences, can be encoded in a similar way.

Thus far, the evidence presented suggests that the sleeping brain is able to track and process highly salient and emotional stimuli, and form implicit memories of stimuli played while sleeping. Past research has often investigated memory formation in sleep by playing participants single, discrete words from a word list. In the present study, we investigated whether implicit memories of a continuous stream of speech could be formed during sleep.

1.4 The present study

Thus far, I have reviewed evidence showing that sleep is a reasonable model for examining cognition in altered states of consciousness. What is clear is that some types of

memory can be formed in various states of sleep, but that the extent and ‘quality’ of those memories varies when compared to the waking state. One outstanding question is whether sleeping people can form implicit memories of a continuous, engaging narrative, and if this will lead to a facilitation of performance when probed on words mentioned in the narrative itself. In this study, I addressed this question by playing sleeping participants an excerpt from an engaging story while they were asleep and then testing their memory for the story details once they had been fully awakened. Based on the information reviewed above, I predicted that participants would form implicit memories of the story while they slept, which would result in faster RTs in a later implicit memory test for directly-mentioned and plot-related words, when compared to semantically matched control words. Through an an exploratory analysis, I also investigated whether the stage of sleep that a word was presented in impacts subsequent RTs.

Chapter 2

2 Methods

2.1 Ethics Statement

Participants provided written, informed consent (see Appendix Section A), and ethics approval for this study was provided by the Research Ethics Board at the University of Western Ontario REB#112576 (see Appendix Section A).

2.2 Participants

Participants between the ages of 17-35 were recruited for this study using Western's Sona System, and advertised using flyers placed around the Western campus. Participants were compensated with course credit, or $14 per hour. Eligibility criteria required that participants had normal or corrected-to-normal vision; normal hearing; no personal history of speech, hearing, learning, neurological, sleep or psychiatric disorders; and were not taking medications that could affect brain functioning.

2.2.1 Experimental Group

28 English speakers participated in the experimental group. However, 2 participants were excluded due to problems in EEG acquisition, and 6 were excluded because they were unable to sleep during the experimental session. The final sample included 20 participants (15 females) ranging from 17 to 30 years old (M = 21.00, SD = 4.48).

Participants were self-reported as being able to nap well in the afternoon. Additionally, participants were asked to wake up 1-2 hours prior to the time they usually would on the day of the study in order to increase sleep pressure and facilitate an afternoon nap. They were asked to refrain from consuming caffeinated beverages or other forms of stimulants on the day of the study.

2.2.2 Story Control Group

16 English speakers (9 females), ranging from 18 to 34 years old (M = 23.19, SD = 5.47) were recruited for the control group.

The purpose of the story control group was to assess how wakeful participants perceived the auditory stimuli presented to them, and their ability to complete subsequent memory tasks in comparison to the experimental group.

2.2.3 No-Story Control Group

11 English Speakers (5 females) ranging from 18 to 22 years old (M = 20.73, SD = 1.62) were included in this sample. Due to the COVID-19 pandemic, the study was halted on March 19th, 2020 and no further data could be collected. Unfortunately, for this reason we were unable to match the number of participants in this control group to the other groups of participants.

2.3 Apparatus

The Brain Products actiCAP 64-channel standard EEG system was used to record brain activity for the duration of the experimental procedure. Four external electrodes were placed on the face in order to measure eye movement and muscle tone for later sleep staging. This included a bipolar electrode beside each eye, and a bipolar electrode on the chin and beside the mouth. The built-in ECG electrode was placed on the tip of the nose for later re-referencing. EEG was sampled at 500 Hz and was referenced online to the built-in reference electrode (near Cz) using the Brain Vision software package. Electrode impedances were kept below 20kΩ.

Computer speakers were used to play participants auditory stimuli and were placed approximately 1.5 meters apart on both sides of the bed for biaunural audio presentation. Audio stimuli were presented from a 2018 MacBook Pro using PsychoPy. Triggers indicating the start and stop times of audio stimuli were sent using the Cedrus StimTracker, which was connected to the MacBook via USB.

2.4 Materials

2.4.1 Auditory Stimuli

Two pieces of audio stimuli were used in this experimental procedure, and the audio levels were adjusted individually for each participant so the stimuli were loud enough to be understood, but not disruptive. The first was a transitory piece of an interview with a

philosopher named John Butler on the topic of his life and meditation, which was played as participants were falling asleep (script in Appendix Section B). During the piloting stage of this study, participants were frequently startled awake when the main experimental audio began playing after falling asleep in a quiet environment. This piece was played, therefore, in order to ease the transition to the stimulus of interest. This audio clip was not included in any analyses.

The second piece of audio was an excerpt from a J.D. Salinger story titled Pretty Mouth and Green My Eyes, which hereafter will be referred to as Green My Eyes (GME) (script in Appendix Section B). GME was chosen as it has been used previously in work conducted by our lab and is known to elicit consistent brain responses across individuals while awake (Yeshurun *et al.,* 2017). The story consists of a phone conversation between two men, and over the course of the story the listener learns that one of the men is involved with the other man's wife. The audio contains voices with different emotions expressed, in addition to an engaging plotline, thus contributing to a higher likelihood of being processed by sleeping participants.

2.4.2 Questionnaires

Participants completed a battery of questionnaires (see Appendix Section C). Prior to napping, demographic information was collected using the Adult Participant Information sheet. Participants completed the Sleepiness & Fatigue questionnaire, which combined the Epworth Sleepiness Scale (Johns, 1991) and the Stanford Sleepiness Scale (Hoddes, Zarcone, Smythe, Phillips & Dement, 1973). This is used to assess how drowsy participants feel on a typical day. Finally, participants completed the Karolinska Sleep Log (Kecklund & Åkerstedt, 1992), which was used to track the nocturnal sleep habits of participants, and compare the night of sleep prior to the day of the study to a typical night of sleep.

After the experimental session, participants completed a post-nap interview, where they were asked questions probing the extent of their memory of the stimuli presented during the experimental session. Additionally, the Karolinska Nap Log (Karolinska Sleep Log

modified for the afternoon nap) was completed by participants in order to assess the quality of their nap.

2.4.3 Implicit memory task

Immediately following the nap, we probed implicit memory formation using an Animacy Decision Task, which was programmed using PsychoPy and performed on a Lenovo ThinkPad E595. A fixation cross appeared on a black screen for 1000 milliseconds and was followed by a word appearing for 500 milliseconds; after which the screen remained blank until a button press was made (see Figure 3). Participants were instructed to indicate as quickly as possible with a button press if the word was an animal (L) or non-animal (A) word (counterbalanced across participants). To reduce the cognitive load, the categorical labels "Animal" and "Word" were placed above the appropriate keys on the keyboard. In order to gain a better understanding the task, participants completed a practice trial involving 16 trials (8 animal, 8 non-animal) before the task began. The 16 words included in the practice trial were unique and did not appear in the main task. In the implicit memory task, there were 200 trials in total, with 100 trials involving animal words, and 100 involving non-animal words (see Appendix Section D for wordlist). The non-animal words contained 30 words directly stated in the GME text (henceforth referred to as 'directly-stated'), 20 words *related* to the plot of GME (henceforth referred to as 'related'), 30 words from a story that participants did not hear called 'Pie Man' (henceforth referred to as 'control story'), and 19 words that were not related to either story (henceforth referred to as 'unrelated'). The unrelated category contained a duplicate word from the directly-stated category. This error was not discovered until all the data was collected, thus the 'unrelated' category was reduced to 19 words. Words from the 'related' category were chosen by examining various book reviews of GME and using words that were commonly used to describe the plot of the narrative. To ensure that the non-animal words were semantically matched on dimensions such as word length and frequency, the words were analyzed using two MATLAB toolboxes. Firstly, each word was transformed into a vector using the Word2Vec toolbox. Next, the vectors were compared using the fastTextWordEmbedding toolbox, which is a program that is pre-

trained on 300 dimensions for one million English words. The words included in the study were determined to be matched, while remaining novel in terms of meaning.

The four categories of non-animal words were included to probe different aspect of memory formation. Directly-stated words were included to determine if sleepers formed implicit memories of words that they had heard in GME, while related words were used to determine if sleepers had formed implicit associations related to the plot of GME. The control story category was included to control for any tendency to remember thematically related words, as directly-stated words may be perceived as having an underlying theme since they were pulled from the same story. Thus, these words were also pulled from a story, but not the story that participants listened to while napping. Finally, the unrelated group was included as a set of linguistically matched control words that had no relevance to GME, nor any thematic relationship with one another.

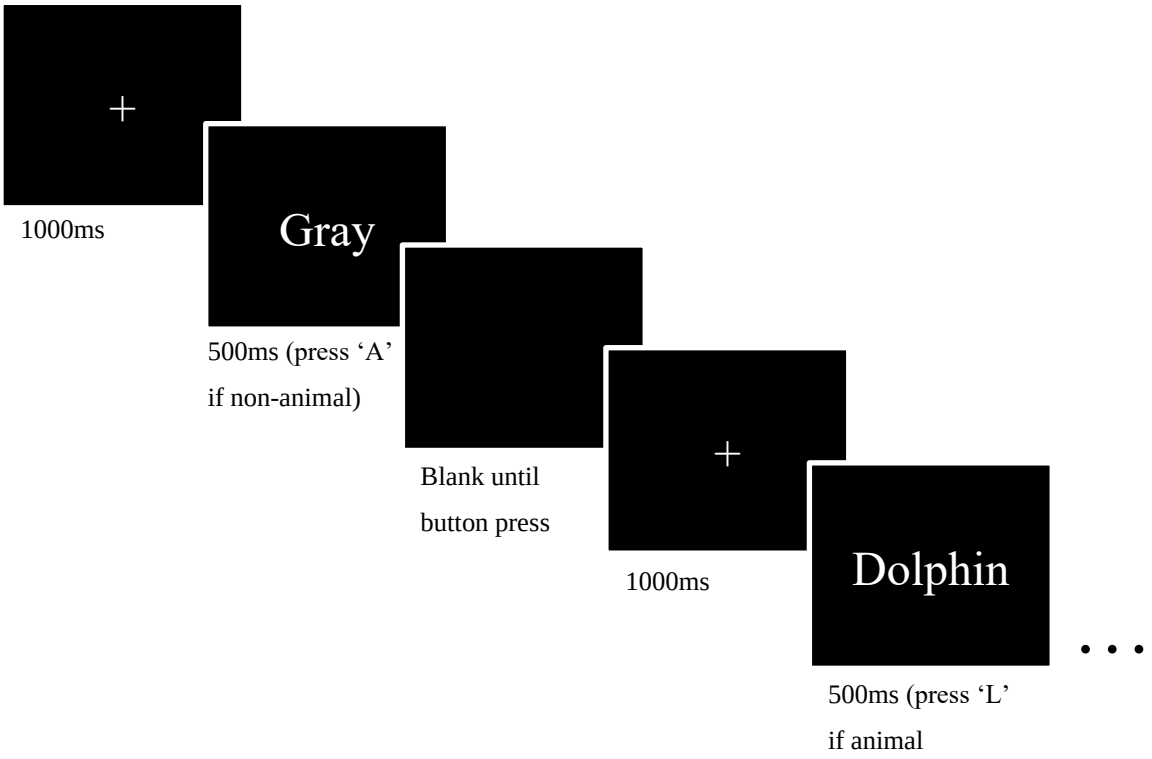

Figure 3. Animacy decision task

Example of the stimulus sequence in the Animacy Decision Task. In this example, non-animal words require an 'A' key response, and animal words require an 'L' response.

2.4.4 Explicit memory task

We probed explicit recall of the GME story using a questionnaire completed on Qualtrics (see Appendix section E). Participants were presented with questions about the plot of GME, and they were given the opportunity to answer by typing in what they remembered, or by clicking "I don't know". If they clicked "I don't know," they were presented with three multiple choice options: a correct answer, an incorrect answer, and a 'I don't know' option. This task was always completed after the implicit memory task and post-nap interview. The reason participants performed the explicit task AFTER the implicit task was because the explicit task contains words that actually appeared in the story. Thus, if they had seen them again, *before* completing the implicit memory task, we may have observed faster RTs to directly-stated and related words simply because they had been re-experienced during the explicit memory task, not because they had heard them in the story.

2.5 Procedure

2.5.1 Experimental design – Experimental Group

After reading the Letter of Information and informed consent was obtained, participants completed the pre-nap questionnaires (see section 2.4.2). An EEG cap was then placed on the head, electrode impedances were tested, and necessary adjustments were made to ensure impedances were below 20kΩ. The participant was then brought to the sleep lab (located at the Brain and Mind Institute, London, ON, Canada). Participants laid down on a comfortable bed in a dark room and were given up to 1.5 hours to sleep. Prior to sleeping, the volume for the auditory stimuli was adjusted individually for each participant such that the speakers' words were loud enough to be intelligible, without being disruptive to sleep.

As participants were falling asleep, the interview with John Butler was played in the background (discussed in section 2.4.1). Online sleep scoring was conducted to detect the emergence of NREM2 in real time by visually identifying K-complexes and sleep spindles in the incoming EEG signal (see section 1.1.2). Once the first K-complex or sleep spindle was identified, we waited for 3 minutes in order to confirm that the NREM2

sleep was stable. Upon confirming NREM2 sleep was stable, the audio from the interview was then switched to GME; at the end of which, participants were left to sleep in silence for the rest of their nap.

At the end of the experimental procedure, participants either woke up naturally or were woken by a knock on the door by the researcher. Participants were given approximately 5 minutes to wake before they completed the Animacy Decision Task. After completing the task, the EEG cap was removed and participants were given the opportunity to wash their hair. Next, participants completed a brief interview with the researcher, where they were asked questions about what they remembered from the nap session. They then completed the Explicit Memory questionnaire on Qualtrics, and finally the Karolinska Nap Log. Participants were debriefed and compensated prior to leaving. The entire procedure took approximately 3 hours.

2.5.2 Experimental design – Story Control Group

After reading the Letter of Information and informed consent was obtained, participants completed the Adult Participant Information sheet (see section 2.4.2). An EEG cap was then placed on the head, electrode impedances were tested, and necessary adjustments were made to ensure impedances were below 20kΩ. The participant was then brought to the sleep lab (located at the Brain and Mind Institute, London, ON, Canada). They were asked to lay on a bed in the Sleep Lab, but remain awake. Their EEG was monitored while the story was being played to ensure they did not fall asleep. Once the audio was adjusted to a comfortable volume, participants were played GME. After listening to GME, participants completed the Animacy Decision Task. Once this task was completed, the EEG cap was removed and participants were given the opportunity to wash their hair. Next, participants completed a brief interview with the researcher where they were asked questions regarding what they remembered from the story session. They then completed the Explicit Memory questionnaire on Qualtrics; participants were debriefed and compensated prior to leaving. The entire procedure took approximately 1.5 hours.

2.5.3 Experimental design – No-Story Control Group

After reading the Letter of Information and providing informed consent, participants in this group completed the Adult Participant Information Sheet. Afterwards, they completed the Animacy Decision Task, having not heard GME. Participants were debriefed and allowed to leave. The entire procedure took approximately 30 minutes.

2.6 EEG Preprocessing and Sleep Scoring

EEG preprocessing was completed using MATLAB software and the EEGLAB toolbox (Delorme & Makeig, 2004). Channels were filtered using a 0.1 - 30Hz digital finite impulse response (FIR) bandpass filter with a notch filter at 60Hz. Channels were flagged for removal using automatic artifact detection, which identified channels whose average amplitude variance was two standard deviations greater than the mean. These channels were replaced using an interpolated signal from surrounding electrodes. Finally, EEG data was re-referenced offline to the average across the whole head. Facial electrodes were filtered separately with a high pass filter = 10 Hz and a low pass filter = 62 Hz.

Although online sleep scoring was conducted to determine when participants entered NREM2, more formal sleep scoring was performed on the acquired EEG data after the experimental session for use in a later data analysis. Sleep was scored in 30 second epochs in accordance with standard criteria (Iber, Ancoli-Israel, Chesson, & Quan, 2007) using the sleepSMG toolbox (Walker laboratory; http://sleepsmg.sourceforge.net/) for MATLAB. Sleep scoring was performed independently by two trained researchers, with a minimum of 80% reliability between scores.

2.7 Statistical Analyses

To analyze the data from the implicit memory task for the Experimental, Story Control, and No-Story Control groups, we first removed all incorrect responses for each participant. This is because we were interested in how participants processed the semantic meaning of the words presented. If incorrect responses were included, we cannot be certain that the words were processed properly up to semantic meaning, and therefore cannot meaningfully interpret RTs. After removing incorrect responses, RTs greater than 5 seconds were excluded as outliers. This 5 second cut off, though arbitrary, was necessary because participants were instructed to indicate as quickly as possible

through a button press if the word presented to them was an animal or non-animal word. Any RT greater than 5 seconds is a trial where a participant was distracted, or something went wrong; therefore, we need to remove those trials under the assumption that they are noise. Next, for each participant, mean RT and standard deviation were calculated within each word condition (e.g. directly-stated, related, control story and unrelated all had their own mean and SD – this is because we were expecting to see differences in means and SDs between groups). Then, for each word category, we used a statistical procedure to remove outliers within each condition (i.e. RTs greater than 2.5 standard deviations from the mean were excluded as outliers). Means were re-calculated with outliers removed and used in subsequent analyses.

All analyses were completed using IBM SPSS Statistics 26 software. A series of planned comparisons were conducted for the Experimental, Story Control, and No-Story Control groups. Firstly, a paired samples t-test was used to compare RTs to directly-stated and related words to determine whether hearing words directly from the narrative led to significantly faster RTs. Second, a paired samples t-test was used to compare RTs to GME and control story words to determine whether participants formed implicit memories to GME. Finally, a paired samples t-test was used to compare RTs to control story and unrelated words to determine if words with an underlying theme with no relation to GME were responded to more quickly compared to semantically matched control words.

Pearson r correlations were used to determine the relationship between the amount of time spent in NREM1, NREM2 and NREM3 sleep, and the strength of implicit memory consolidation. We used the mean difference in RT (Control Story mean RT – GME mean RT) as our measure of implicit memory strength. Pearson r correlations were calculated to compare the mean differences in RT to time spent in NREM1, NREM2 and NREM3.

An independent samples t-test was conducted to compare the mean difference in RT (Control Story mean RT – GME mean RT) for the Experimental and Story Control groups. The purpose of this comparison was to determine whether sleepers benefitted more from GME words compared to wakeful participants.

Finally, an independent samples t-test was conducted to compare the number of correct responses on the explicit memory task for the Experimental and Story Control groups. The purpose of this comparison was to identify how explicit memory formation differed in participants who heard GME while they were sleeping versus those who were played GME during wakefulness.

Chapter 3

3 Results

3.1 Accuracy

The Experimental, Story Control, and No-Story Control groups performed well on the animacy decision task, scoring 94.78% (*SD* = 3.76), 94.89% (*SD* = 4.30), and 91.74% (*SD* = 3.49) correct, respectively.

3.2 Experimental Group

Sleep scoring indicated that two participants were awake for 5 of the 16 epochs of GME, which means they were awake for 150 seconds of the 420 second story. Participants who had 3 or more sequential epochs scored as 'awake' were removed from the analysis. Because of this, the data from these two participants were excluded, resulting in *N* = 18 participants in the final analysis.

Across participants who slept, the average time spent in each stage of sleep was as follows: NREM1 (*M* = 370.00, *SD* = 234.65, range = 90 to 990 seconds); NREM2 (*M* = 1736.67, *SD* = 640.45, range = 900 to 2850 seconds); NREM3 (*M* = 856.67, *SD* = 768.25, range = 0 to 2610 seconds). We did not have any participants reach REM sleep (see Figure 4). Mean differences in reaction times (milliseconds) for directly-stated (*M* = 647.97, *SD* = 130.69), related (*M* = 652.72, *SD* = 132.59), control story (*M* = 673.56, *SD* = 138.63), and unrelated (*M* = 658.61, *SD* = 152.07) categories were examined using a set of three planned paired samples t-tests (see Figure 5).

The first planned comparison sought to examine differences in RT between the directly-stated and related groups. The purpose of this comparison was to identify if, in order to elicit quicker responses, words had to be explicitly stated in the story or if words simply needed to be semantically related to GME. There was no significant difference in RTs to the two types of words $t(17) = -0.56$, $p = .59$.

The second planned comparison was to establish whether words related to GME were responded to more quickly than words that were related to one another, but not related to

GME. Accordingly, the directly-stated and related words were combined and compared to the control story words. There was a significant difference in response times to the two sets of words, $t(17) = -2.66$, $p = .02$, with significantly faster RTs for GME-related words compared to control story words.

The final planned comparison for this group aimed to examine differences in RT between control story and unrelated words. This was to determine if words that were related to a common storyline (but not related to GME) were responded to more quickly than semantically matched words with no underlying theme. There was no significant difference between these two word categories, $t(17) = 1.31$, $p = .21$.

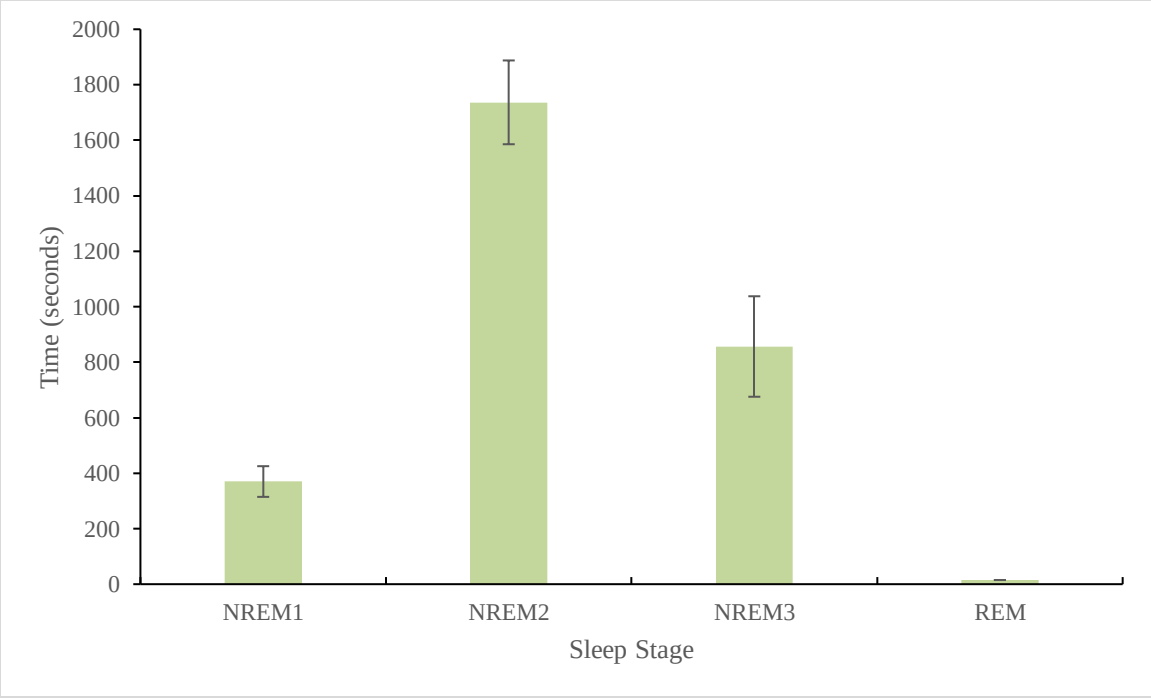

Figure 4. Average time spent in each sleep stage

Mean time (seconds) spent in each sleep stage across participants in the Experimental Group.

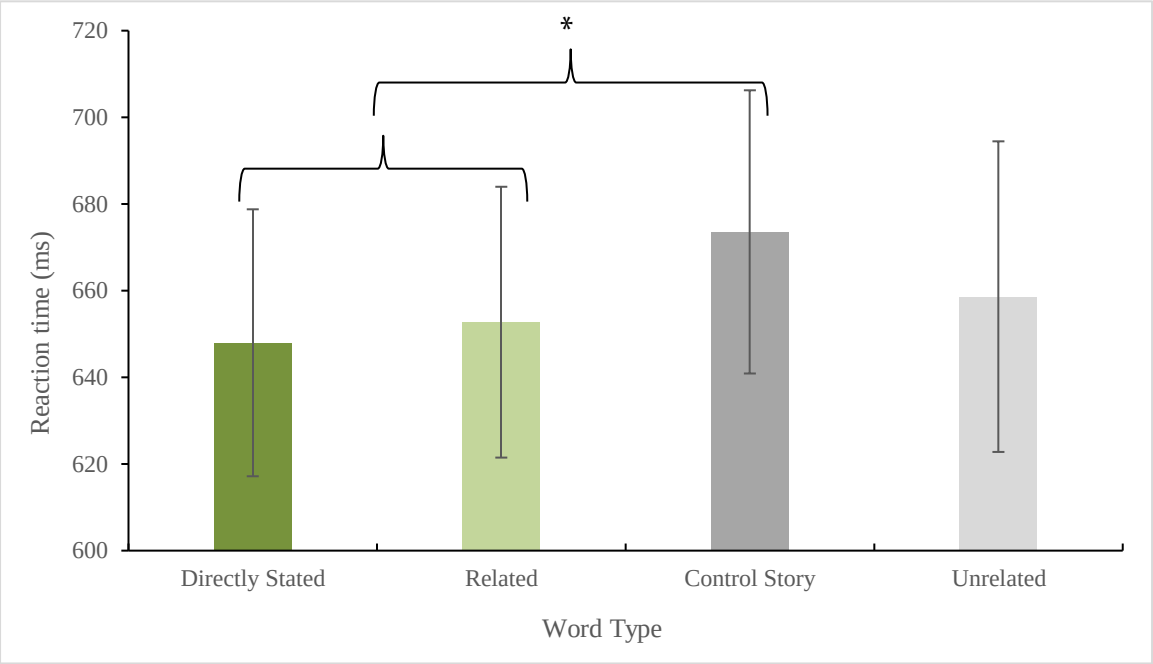

Figure 5. Sleepers responded faster to GME compared to control story words
Mean reaction times (milliseconds) to word category across participants in the Experimental Group. The error bars represent the standard error of the mean. A significant difference in reaction time was found between GME-related words (i.e. directly-stated and related combined) compared to control story words. *Note: an asterisk (*) indicates $p < .05$.*

To ascertain whether memory for the presented material was related to the amount of time participants spent in different stage of sleep, Pearson correlations were performed. The mean difference in RT between control story and GME-related (i.e. directly-stated and related combined) words was used as a measure of memory strength. This value was calculated by subtracting the RT to GME-related words from the RT for control story words for each participant. The correlation between this mean difference and the time each participant spent in NREM1, NREM2, and NREM3 was then calculated. There were no significant correlations between the measure of memory strength and the time spent in NREM1, $r(16) = 0.12$, $p = .64$; NREM2, $r(16) = 0.19$, $p = .46$; or NREM3 $r(16) = -0.04$, $p = .88$ (see Figure 6).

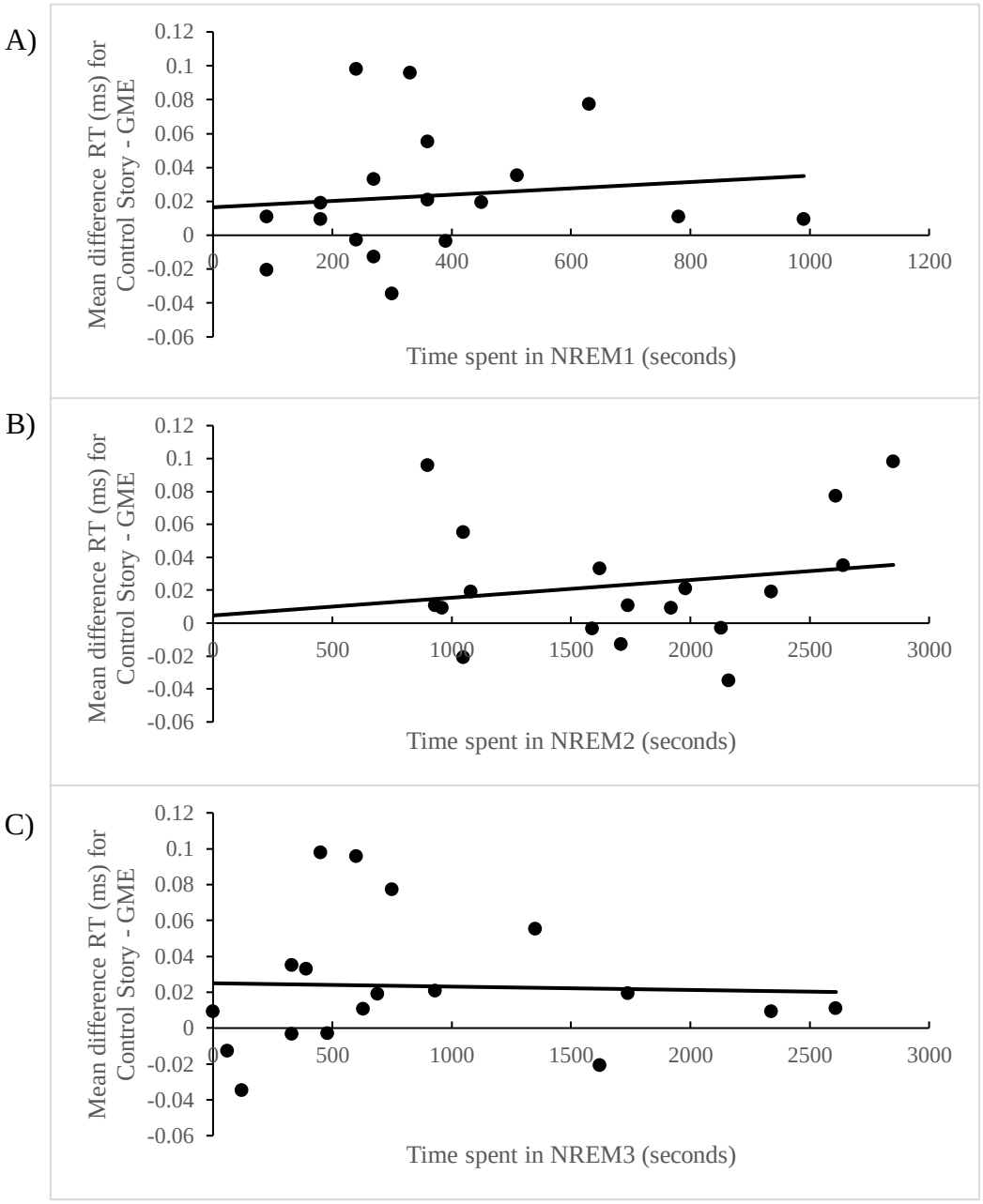

Figure 6. Correlations between mean difference in RT and time spent in sleep stages

Correlations of the mean difference in RT (milliseconds) for Control Story RT minus GME RT (i.e. directly-stated and related combined) and A) Time (seconds) spent in NREM1; B) Time (seconds) spent in NREM2; and C) Time (seconds) spent in NREM3. *Note: all three correlations were not significant ($p > .05$).*

3.3 Story Control Group

Mean reaction times (milliseconds) for word categories were as follows: directly-stated (*M* = 617.77, *SD* = 74.11); related (*M* = 614.49, *SD* = 57.76); control story (*M* = 633.45, *SD* = 63.84); and unrelated (*M* = 615.51, *SD* = 70.62) (see Figure 7). As with the Experimental Group, differences in RT between word categories were compared using a set of three planned paired samples t-tests.

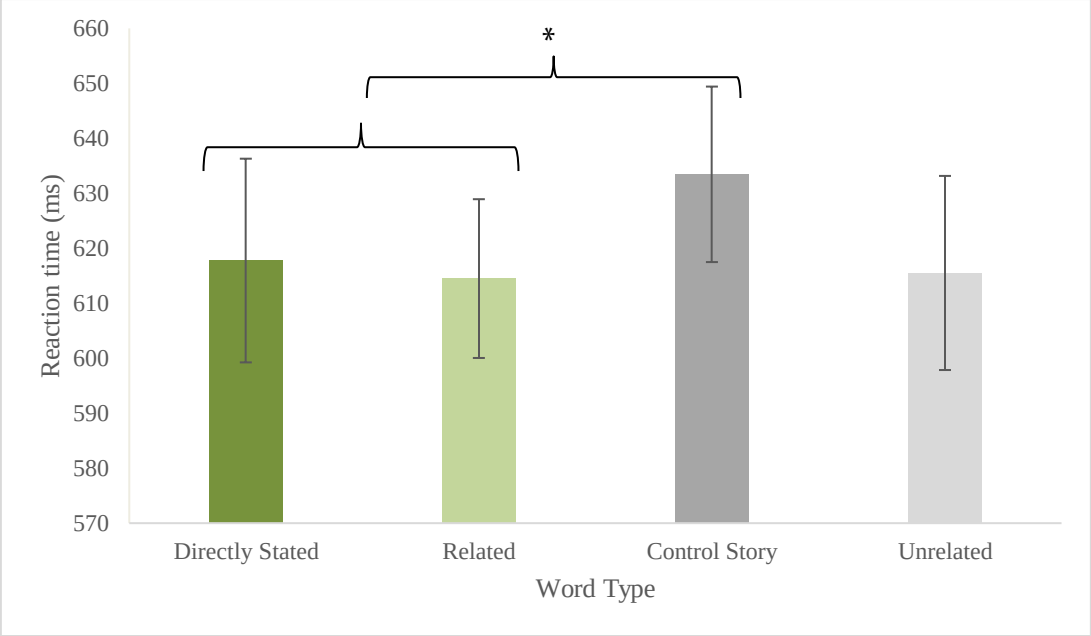

Figure 7. Story controls responded faster to GME compared to control story words

Mean reaction times (milliseconds) to word category across participants in the Story Control Group. The error bars represent the standard error of the mean. A significant difference in reaction time was found between GME words (i.e. directly-stated and related combined) compared to control story words. *Note: an asterisk (*) indicates p < .05.*

The first planned comparison sought to examine whether there were differences in RT between the directly-stated and related words. There was no significant effect of word category on RT, $t(15) = 0.24$, $p = .81$.

The second planned comparison aimed to determine if GME-related words were responded to more quickly than control story words. There was a significant effect of word category, $t(15) = -2.32$, $p = .04$, with significantly faster RTs for GME words compared to control story words.

The final planned comparison for this group was to examine whether there were differences in RT between control story and unrelated words. Again, this was to determine whether words that were related to a common storyline (but not related to GME) were responded to more quickly than semantically matched words with no underlying theme. There was no significant effect of word category on RT, $t(15) = 1.57$, $p = .14$.

3.4 No-Story Control Group

Mean reaction times (ms) for directly-stated ($M = 620.24$, $SD = 106.42$), related ($M = 610.94$, $SD = 84.23$), control story ($M = 625.05$, $SD = 104.56$), and unrelated ($M = 624.97$, $SD = 146.83$) categories were compared (see Figure 8). As with the Experimental and Story Control Groups, differences in RT between word categories were compared using a set of three planned paired samples t-tests. The purpose of this control group was to ensure that there were no inherent biases in the non-animal words in the implicit memory task. If the non-animal words were truly linguistically equivalent, there should be no significant difference in RT between them.

The first planned comparison was to examine differences in RT between the directly-stated and related groups. There was no significant effect of word category on RT, $t(10) = 0.56$, $p = .59$.

The second planned comparison aimed to determine if GME words were responded to more quickly than control story words. There was no significant effect of word category on RT, $t(10) = -1.22$, $p = .25$.

The final planned comparison for this group was to examine differences in RT between control story and unrelated words. There was no significant effect of word category on RT, $t(10) = 0.004$, $p = .997$.

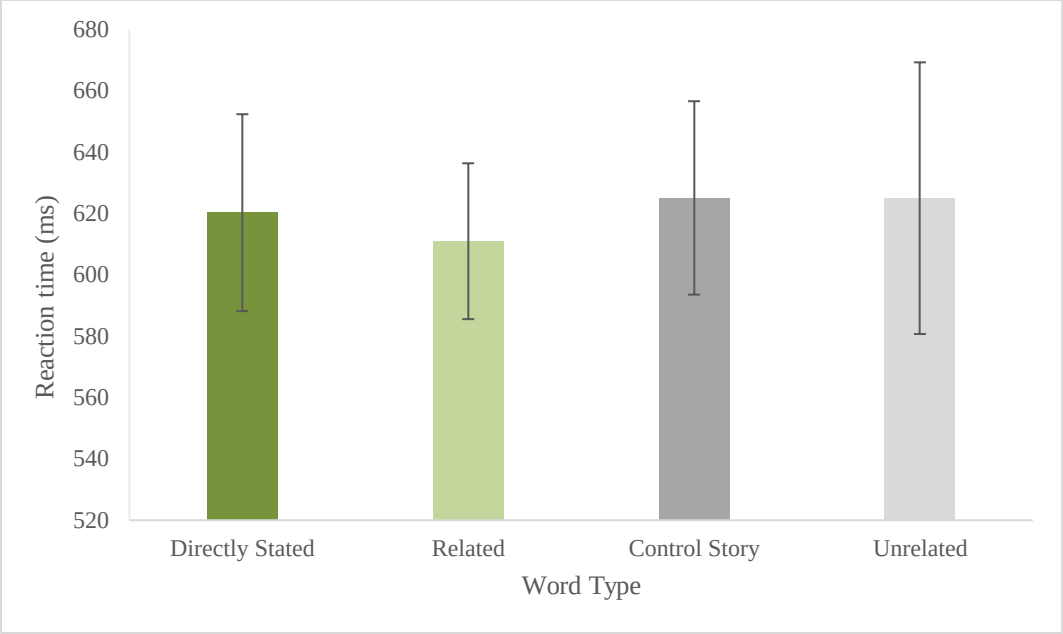

Figure 8. No-Story Controls showed no significant difference in RT to word categories

Mean reaction times (milliseconds) to word category across participants in the No-Story Control Group. The error bars represent the standard error of the mean. No significant difference was found between groups.

3.5 Experimental and Story Control comparison

To ascertain whether sleepers or wakeful participants benefitted more from GME words, an independent samples t-test was conducted, comparing the mean difference in RT (Control Story – GME) for the Experimental (M = 23.39, SD = 37.38) and Story Control (M = 16.90, SD = 29.18) groups. Levene's test of homogeneity of variance was not significant, $F(1, 32) = .93$, $p = .34$, and equal variances were assumed. There was no significant difference in the mean difference in RT for the two groups, $t(32) = 0.56$, $p = .58$.

3.6 Explicit memory performance

Finally, we compared explicit recall across participants who heard GME. The explicit memory task contained 14 questions regarding the plot of GME, and the number of

correct responses was used as a measure of conscious recollection. If participants indicated “I don’t know” in the forced choice response, this was scored as an incorrect response. An independent samples t-test was conducted, comparing the number of correct responses for the Experimental (*M* = 2.00, *SD* = 1.08) and Story Control (*M* = 10.88, *SD* = 2.06) groups. Levene’s test of homogeneity of variance was significant, $F(1, 32) = 4.64$, $p = .04$, and equal variances were not assumed. There was a significant effect of group, $t(22.11) = -15.43$, $p < .01$, where participants in the Story Control group answered significantly more questions correctly than participants in the Experimental group. In particular, sleepers indicated “I don’t know” for many of the forced choice questions.

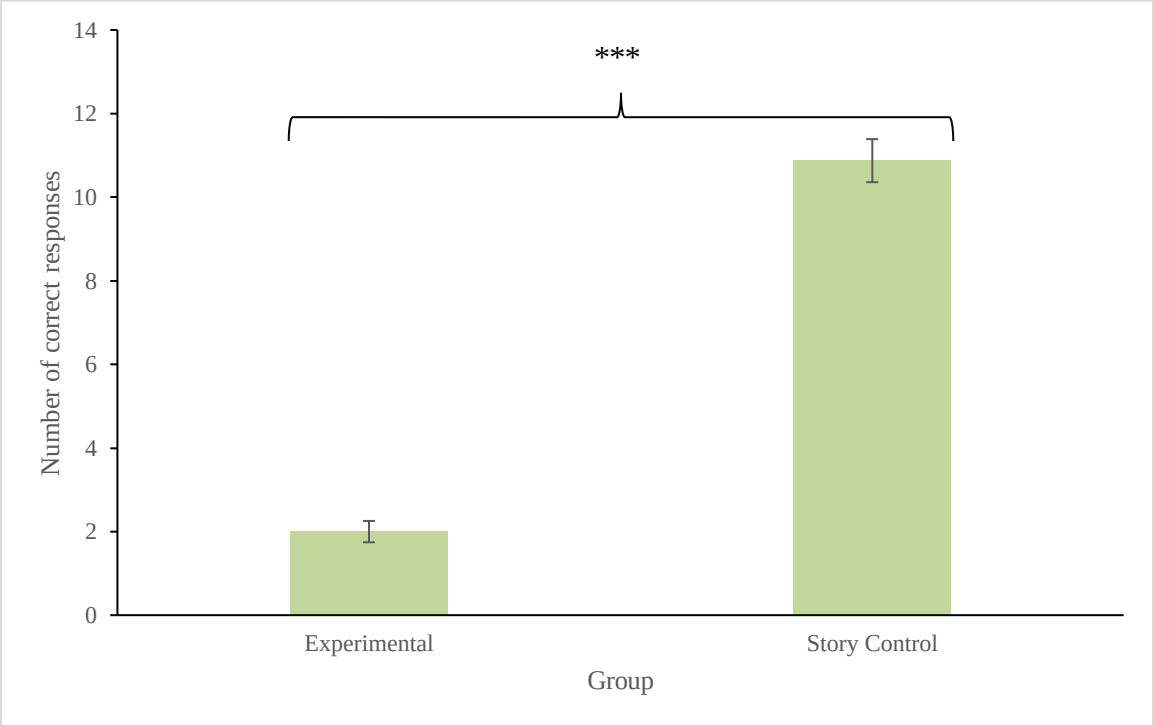

Figure 9. Participants in the Story Control group answered more explicit memory questions correctly than those in the Experimental group

The number of correct responses to 14 explicit memory questions across participants who heard GME. The error bars represent the standard error of the mean. A significant difference in the number of correct responses to questions on the explicit memory task was found between the Experimental and Story Control groups. *Note: an asterisk (*) indicates p < .01.*

Chapter 4

4 Discussion

The present study, to my knowledge, is the first investigation of conscious processing and implicit memory formation of an engaging narrative in sleepers. Three groups of participants were tested, including an Experimental, Story Control, and No-Story Control group. Participants in the Experimental group were played GME while sleeping, while the Story Control group heard the narrative while awake. The No-Story controls did not hear GME at all. Participants then completed an Animacy Decision Task, which tested for implicit memory formation of words that were either mentioned in GME or words related to those mentioned in GME. Thus, this task involved four different word categories: directly-stated, related, control story, and unrelated. In summary, participants in the Experimental and Story Control group demonstrated faster RTs to GME words (i.e. directly-stated and related) compared to control story words. Additionally, the Experimental and Story Control groups demonstrated no significant difference in RTs between the directly-stated and related categories, as well as between the control story and unrelated categories. The No-Story control group demonstrated no significant difference in RT when comparing GME and control story, directly-stated and related, or control story and unrelated words. Furthermore, in a test of explicit memory, participants who heard GME while awake performed significantly better than those who had been played the story while asleep. These results suggest that sleepers are capable of higher levels of conscious perception and implicit memory formation of a narrative presented while sleeping.

4.1 Implicit memory formation

4.1.1 Directly-stated and related

In order to ascertain whether faster response times to GME words were driven by semantic relatedness to the plotline or the direct effect of experiencing the words from the story itself, directly-stated and related RTs were compared in a paired samples t-test for all 3 groups. There was no significant difference in RT for the directly-stated and related words for the Experimental, Story Control, and No-Story Control groups.

As there was no significant difference in RT for directly-stated and related words for the Experimental and Story Control groups, this suggests that words do not have to be explicitly stated in the narrative in order to facilitate RTs to GME words on the Animacy Decision Task. Words from the directly-stated category came from the narrative itself, meaning that participants heard each word from the category spoken during the study session. However, words from the related category maintained a thematic similarity to the plot of GME but did not appear explicitly in the narrative. If there had been a significant difference in RT between directly-stated and related words, it would have confirmed that one category of words had a benefit over another (e.g. directly-stated words were responded to faster because participants were primed from hearing it in the story). However, the fact that there was no significant difference between these word categories, suggests that memories are formed to words that are semantically related to GME, whether they are explicitly mentioned in the narrative or not.

As hypothesized, there was no significant difference in RT for directly-stated and related words in the No-Story control group confirming that these two word categories were linguistically and mnemonically equivalent.

4.1.2 GME and control story

A planned, paired samples t-test for the Experimental Group found a significant difference in RT between GME and control story words, where GME words were responded to more quickly. This result supports our hypothesis that participants form implicit memories of narratives presented during sleep. Faster RTs suggest that GME was processed to some degree, and that memories of the narrative were formed while the participants slept, which produced a facilitation effect on the subsequent memory task. Interestingly, when participants in the Experimental Group were probed after the study procedure, they indicated that they were not explicitly aware that they heard GME. When formally tested, participants only answered an average of 2.00 out of 14 questions correctly (or 11.76%), compared to the Story Controls who answered an average of 10.88 of 14 questions correctly (or 77.71%) (see Figure 9).

The most likely explanation for faster RTs to GME words is that the engaging nature of the narrative was able to 'pierce through' protective sleep architecture, such as K-complexes, and continue to be processed to some extent (Blume *et al.,* 2016). GME contains a suspenseful plot, and varied emotionality of the narrator's voice, both of which may have led to continued processing during sleep. Additionally, sleep spindle activity has been shown to allow for continued processing of salient stimuli while sleeping (Blume *et al.,* 2018), as well as involvement in reactivation of emotional memories (Cairney *et al.,* 2014).

In addition, our results suggest that thematic relatedness to GME is driving this effect, and not semantic similarity within word categories. The words in the Control Story category were all taken from a story that participants did not hear, meaning that these words also had an ongoing theme. If it were solely thematic relatedness that was driving this effect, we would expect to see no significant difference in RT for these two groups of words.

Our finding that participants form implicit memories while sleeping is supported by previous evidence in the literature (Andrillon & Kouider, 2016; Arzi *et al.,* 2012; Züst *et al.,* 2019). For example, sleepers have been shown to form implicit memories of words played during NREM2 (Andrillon & Kouider, 2016). In that study, participants generally categorized words from a sleep word list as 'new', indicating a lack of explicit recollection. However, when sleep words were categorized as 'old' (that is, previously experienced), participants were significantly more confident in their choice compared to words from a new list that they labeled as 'old' (that is, words that they incorrectly identified as having been heard before). The current study has extended the literature in this regard, by using a direct behavioural measure (RT) to assess implicit memory, rather than a secondary measure such as confidence ratings (Andrillon & Kouider, 2016). Additionally, the current study used a continuous narrative instead of discrete words from a wordlist. This demonstrates that participants are capable of forming implicit memories, not only of single words, but also words and concepts derived from a narrative that is spoken in a naturalistic manner.

As with the Experimental Group, a paired samples t-test for the Story Control group revealed that GME words were responded to significantly faster compared to control story words confirming that these participants had formed memories of GME. This is not an unexpected result – the Story Control group was awake and aware during the presentation of GME and so participants had the opportunity to be primed with directly-stated words while fully conscious, in addition to being able to follow the plot of the story. As was the case in the Experimental group, the relatedness of words to GME appeared to be driving this effect and not semantic similarity within word categories.

Finally, a paired samples t-test was conducted for the No-Story Control group and, unlike the other two groups, there was no significant difference in RT between GME and control story words. This result provides additional evidence that enhanced RT to GME words in the other two groups is because they have experienced and processed the narrative for later recall; however, this group is low in power ($N = 11$) and the results should be interpreted accordingly. In general, the purpose of including this group was to ensure that all the words included in the Animacy Decision Task were linguistically and mnemonically matched. For instance, if GME words were always responded to more quickly on average, even by participants who did not hear the narrative, that would indicate that these words were intrinsically more memorable. The fact that there was no significant difference in RT between GME and control story words for the No-Story Controls, confirms that such a factor is not responsible for the effects observed in the other two groups.

4.1.3 Control story and unrelated

The purpose of this comparison was to determine if words that were semantically related to each other, but not GME, lead to faster RTs due to the participant's awareness of thematic trends within a word category. The words from the Control Story condition were all taken from a story that the participants did not hear – thus, they all have a certain degree of relatedness. We sought to determine if this relatedness resulted in faster RTs compared to semantically unrelated, matched control words.

As hypothesized, there was no significant difference in RT for control story and unrelated word categories for the Experimental, Story Control, and No-Story control groups, suggesting that words that are thematically related are not inherently responded to more quickly than words that are not related in this way. This confirms again that it is relatedness to GME that is driving the faster RTs described in section 4.1.2.

In addition, because there was no significant difference in RT for the No-Story control group, this further suggests that there was no significant difference between word categories. That is to say, if there were an inherent bias in word categories, it would be observed in the No-Story control group, as they had not been exposed to GME.

It is important to note that the RTs across word categories for the Experimental group (M = 659.08) were slower on average compared to the Story Control (M = 621.70) and No-Story Control (M = 621.08) groups. The reason for these slower responses in the Experimental group is likely because the task was completed immediately after the nap session and participants had only been awake for 5-10 minutes before completing the Animacy Decision Task. Drowsy participants have been shown to exhibit slower RTs in comparison to alert, wakeful participants (Matchock & Mordkoff, 2007). Therefore, it is likely that drowsiness resulted in slower RTs in these participants relative to those in the groups who had not recently woken from a nap.

4.2 Role of sleep stage on memory consolidation

In an exploratory analysis, time spent in different stages of sleep and implicit memory consolidation was investigated. Among participants who slept, we found no significant correlation between the mean difference in RT (Control Story – GME) and the amount of time spent in NREM1, NREM2, nor NREM3. Past literature has found evidence that sleep improves consolidation of implicit memories; however, it appears that it was mainly REM that drove this effect (Diekelmann *et al.*, 2009; Rasch & Born, 2013; Smith, 1995). For example, in one study participants completed a pre-test session involving a number of implicit tasks (e.g. word fragment completion task, the Tower of Hanoi) (Smith, 1995). Afterwards, participants slept, but they were deprived of the last two REM

cycles of the night. When tested one week later, participants demonstrated impaired performance on the implicit tasks compared to controls.

In the current study, none of the participants in the Experimental group acquired REM sleep, which is the most likely reason that we do not see a correlation of time spent in a stage of sleep with the mean difference in RT. Although it has been demonstrated that implicit word associations can be formed in NREM3, specifically during slow wave peaks (Züst *et al.*, 2019), the stimulus used in the current study was a continuous narrative rather than word pairs. Therefore, it was not possible to present directly-stated words specifically during a slow wave peak. This may be why we did not see a correlation of NREM3 sleep with the mean difference in RT.

4.2.1 Investigating changes in RT due to sleep

In order to determine whether participants in the Experimental and Story Control groups benefitted equally from GME words, an independent samples t-test was conducted. No significant difference was found when comparing the mean difference in RT (Control Story – GME) between the Experimental and Control Story groups.

Past evidence suggests that sleep aids in memory consolidation (Rasch & Born, 2013; Stickgold *et al.*, 2000; Stickgold, 2005; Walker & Stickgold, 2004). For instance, in one study participants completed a repeated visual search task, where a target letter remained in the same location for half the displays, and changed locations for the others (Geyer *et al.*, 2013). Participants who had the opportunity to nap before completing the visual search task a second time were significantly faster at finding the target letter for the repeated displays compared to participants who rested quietly between the two tasks.

In spite of this evidence, our results do not support this effect because both the Experimental and Story Control groups benefitted equally from the GME words. A potential reason we do not see this effect is that past evidence of sleep improving memory consolidation has been based on memories formed prior to sleeping, where sleep assisted in strengthening memories that already existed (Geyer *et al.*, 2013). In the current study, memories were being formed during sleep; it is not well understood if learning new information and consolidation of these memories can occur simultaneously

(Badia, 1990). If memory consolidation cannot occur synchronously with learning during sleep, this might be why participants in the Experimental group did not experience improved memory consolidation due to their nap (relative to those who had not napped). Rather, they only acquired new information, like wakeful participants. As there was no significant difference in the mean difference in RT for the two groups, this suggests that memories formed during sleep do not benefit from improved memory consolidation, unlike memories acquired prior to napping. In this case, it appears that implicit memories that are formed during sleep are similar to those created during wakefulness.

4.3 Limitations and future directions

The fact that significant differences were seen in the Experimental and Story Control groups suggests that sufficient power was acquired for these two groups. However, the effect of low power on the lack of any significant effects in the No-Story control group cannot be ruled out. Ideally, it would have been beneficial to perform a direct comparison between the No-Story Control group and the Experimental group to examine the interaction term. However, because the former group does not have sufficient power, this analysis was not possible. After the pandemic subsides, more participants should be tested to determine more concrete trends in the data, especially for the No-Story control group.

One major limitation of this study is that we could not control the stage of sleep in which GME was presented to participants. Our goal was to play participants GME during NREM2 sleep; however, people can shift through different stages of sleep very quickly. There were several participants who were in NREM2 when GME began and shifted into NREM3 over the course of the narrative. The characteristic sleep architecture of NREM3 protects sleepers from waking, meaning that GME may have been salient enough to be processed during NREM2, but not NREM3. In future, it would beneficial to investigate whether the stage of sleep in which GME was presented impacts RT on the Animacy Decision Task, or implicit memory strength; although to do this, much better control of sleep staging would be required. Clearly it is not possible to ‘control’ sleep staging, although if longer sleeps were used there would be more opportunity to ensure that the

story was delivered within any one sleep stage and also to compare how memory for the story differed depending on which stage it was presented in.

There are several other possible future directions for this research. One potential direction would be to investigate the amount of time spent sleeping after the narrative finished, and if changes in the quantity of time impacts RT on the Animacy Decision Task. Additionally, ratings of engagement for the story could also be collected and used to examine if directly-stated words that are associated with more engaging aspects of the story are also responded to more quickly.

4.4 Conclusion

The current study is an important investigation into the upper limit of implicit memory formation during sleep in human participants. Having some level of awareness during sleep is vital, as our safety requires that we are able to wake up to relevant stimuli. However, the extent of this processing is poorly understood. In addition, understanding the extent of memory formation to stimuli during sleep is an important step in learning the abilities of the sleeping brain.

The evidence from the current study suggests that participants are capable of forming implicit memories of an engaging narrative presented during sleep. Participants from the Experimental and Story Control groups were significantly faster at responding to GME words compared to semantically matched control story words. We were also able to demonstrate equivalency between word groups, in that there was no significant difference in RT between GME and control story words in the No-Story Control group. To my knowledge, this is the first time that sleepers have been shown to form new implicit memories of a narrative. The fact that sleepers were capable of performing like wakeful controls on the Animacy Decision Task is indicative of the complex nature of sleep, and that sleep should not be considered a state of unconsciousness. Rather, it should be thought of as an altered state of consciousness; a complex state that shifts through different levels of wakefulness and awareness, where emotionally salient stimuli continue to be processed despite no explicit awareness.

Additionally, the results of the current study indicate that sleepers and wakeful participants benefitted from GME words to the same degree. This suggests that, despite having formed memories in an altered state of consciousness, sleepers had similar memories of GME as wakeful participants. This leads to a number of questions, including exactly how learning and consolidation of new information occurs in sleepers. The results from the current study suggest that, when learning new information during sleep, participants do not experience the same memory benefits as people who learn prior to sleeping. However, significantly more research is needed in order to understand this effect more clearly.

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Appendices

Appendix A: Ethics Approval and Consent Form

Western Research

Date: 17 August 2019

To: Dr Laura Batterink

Project ID: 112576

Study Title: Studies of sleep and language learning

Application Type: Continuing Ethics Review (CER) Form

Review Type: Delegated

Meeting Date: 06/Sep/2019

Date Approval Issued: 17/Aug/2019

REB Approval Expiry Date: 31/Aug/2020

Dear Dr Laura Batterink,

The Western University Non-Medical Research Ethics Board has reviewed this application. This study, including all currently approved documents, has been re-approved until the expiry date noted above.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario. Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Daniel Wyzynski, Research Ethics Coordinator, on behalf of Prof. Randal Graham, NMREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Project Title: Studies of Sleep and Language Learning

Principal Investigator:
Dr. Laura Batterink
Department of Psychology, The University of Western Ontario, London, ON
Telephone: [redacted]; Email: [redacted]

1. Invitation to Participate
You are being invited to participate in a research study about how the role of sleep in memory consolidation and language learning.

The purpose of this letter is to provide you with information required for you to make an informed decision regarding participation in this research. It is important for you to understand why the study is being conducted and what it will involve. Please take the time to read this carefully, and feel free to ask questions if anything is unclear or if there are words or phrases you do not understand.

2. Why is this study being done?

The purpose of the study is to investigate how sleep contributes to the learning, consolidation and retention of different aspects of language, such as vocabulary and grammar. The results from this research will help us understand how sleep contributes to language learning, including clarifying whether sleep plays a more central role in learning some aspects of language compared to others. Our results will also help to pinpoint the underlying physiological mechanisms during sleep that may contribute to language learning and consolidation. This research has important implications for adult second language learners and may eventually lead to novel methods of boosting second language learning and retention through sleep.

3. How long will you be in this study?

It is expected that this study will take approximately [# of hours 3 - 5] hours to complete.

4. What are the study procedures?

The experiments conducted as part of this study will test how humans process and learn about different types of linguistic stimuli, such as syllables, words, phrases and sentences. If you agree to participate, you will be asked to listen to language-related auditory stimuli and/or read words and sentences on a screen. You may be asked to perform different tasks associated with the stimuli, such as responding to targets by pressing a button, or making different judgments or ratings about your

impressions of the stimuli. You may be asked to respond using your voice, and your voice may be recorded using an audio recorder. If you do not wish to be recorded, you can still participate in other parts of the study.

Your brain activity will be recorded using a technique called electroencephalography (EEG), where electrodes placed on the scalp measure electrical signals that brain cells use to communicate. An elastic cap will be placed on your head. The cap will be strapped down to fit snugly and comfortably. The sensors, which look like white pieces of plastic about 1 inch in diameter attached to the cap, will be filled with a small amount of conductive gel. To monitor blinking and eye movements, the experimenter will place similar sensors on the skin surface near your eyes. These sensors will be secured in place using tape. When the sensors are removed, the gel will be wiped off using tissue. Some gel may remain in your hair, but it can easily be removed by rinsing with water. You will be given the opportunity to wash your hair at the end of the study.

You will be given the opportunity to take a nap in the sleep lab [redacted] while your brain activity is recorded using EEG. Each room in the sleep lab is equipped with a comfortable bed. You will be asked to lie down in the bed for a [1-2] hour period. While you nap you will be monitored using video and audio monitoring equipment by the experimenter in an adjacent room. The experimenter will be available throughout the nap if needed, and you can communicate with the experimenter at any time during this nap opportunity through use of the 2-way audio monitor.

The task(s) will be conducted in the [redacted] the University of Western Ontario campus.

5. What are the risks and harms of participating in this study?

There are no known or anticipated risks or discomforts associated with participating in this study. However, you may experience a minor inconvenience as some gel may remain in your hair at the end of the study. The gel can easily be removed by washing your hair. You will be given the opportunity to wash your hair at the end of the study.

6. What are the benefits?

You do not directly stand to benefit from this study. Although you may not directly benefit from your participation, the information gathered may provide benefits to society as a whole which include enhancing our scientific understanding of sleep, memory consolidation, language, learning, and the brain, and leading to advancements in second language training and treatment of language-related disorders (for example, specific language impairment and autism).

7. Can participants choose to leave the study?

You may refuse to participate, refuse to answer any questions or withdraw from the study at any time. If you decide to withdraw from the study, you have the right to request withdrawal of information collected about you. If you wish to have your information removed please let the

researcher know. Withdrawing or refusing to answer questions will not result in loss of promised compensation.

8. How will participants' information be kept confidential?

Any personal or identifying information obtained from this study will be kept confidential and will be accessible only to the investigators of this study. Identifiable information that will be collected during the study includes your full name, telephone number, email address, partial date of birth (month and year) and, in some cases, audio voice recordings. In the event of publication, any data resulting from your participation will be identified only by case number, without any reference to your name or personal information. Only the research team will have access to information that identifies you to carry out this research study.

If files are shared with other researchers or the results are made public, any personal information that could identify you will be removed. Only anonymized data will be shared outside the research team (e.g., in an open access repository for publication purposes, or for other researchers to verify the findings or re-analyze).

Any documents identifying you by name will be kept separately from your data, and will be destroyed after 7 years. De-identified and anonymous study records will be maintained for a minimum of 7 years. A list linking your study number with your name will be kept by the researcher in a secure place, separate from your study file.

Representatives of the University of Western Ontario Non-Medical Research Ethics Board may require access to your study-related records to monitor the conduct of the research.

9. Are participants compensated to be in this study?

You will receive course credit (1 credit per hour) or monetary compensation ($14 per hour) for your participation in this study. If you do not complete the entire study you will still be compensated a pro-rated amount (based on the same rates specified above: 1 credit/h or $14/h). When calculating prorated compensation, your total participation time will be rounded up to the nearest half hour. For example, if you withdraw after 1 hour and 15 minutes, your participation time will be rounded to 1.5 h and you will receive 1.5 credits or $21. Therefore, even if you withdraw prior to completing study, you will still be compensated for the amount of time you spent participating.

10. What are the rights of participants?

Your participation in this study is voluntary. You may decide not to be in this study. Even if you consent to participate you have the right to not answer individual questions or to withdraw from the study at any time. If you are a student at Western and you choose not to participate or to leave the study at any time, it will have no effect on your academic standing.

We will give you new information that is learned during the study that might affect your decision to stay in the study.

You do not waive any legal right by signing this consent form

11. Whom do participants contact for questions?

If you have questions about this research study please contact Laura Batterink, Principal Investigator, Telephone: [redacted]; Email: [redacted]

If you have any questions about your rights as a research participant or the conduct of this study, you may contact The Office of Human Research Ethics [redacted] email:[redacted]

This letter is yours to keep for future reference.

Consent Form
Project Title: Behavioral and EEG studies of language learning
Study Investigator's Name: Dr. Laura Batterink

I agree to be audio-recorded in this research.

☐ **YES** ☐ **NO**

I agree to be contacted for future research studies.

☐ **YES** ☐ **NO**

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Participant's Name (please print): _____

Participant's Signature: _____

Date: _____

My signature means that I have explained the study to the participant named above. I have answered all questions.

Person Obtaining Informed Consent (please print): _____

Signature: _____

Date: _____

Appendix B: Scripts for John Butler interview and GME

John: John: [Nods head], mmm, he was a quiet man, an artist, a craftsman. Very conscious of his surroundings. A landscape artist mostly at that time. So, he taught me to observe nature, to see the beauty of what was in front of me. Nothing elaborate, just the hedges, the trees, the grass, to notice the sky. He was also very conscious of good work. He loved carpentry, he taught me how to use tools and I remember so well him saying "pay attention, keep your eye on what you are doing. When you are sewing a piece of wood, listen to and watch the movement of the saw, watch the hammer so that you hit the nail straight. And these two lessons of 100% giving attention and observing what was around me have stood me in good stead all my life.

Iain: They're wonderful qualities which are probably quite rare these days which is sad but that is the way the world is…and what did you get from your mother?

John: Mum was Russian. Well, she was also an artist in her way. She was a housewife of course, which is what women were then they called themselves that and were proud of it. Mum was always, when Women's Lib[eration] came in she said there is nothing wrong with being a mother and a housewife. Anyway, what I got from mum was primarily a Russian heart and Russian hearts they just spill out all over the place. And I was always told as a child that I wear my heart on my sleeve, well, people laughed at me but it is one of the best things, to have a great heart. To work from the heart, to recognise the existence of the heart and the whole household shone with that tender loving care that emanates from someone that loves their work and gives themselves to it; the way the table was laid, the way she knitted our clothes for us, did the mending, did the washing up, everything was a work of art and done with love.

Iain: And I know at seven years of age you were sent to boarding school and that was a little bit of a shock but you escaped to the chapel and pray when you needed didn't you, to find your solitude and balance again.

John: [Laughs] It was a shock because up till then we had lived in the deep country and I hardly knew what another little boy was. My companions were nature and

animals. And I was suddenly thrown into this world of other little boys and I was completely lost and for the first time in my life I knew what it was to feel isolated and lonely. And God the school was in a rural setting so there were big gardens where I could go and, also in my little childish way I remember so well just burying my little head in my hands and closing my eyes and saying God bless mummy and daddy and my sister and our dog and what a haven of home and security that was for me.

Iain: It seems even at an early age you had a way of going inside and finding somewhere you could rest, as you used the word *haven* just now.

John: Yes, I think that probably was so, if not inside, at least to stillness and quietness. In nature, it is outside, isn't it? You look at a tree and put your arms around a tree and you're held in stillness, in quietness, in that reassurance of simply being itself. And what a contrast it is to the noise and the agitation that you get from most people.

Iain: And you talk about, I don't know if you remember, at the beginning of this book [*Wonders of Spiritual Unfoldment*] you talk about, it's a book about [being] committed to discovering stillness.

John: Well I wouldn't say that, no, it is really a book committed to discovering…well, I don't really know what really…if I use clever words like the Infinite, or even God it, as a young man I wasn't, I still don't know really what they are, who does know what God is [laughs]? Nobody knows what God is, but there's, how can I put it? Perhaps one longs for the unlimited, for freedom and for love and any worldly experience, all these things are finite; they have an end. You go out, you discover freedom, go out and climb a mountain but then you have to come home again. Love is wonderful in its flowering but then sooner or later it says "no", it has an end. All the things you love, the happiness, it all comes and goes, doesn't it? I think that perhaps I was just greedy, I wanted that which didn't end.

Iain: but sometimes we need that, you call it *greed*, that commitment to find, otherwise we never find it.

John: Well, absolutely, that's the motivation, isn't it?

Iain: We will come on to that a bit litter, I just want to go through your story a little bit sequentially and just discover these important pointers in your life. So, there's so much we could do because you are now seventy-nine years old, there's so much we could talk about but I'm going to summarise it to some extent:
You were an army officer, which I guess was National Service, involved with the family business and then in 1963 you went to South America…

John: Yes.

Iain: What's the reason you went to South America?

John: Oh, I wanted to make the world a better place [laughs].
Iain: What was your vision of making the world a better place?

John: Well, I was a farmer, I'd loved farming since my first breath, I was soaked in farming. I wanted to be a farmer, it was my overriding dream really. And I had spent some time, I had studied the subject and it was the time when these charities like OXFAM were just beginning, so it was the fashionable thing really, I suppose. I had another mate and we were going out to Bolivia, we were going to take a…they were giving grants of a thousand hectares to new settlers who would go out and grow food for the hungry, so we thought we would go out and do that. We were young and strong but my mate didn't come, he met a girl who stayed in England and I met a Peruvian girl and her father invited me to go and work for him in Peru, so I did that on a big sheep hacienda. But that was my Socialist time of life and I wanted to do good so I ended up working as a volunteer agriculturalist in the mountains of Peru.

Iain: Which must have been beautiful, actually.

John: Uh huh [nods head].

John: Well I wouldn't say it was easy but there was plenty of space up there and I loved that, I loved the donkeys and the oxen. And yes it was a good year but I think like most people who had done voluntary service, I learnt, it gave me much more than I gave to it

really and I learnt probably the greatest lesson of my life: I remember sitting on a mountainside one day, I had done a lot of work and a little bit of work planting trees on eroded mountainsides and of course the local sheep and goats had come and eaten them all off, so I was sitting there a bit depressed. And it seemed, a little voice said to me "make whole, be whole."

Iain: Make whole, be whole.

John: To make whole, be whole. Well I hardly understood what that was then but I had read a little bit about meditation, not that I really understood it. But I saw myself as a mixed-up young man trying to help people, the local Indians, who were older and wiser than myself and more able to live. And I realised I had to do something about sorting out myself before I could be much use to others. So, having read a bit about meditation, when I came home to England, I looked for and I found a school of meditation.

Iain: I wanted to just point out one more thing that I thought was important in your book was, there was a situation, you were in the mountains, in the jungle I think in Peru and you felt the only way was to *surrender*.

John: Ah, yes [laughs].

Iain: Do you remember that? That was quite important I think.

John: Yes, I had a pal and we'd found an Indian who would take us, and we had several days in the jungle, just walking through the jungle which was…

Iain: …it must have been an incredible experience.

John: It was an incredible experience, it was absolutely wonderful. The jungle is very thick it is quite difficult to walk through, with great trees above us, very little sunlight comes down to the forest floor, you creep along over the fallen leaves, these huge lizards, snails and snakes, you see monkeys up in the trees and at one point we came to a little creek with sandy banks and there was a great sought of furrow gouged out of the sand as though someone had dragged a big oil barrow through it. And we looked at the guide and it was a huge snake, an anaconda and I wanted to follow up and find it but he wouldn't let

me, he said it would be lying curled up ready to grab us. And then it started to rain and we camped just near there, just beside it and we made a little fire, just sleeping on the ground there and I didn't sleep very well, I think maybe I woke up in the middle of the night and the rain had cleared, and you know the jungle's full of shrieks and funny sounds, rustlings at night, all the animals come out and move around and I sat there by the campfire, in this little circle of light and I thought of this great snake, I could reach out and touch it probably for all I knew. And I began to feel fear and we were alone in this jungle and if the Indian deserted us God knows what we would have done. And then quite inexplicably I just, perhaps I had stopped fighting, I gave up the struggle, I surrendered. I just relaxed into the situation as it was, into the unknown and I suddenly felt peace, such as that I'd never felt before. Just total peace, in which all the threats that surrounded us were contained and alright. And I look back on that as one of my first great spiritual experiences.

Iain: Yes, you say in the book "I put my trust in forces greater than me."

John: Yes.

Iain: Yes, which we all have to do, don't we sometimes, if not all the time?

John: Yes, in a way, I've been doing it all my life. That is the essence.

Iain: [Reading from the book] "putting your trust in forces greater than you."

John: That's right.

Iain: Yes. Do you feel that peace now?

John: Absolutely.

Iain: Yes

John: Of course. I am nervous before an interview but what do I do? I find that stillness and I feel confident, it's like an invisible hand to hold, a rock.

Iain: So how do you find the stillness?

John: How do I find it? Well it can't be described.

Iain: Yes and you said you were nervous before the interview and you find that stillness…

John: …yes, how do I find it? I've had many years of practice, it is second nature to me now. Probably my first nature. It is so obvious, we are sitting in it like fishes in the sea. You can never not be still but the trouble is we just don't see it. We look down and we just live in this cocoon of mental agitation [covers his eyes with his hands], lost in thought; that's the human condition. At least what we call the human condition, but actually it's lost, it is not reality at all, what we are, and that is the cause of all of our problems. We are absent from the presence of God.

Iain: And this in a way, the groundwork is what your father was teaching you, about watching the now…

John: yes, to be present, to be present. The present is such an important word, now, the present moment here and now. The present moment…[the church bells begin to chime]…you can hear the church clock chiming, can't you?

Iain: I can.

John: It is sounding in stillness, isn't it?

Iain: It's one o'clock…

John: …in stillness and in timelessness. Time goes round, round and round in eternal presence, the peace of God that passeth understanding, right here and now, you can never be closer to God than right here and now.

Iain: Okay, so I am going to keep going with your story, see what else comes out of that. You were starting to say that when you got back from South America you were twenty-seven and you discovered this school of mediation.

John: Yes.

Iain: Tell us about that, about how you discovered it, not so much how you discovered it but how it was important to you.

John: Well, it certainly was very important. Yes, I had to go to London to be taught, I was taught. My first farm was at Bakewell then, so I had to get the late night train back from London to look after my animals the next morning and I was sitting in St Pancreas station waiting room, among all the rubbish and the unfortunate drunks and homeless that used it and I sat and closed my eyes and meditated as I had been told and there and then in that seemingly uncongenial situation it opened up, like that [raises his arms high] and I realised that all the space, the freedom that I had longed for and that I had been travelling the world to find, the deserts and the mountains of this world where within me, and that discovery, that discovery, well it has been going on ever since. Bigger and bigger, greater and greater, better and better.

Iain: So the discovery was the beginning of something in a way.

John: It was the beginning of realisation. Of course, I had the theory, I was brought up in a Christian school, I had ten years of compulsory chapel and scripture lessons, I knew a lot of the Bible by heart and the old prayer book; "The kingdom of God is within you," you know I'd learnt that but what did it mean? I didn't really know but very soon in those first few periods of meditation I had realised there was this dimension that was not of this…not what we call…this world. There was a further dimension that could be realised. That's the word *realisation*. The Biblical phrase comes alive *The Kingdom of God*, what does that mean, I don't know it's difficult to say even now but it's within you, it really is within. And the peace of God that passes understanding, it is beyond the thinking mind. You don't get it by substituting one thought for another but by opening-up to this dimension of spirit really, that's what it is. Invisible. You can't describe it. Everybody knows what silence is but no one can describe it. Who knows what silence is?

Iain: I'm not sure that everyone knows what silence is actually. They think it's just not hearing any noise.

John: Well, exactly.

Iain: We will go into more detail later but I think there is almost an art to silence somehow. I know you had some, again, important experiences which helped deepen your realisation, there was one time when you were on the underground train in London and you saw everyone as Jesus, is that right?

John: Well I know I used the word when I described it, but I'm not sure really what I meant by it. I think the words *Jesus* and *Christ* so often get used with very nebulous meaning and different people of course mean it in different ways but I think how I would describe it now as far as I remember, it was this realisation of this stillness, that there in this underground carriage was full of this stillness and within this stillness the bodies, the sounds, the personalities took place and actually pervaded everybody.

Iain: Whether they realised it or not.

John: Oh absolutely, I mean if you look at people's eyes, everybody every eye shines with more or less light even if the eye is very dull, it is the same light isn't it, how many lights are there? There is only one light isn't there? And so, it is, there is only one stillness, there's only one stillness. And I think these first experiences of mine were like that.

Iain: You had another time when I think you were also in London where even you saw the garbage as beautiful, everything was shining.

John: Yes, well again it depends what you're focussed on. There are levels of consciousness, if your heart is light, if your heart is full of light, you see light. And everything that is in it is light, you know beauty is in the eye of the beholder isn't it, if your eye is full of beauty that's what you see.

Iain: Yes but I think it was also important from what you explained in the book about that realisation, I am just trying to find the words here [from the book] that forced you to review some deeply negative attitudes towards civilisation's city life.

John: Absolutely, yes, well I think I said, being a country boy I was at that time very negative about city life as a sort of worst of the worst [laughs], you know we used words like *Townies* to describe those not fortunate enough to live in the country and civilisation was the very antithesis of nature. Unnatural wasn't it, and so these were some of the great lessons I had to overcome and certainly meditation did help to clear-out some of those negative thoughts from my mind but unfortunately there were many, many more of them deeply buried inside, it is a long process.

Iain: It is a long process and I think that one of the things that comes across, certainly in your book and your story is this motivation, this determination to keep going somehow, you didn't give up. Let's go through the story and we'll come to some examples of this, so in your thirties you were, you actually thought of becoming a monk at one point, you were in and out of monasteries, you were searching still in the Christian tradition I guess there.

John: Mmm, yes, I don't remember too clearly what my motivation was, I think perhaps it was a reaction you know I didn't want to be what most of my contemporaries were, I didn't want to go into business, I didn't want to go into the professions. Monastic life seemed to offer an alternative but that was about the same time as I learned to meditate and it certainly raised the question do I follow this way or the way of meditation? I don't see any conflict now but then I did it seemed an either/or situation. At that time…things have changed a lot in that last fifty or sixty years, the Church was really, quite suspicious of meditation it, it regarded it as something Eastern which is very odd, but anyway it did and I guess I was caught up in that but anyway I decided to stay with meditation, because even in those early months I realised, or I felt it was, at least for me a more effective way of spiritual work.

Iain: You say more than once in the book that your two loves at that point were meditation, farming and animals and there's a lovely example you gave, one point you had to sell your farm and you were quite sad about that and you were just sitting, feeling it and this ram came over to you. Just talk us through what happened there.

John: Excuse me, may I just jump back for a moment to make a little comment about that decision about meditation?

Iain: Of course.

John: The accusation is often made that meditation is a withdrawal from this world but absolutely on the contrary, the key principle of the method that I taught was that you practise it while living in the world. A monk's life may possibly be considered a withdrawal from worldly life but meditation, absolutely not. It is the art of finding the eternal, in the midst of the marketplace, the stillness in the movement.

Iain: To be, I forget the exact phrase, but *to be in the world but not of the world.*

John: Absolutely, that's the good phrase *in the world but not of the world.* Yes.

Iain: I understand that.

John: Yes, and it is utterly practical. It is absolutely not a withdrawal, an opting out, it is a completely different understanding.

Iain: I have read many things over the years about monks that have spent years meditating in very confined places, like a cave or a monastery and they come to the city and they are lost.

John: Yes.

Iain: And what you're saying is that, that stillness, that presence it's right in the marketplace, in the city.

John: Yes, in the most chaotic imaginable situation. Yes.

Iain: Yes.

John: God is with us.

Iain: Yes. I am going to insist on the story about the ram because I love the story.

John: Yes, so do I [laughs]. I think it is one of those wonderful things that I have got no explanation for but at that time...one of the great loves of my life are sheep...I can tell you a lot about my understanding of the *lamb of God* [laughs] anyway, at that time I had quite a considerable flock of sheep; about one hundred and fifty sheep, and five rams I think and one of these rams was an old warrior, where through much fighting he'd split his skull and was...old soldier [laughs]. And just before things happened; I had to move on from my first farm. I was sitting on one side of the field, I'm not sure if I'd been crying, but I was very unhappy about it all, losing my beloved animals and these rams were lying under a hedge at the other side of the field about, I suppose, a hundred yards or so away. And to my amazement, one of these rams; this old warrior, he stood up, he left the others, slowly and deliberately he walked across the field, he laid his head in my lap and just stood there for a minute or two, or three. And he turned away and went back and laid back with his companions. It brings tears to my eyes to tell you. Well, what do you make of that?

Iain: That extraordinary connection that you have had with nature, which is everyone's potential in a way.

John: Well, maybe that was it. I did consider that [to be] one of the greatest honours of my life. I couldn't ask for more.

Iain: *One of the greatest honours of your life* [nodding]. Yes, wonderful.

John: See, [this] Russian heart brings tears to my eyes [wipes his eyes dry] even in front of a camera, I'm sorry.

Iain: Well, you have had a bit of an up-and-down story in some ways and I'm going to now move on because in your late forties, your life fell apart and you had quite bad depression. How did that start?

John: Well, I had a second farm then, it was a lovely little farm and that is really another little story. I was happy as a farmer, I was married by then and had a good wife...but we had many meditation students at that time who used to come to the farm. I was quite well known, as one of the first organic farmers. There was a woman that came to meditate

and on one occasion...we meditate with closed eyes by the way...we were sitting together and we'd just come to stillness and I saw our two souls rise from our bodies and merge as one. She was a woman with very open clear eyes and when I looked at her, I saw right through to the infinite beyond.

Iain: So, what does that mean?

John: What does that mean?

Iain: The "infinite beyond." What did you actually see?

John: Well you have got to realise there are two sorts of sight; there's the eyes of flesh and there's what's called *insight*...seeing with the eyes of the heart. [smiles]. Flesh sight is always limited; it has a boundary, flesh sees flesh. But we all have to some extent a sense of indescribable beauty, or indescribable peace...something like that. What did I see? I saw the indescribable, right there. I saw the infinite indescribable. But it is the realest of the real when you see it. And what really tipped me back, tipped me into depression was that I was still a young man, a hot-blooded young man, still very much living in my physical body and my human emotion. How do you reconcile the two? There was that spiritual union, if you like, the mystical marriage, contrasted with two people living lives both with their own marriages, their homes, their jobs that were separate. How do you reconcile unity with separation? Well, I couldn't at that time. It was beyond my ability, my experience. I couldn't go back into that old life. Of course, I couldn't escape it either, really, I was sort of, imprisoned in it.

Iain: So it was an experience that took you out [raises arms in a wide arc above his head] of your world.

John: Yes, that's right. I suppose in modern jargon, it blew my mind. I'm not sure if that is accurate or not. It's not a phrase I normally use.

Iain: Sounds very accurate! It blew your mind [laughs].

John: But, I went back home and there was my dear wife but somehow it was all too small, I couldn't...I had been shown something...well anyway, the gist of it was it threw me into a turmoil of emotions and I left. I had to really break away.

Iain: You had to leave your marriage.

John: I left my farm, I left my home.

Iain: Wow.

John: I had one of the little motor caravans of that time and I drifted around for some years homeless, jobless, loveless and alone. And it was a wretched time of life. I just picked through it, I did what I could.

Iain: But you'd had that experience. So, had that given you a reference point, had it given you an opening?

John: Yes it did because how can one access it? Well, meditation of course does just that. Because in meditation you...if I can give you a demonstration, the beautiful demonstration of meditation, I hope the camera can see my hands, is just that; [unfolds clenched fingers into open palms].

Iain: It's just an opening.

John: It's letting go.

Iain: letting go.

John: Now this is how we live [tightens fingers again], forgetting, forgetful of the One.

Iain: Trying to hold on.

John: ...trying to hold on. We hold on to our personal life and so we are imprisoned with our ego, which is our sense of separation. And in meditation, it starts very gently at first, so it is not frightening or anything but very gently it helps you to do that [unfolds fingers to open palms again]. Now when you let go, you discover that you are not

actually separate at all. You are united. You are in that which is undivided. Indescribable but undivided. There's not two at all, there's just One. One love. One person. Singular. Adam in the paradise was singular, one I Am. Now that's what I had been shown in this dramatic episode with this woman; the Oneness. Well, you could say, that then the work, the real work began because the two polarities had been clearly identified to me. I was too muddled really to put it as clearly as I am saying to you now but that's what gradually dawned on me. At one time in the motor caravan I went to spend a winter in Spain, alone of course and I spent hour after hour after hour just meditating. I moved from doing the standard half-hour morning and night and meditation became salvation because in salvation you are taken out of this imprisonment and [unfolds arms] you are shown what's real. You're saved from drowning in this world, just like Saint Peter was walking on water; he was drowning in the world, [and] there was Jesus free beside him. Peter was drowning, he reached, he said, "help me." Jesus said "what were you frightened about? What were you drowning for? Have faith."

Iain: Have faith.

John: That's what it's all about.

Iain: And you never stopped having faith even though it was a difficult time?

John: I don't think I ever did because I had this wonderful practice and this practice [meditation] is such a wonderful way of putting it into practice. So twice every day without fail and for increasing lengths of time. I was just surrendering to that total presence and to that love that has no end. That love that never says no. To pure, total love which is, which I'd seen in her eyes you see? And yet the body of course said no...

Iain: ...in a way it wasn't to do with *her*...

John: ...well...

Iain: ...she was a portal somehow...

John: well the body was a portal because that isn't really what we are. And this is the great discovery; that man is not limited to the flesh, the flesh as the Bible tells us is prophet of nothing.

Iain: Yes.

John: The flesh is just...look, anything that dies, mortality, the whole world [that] comes to pass is not what we are. Man, is eternal being.

Iain: Okay. I am going to go back to your story a little bit because I think it is important for people to see that your path wasn't always smooth, it had ups and downs, and how you dealt with the downs I think is so important and people somehow, they get stuck in having the highs, as they see them; the experiences but these practicalities.

John: Yes of course, well, it's discipline that pulls you through. You have just got to keep on practising. Practise, practise, practise.

Iain: This discipline, in the motor-home, you kept the discipline of meditation.

John: Yes, but in a way, it isn't difficult because it is a way, in a way it is like, well it is being described as a trail of grains of sugar, you know? You follow it because it's always leading you from better, to better, to better.

Iain: From better, to better, to better.

John: Yes, it's described as a trail of sugar, you see, leading to the sugar mountain, which is of course the Kingdom of God.

Iain: Yes but unfortunately in our society there's so many false trails, trying to take you from better, to better, to better and all you end up with is an unhealthy body and an overdraft and credit card bills [laughs] and...

John: Well that's why it's...well I think one of the impediments, one of the things that stops us setting out on the spiritual life is that we are not sufficiently unhappy. We are too content with this sort of compromise with life, with all the little sandwich bars and

baubles that life offers to us; that comfort of a teddy bear and you know for some people that's not good enough, you want more, you want the real thing. And I guess I was one of those people.

Iain: Yes but you also had what I would call, the taste, not the taste, as it is not a strong enough word but you had visions, in one way, you had big, big, clues and not everyone has that.

John: Well yes, that's also true and am I not blessed?

Iain: There is a blessing in that, you are absolutely right.

John: Absolutely, you know they say, the Bible tells us we are saved by grace. What is grace? It is something that comes unseen, unknown, you know, it is like memory, where does memory come from? It just comes, doesn't it?

Iain: I think what we are going to do is a part two of this interview because we have about ten minutes left and I am only...so we will keep going and there will be a part two. So, what happened next was in 1998 you went to Africa for a time.

John: Yes, I was offered a job out in Africa, South Africa. I went out there, the job didn't work out, so after some time I hired a little car and I just drove off. I didn't really have a plan, I didn't really have a proper map but I just followed the road and it all unfolded in front of me. I slept in the back of the car or out on the ground under the stars, oh I actually loved it. The space, the glorious space. And I never went to any big towns only little ones, I just bought what I had to and got out into the open again [laughs]. I just found the big empty spaces on the map and I went there.

Iain: It comes across in the book that you are always drawn to wide-open, preferably wild places.

John: Yes.

Iain: and but for the wind there was [were] utter silences that you'd never known before.

John: Yes.

Iain: There was no place for your depression anymore.

John: No, I suppose, out there...I was so thrilled by it, so...

Iain: Utter silence.

John: Yes, so I just couldn't get enough of space and silence. I have always loved space and silence, they're just natural to me, I belong there. That's where I feel at home.

Iain: But it seems to me that it is kind of, what you've told us so far about your life, it's almost like there is this dance of space and you are drawn to this space on the outside, you recognise the real space is primarily on the inside. And you are in Africa and of course you are completely attracted to the stillness of the space, nothing around for miles and miles.

John: Yes, I actually loved that. When I was a boy at school, my favourite picture was of a cowboy riding up to the crest of a hill with the caption "don't fence me in" I loved that phrase. And Africa was in that sense...yes and then I went on, I was in the Kalahari and the Namibian desert and that...oh I just loved it. It always seemed to me [to be] obvious why the early Christians, why men of prayer went to the desert and I experienced it for myself and it is just all so obvious there, it is all just before you; the Infinite. You are nothing. You are taken into the immensity of what's there.

Iain: Because you talk in the book about there, when you are in Africa about the absence of subject/object relationships. It's not you and the other, it's just the One.

John: No, that's right. All that dies away. All the personality is, is nothing.

Iain: Yes.

John: The 'me', the John Butler is just...you forget about it...it's just nothing.

Iain: Yes, and of course you came back from Africa to England...

John: Yes, [laughs] where you can imagine that is the opposite, getting back to [England]...well I'd get back into John Butler again [laughs]. Or what the world considered that to be.

Iain: And you found it tough again, didn't you?

John: Well, I, you know, I had lost my job as a farmer. I was desperate to find some sort of work and what on earth could I do? I wrote a CV [curriculum vitae] at that time and I remember more-or-less what I wrote. I wrote I knew something about freedom and therefore I could help others to freedom. And of course, freedom is love. Love is freedom. The two are really the same thing, spiritually speaking. And if someone could give me a channel for my love, I would give my all. That was what I was looking for. And of course, who answered my CV? Nobody [laughs]! I was looking for freedom in the world of bondage.

Iain: But you'd also had the realisations before when you were in London and you saw the garbage as beautiful in the underground [tube station] and somehow, you'd had those experiences but something...it is hard isn't it? I'm just pointing out that you had had these reference points but you had this openness in Africa, this stillness. John Butler has almost disappeared and you get back to England, and the reality of day-to-day life hits you again.

John: Well, I suppose, I hadn't...I was still...we are such spiritual infants, you know, even now as an old man I am still a spiritual child. It's a long journey and one is learning all the time. You learn something every day. And at that time, I was still grappling with questions that I, that now, I no longer have these problems. But at that time, I did.

Iain: I just wanted people to understand where you really were. You said again, [that] you fell into personal desire. You had to deal with what you call *the cancerous root of egoism* by exposing it bit-by-bit. How did you expose it bit-by-bit? The cancerous root of egoism.

John: Yes, that's a good phrase [laughs]. How did I deal with it? Well, how indeed. I'm not sure that *we* can deal with it because you see *we, I* am the ego, so it is the

ego trying to deal with the ego. It's the pot calling the kettle black. The blind leading the blind. We are saved by grace. Well, I meditated. At that time, I met a teacher, a young man and I looked into his eyes and I had that same experience of seeing the infinite beyond.

Iain: That you'd had with that woman.

John: Freedom, yes. And I followed him out to America, to San Francisco. I was that desperate. I knew that's what I wanted, I didn't want anything else. So, as it were, I jumped off the precipice to him and while I was in America after I had been with him a few days...I remember it was a big meeting, and he looked at me and he pointed out my pride, my arrogance and my egoism, which completely crushed me. I was exposed in this room of, I suppose, a couple of hundred people. I'd been called in the room and I felt within me a monstrous, almost like a worm and I didn't know what to do with it at all. I was absolutely terrified, and I fled. Where did I flee to? I fled into the wilderness. I got a car and I just drove into the desert. And I thought I was going mad at that time. I had such a sense of evil within me and I didn't know how to deal with it at all. I meditated but somehow even meditation didn't deal with it and fearing I was really going to lose my wits [mind/ability to think] I took a job as a cook in a funny little motel/gas station, I worked in the kitchen there, frying eggs and things...and it was in the Maharvi desert, which is just on the border of Arizona. Surrounded by desert-country. One day after work, I walked up the side of the valley, there was this little motel, this little spot at the side of the valley, I sat on a rock and I think I put my head in my hands and I think I just was finished then. And someone came and stood beside me. I didn't see anybody, I didn't hear anybody, no man was involved at all but I felt there was a presence beside me. I suppose it was Jesus. I never doubted it. It was nothing to do with the church, nothing to do with religion at all. And I didn't really notice any difference, the depression didn't end but I wrote a poem, that's right "depression didn't end but from then on I had a friend." I certainly didn't have any human friend at that time. And then a few more months passed and I ended this job with a pocket full of money, so once more I hired a car and had a wonderful time exploring the western states, the cowboy country and more

animals and more beloved prairie, then I came home and once again in this awful abyss of not knowing what to do.

Iain: I just want to...so, we have to finish...let's call this part one...so what the breakthrough was for you was the appearance of what you felt might have been, could be Jesus. It was about having a companion, a friend, a support, a guide...am I using the right words?

John: I think you are making too much of it. I wouldn't use any of those words, it was less defined. It was very undefined. Soon after I got back, I had some friends then that did healing and I remember they prayed over me and it was extraordinary, I felt like, I found myself screaming, I was thrown into the ground and something was expelled, some revolting thing came out of my mouth, it opened my mouth so wide that my mouth split but what came out? I never saw it. I suppose, one idea expelled by another. And just before that happened, I had gone into a job centre and I was invited to an open day and I was invited to go to Nottingham University to study Russian as a very mature student.

Iain: Okay, we're going to stop there because that's a great start for part two. So, thank you very much for doing part one. Thank you everyone for watching part one, here with John and we will see you again for part two.

0:00 – 0:44: When the phone rang, the gray-haired man asked the girl, if she would rather for any reason he didn't answer it. The girl heard him as if from a distance, and turned her face toward him. The gray-haired man asked her to hurry up, and she raised up on her right forearm just quickly enough so that the movement didn't quite look perfunctory. She cleared her hair back from her forehead with her left hand and said, "God. I don't know. I mean what do you think?" The gray-haired man said he didn't see that it made a helluva lot of difference one way or the other. He reached for the phone with his right hand. "Hello?" he said resonantly into the phone. The girl stayed propped up on her forearm and watched him.

0:44 – 0:53: A man's voice — stone dead, yet somehow rudely, almost obscenely quickened for the occasion — came through at the other end: "Lee? I wake you?"

0:53 – 0:59: The gray-haired man glanced briefly left, at the girl. "Who's that?" he asked. "Arthur?"

1:00 – 1:01: "Yeah — I wake you?"

1:01 – 1:03: "No, no. I'm in bed, reading. Anything wrong?"

1:04 – 1:12: "The reason I called, Lee, did you happen to notice when Joanie was leaving? Did you happen to notice if she left with the Ellenbogens, by any chance?"

1:12 – 1:16: "No, I didn't, Arthur," he said. "Didn't she leave with you?"

1:16 – 1:19: "No. Christ. You didn't see her leave at all, then?"

1:20 – 1:25: "Well, no, as a matter of fact, I didn't, Arthur. Why? What's up? Joanie lost?"

1:25 – 1:33: "Oh, Christ. Who knows? I don't know. You know her when she gets all tanked up and rarin' to go. I don't know. She may have just — "

1:33 – 1:36: "You call the Ellenbogens?" the gray-haired man asked.

1:37 – 1:50: "Yeah. They're not home yet. I don't know. Christ, I'm not even sure she left with them. I know one thing. I know one goddam thing. I'm through beating my brains out. I mean it. I really mean it this time. I'm through. Five years. Christ."

1:50 – 2:02: "All right, Arthur," the gray-haired man said. "In the first place, if I know the Ellenbogens, they probably all hopped in a cab and went down to the Village for a couple of hours. All three of 'em'll probably barge — "

2:02 – 2:14: "I have a feeling she went to work on some bastard in the kitchen. I just have a feeling. She always starts necking some bastard in the kitchen when she gets tanked up. I'm through. I swear to God I mean it this time. Five goddam-"

2:14 – 2:18: "Where are you now, Arthur?" the gray-haired man asked. "Home?"

2:19 – 2:20: "Yeah. Home."

2:20 – 2:28: "Look, Arthur. You want my advice?" he said. “Get in bed and relax. Is it going to do any good to sit around and stew?"

2:28 – 2:44: "Yeah, I know. I wouldn't even worry, for Chrissake, but you can't trust her! I swear to God. I swear to God you can't. You know what I do? I'm ashameda tell ya, very nearly goddam do every night? When I get home? You want to know?"

2:44 – 2:46: "Arthur, listen, this isn't — -"

2:47 – 2:59: "Wait a second — I'll tell ya, God damn it. I practically have to keep myself from opening every goddam closet door in the apartment — I swear to God. Every night I come home, I half expect to find a bunch of bastards hiding all over the place."

2:59 – 3:16: "All right. All right. Let's try to take it a little easy, Arthur," the gray-haired man said. He turned his head again toward the girl, perhaps to show her how forbearing, even stoic, his countenance was. But the girl missed seeing it. Her eyes looked up at him a second too late.

3:17 – 3:33: "In the first place," he said, into the phone, “You know what you do? You actually go out of your way to torture yourself. As a matter of fact, you actually inspire Joanie-" He broke off. "You're bloody lucky she's a wonderful kid. I mean it.”

3:34 – 3:45: “You know who I'm married to? I'm married to the greatest living undeveloped, undiscovered actress, novelist, psychoanalyst, and all-around goddam unappreciated celebrity-genius in New York. You didn't know that, didja?”

3:46 – 3:51: “For a helluvan intelligent guy, you're about as tactless as it's humanly possible to be."

3:51 – 3:55: “She doesn't respect me. She doesn't even love me, for God's sake.”

3:55 – 4:09: The gray-haired man listened another moment. “Now, Arthur. Listen. I say this in all sincerity. Willya get undressed and get in bed, like a good guy? And relax? Joanie'll probably be there in about two minutes.”

4:09 – 4:18: "Yeah. I hear you. Listen. I've kept you awake all night anyway. Could I come over to your place for a drink? Wouldja mind?"

4:18 – 4:25: The gray-haired man straightened his back and placed the flat of his hand on the top of his head, and said, "Now, do you mean?"

4:25 – 4:34: "Yeah. I mean if it's all right with you. I'll only stay a minute. I'd just like to sit down somewhere and — I don't know. Would it be all right?"

4:34 – 4:50: "Yeah, but the point is I don't think you should, Arthur," the gray-haired man said, lowering his hand from his head. "I mean you're more than welcome to come, but I honestly think you should just sit tight and relax till Joanie waltzes in."

4:50 – 4:53: "I don't know. I swear to God, I don't know."

4:53 – 4:58: "Look. Why don't you hop in bed now, and relax, and then later, if you feel like it, give me a ring."

4:58 – 4:59: "All right."

4:59 – 5:06: The gray-haired man continued for a moment to hold the phone to his ear, then lowered it into its cradle.

5:06 – 5:09: "What did he say?" the girl immediately asked him.

5:09 – 5:11: "He wanted to come over here for a drink."

5:11 – 5:15: "God! What'd you say?" said the girl.

5:15 – 5:18: "You heard me," the gray-haired man said, and looked at her.

5:18 – 5:24: "You are wonderful. Absolutely marvellous," the girl said, watching him.

5:24 – 5:29: "Well, it's a tough situation. I don't know how marvellous I was."

5:29 – 5:31: "You were. You were wonderful."

5:31 – 5:39: The gray-haired man looked at her. "Well, it's a very, very tough situation. The guy's obviously going through absolute — "

5:39 – 5:47: The phone suddenly rang. The gray-haired man said "Christ!" but picked it up before the second ring. "Hello?" he said into it.

5:47 – 5:49: "Lee? Were you asleep?"

5:49 – 5:50: "No."

5:50 – 5:54: "Listen, I just thought you'd want to know. Joanie just barged in."

5:54 – 5:55: "What?" said the gray-haired man.

5:56 – 6:26: "Yeah. She just barged in. About ten seconds after I spoke to you. I just thought I'd give you a ring while she's in the john. Listen, thanks a million, Lee. I mean it. Apparently Leona got stinking and then had a goddam crying jag, and Bob wanted Joanie to go out and grab a drink with them somewhere. Anyway, so she's home. What a rat race. Honest to God, I think it's this goddam New York. I mean — except you — who do we know in New York except a bunch of neurotics?

6:26 – 6:40: "Listen, Arthur," the gray-haired man interrupted, taking his hand away from his face, "I have a helluva headache all of a sudden. You mind if we cut this short? I'll talk to you in the morning — all right?" He listened for another moment, then hung up.

6:40 – 6:57: Again, the girl immediately spoke to him, but he didn't answer her. He picked a burning cigarette out of the ashtray and started to bring it to his mouth, but it slipped out of his fingers. The girl tried to help him retrieve it before anything was burned, but he told her to just sit still, for Chrissake, and she pulled back her hand.

Appendix C: Questionnaires

ADULT PARTICIPANT INFORMATION SHEET

Subject Code: _____ Birth date: _____ Sex:_____

Do you consider yourself: ☐ right-handed ☐ left-handed ☐ ambidextrous

LANGUAGE BACKGROUND

Is English the first language that you learned? ☐ yes ☐ no

If *No*, what language did you first learn?_____

If *No*, at what age did you first begin learning English?_____

In what context?_____

If *No,* in which language (English or your native language) are you more comfortable?_____

Are you fluent in any language other than English? ☐ yes (list language),_____ ☐ no

Are you regularly exposed to any language other than English? ☐ yes,_____ ☐ no

If *Yes*, in what context? _____

Are there are other languages not asked about above that you know? ☐ yes,_____ ☐ no

If *Yes*, please list and describe how you learned them. _____

_____

_____

What is your field of study/major? _____

NEUROLOGICAL HISTORY

Have you ever had brain surgery? ☐ yes ☐ no

Have you ever had, or do you currently have, any neurological disorders (e.g., seizures, schizophrenia)?

☐ yes ☐ no If *Yes*, please explain: _____ _____

Are there any known neurological problems in your family? ☐ yes ☐ no

If *Yes*, please explain: _____ __

Are you currently taking any medication(s) that may affect brain functioning (including but not limited to anti-depressants, anti-psychotics, anti-seizure)? ☐ yes,_____ ☐ no

Have you ever had, or do you currently have, any speech, hearing, learning, or psychiatric disorders?

☐ yes ☐ no If *Yes*, please explain: _____

VISION AND HEARING

Do you have normal or corrected-to-normal vision? ☐ yes ☐ no

Do you have normal hearing? ☐ yes ☐ no

CURRENT STATE

How many hours of sleep did you get last night? _____

How many hours of sleep do you typically get per night? _____

Do you feel like you got enough sleep last night to function normally both physically and mentally?

☐ yes ☐ no If no, please explain: _____ _____

Is there any *other* circumstance (not asked about above) that makes you feel like you are not at your mental best right now? ☐ yes ☐ no If yes, please comment: _____

Please rate your level of current fatigue on a 1-10 scale, where 1 is "so tired I can barely function today" and 10 is "I feel super rested, I've never felt better." (Circle 1-10)

(very tired) 1 2 3 4 5 6 7 8 9 10 (feel great)

Participant ID_____

How likely are you to doze off or fall asleep in the situations described below under normal circumstances?

Use the following scale to choose the most appropriate number for each situation:
0 = would never doze
1 = Slight chance of dozing
2 = Moderate chance of dozing
3 = High chance of dozing

Situation - Chance of dozing

Sitting and reading . . . . . _____
Watching TV . . . . . _____
Sitting, inactive in a public place (e.g. a theatre or a meeting) . . . . . _____
As a passenger in a car for an hour without a break . . . . _____
Lying down to rest in the afternoon when circumstances permit . . .. _____
Sitting and talking with someone . . . . . _____
Sitting quietly after a lunch without alcohol . . . . _____
In a car, while stopped for a few minutes in traffic . . . . _____

Please rate your current degree of sleepiness:

Pre-nap:

Degree of Sleepiness	**Scale Rating**
Feeling active, vital, alert, or wide awake	1
Functioning at high levels, but not at peak; able to concentrate	2
Awake, but relaxed; responsive but not fully alert	3
Somewhat foggy, let down	4
Foggy; losing interest in remaining awake; slowed down	5
Sleepy, woozy, fighting sleep; prefer to lie down	6
No longer fighting sleep, sleep onset soon; having dream-like thoughts	7
Asleep	X

Post-nap:

Degree of Sleepiness	**Scale Rating**
Feeling active, vital, alert, or wide awake	1
Functioning at high levels, but not at peak; able to concentrate	2
Awake, but relaxed; responsive but not fully alert	3
Somewhat foggy, let down	4

Sleepy, woozy, fighting sleep; prefer to lie down	6
No longer fighting sleep, sleep onset soon; having dream-like thoughts	7
Asleep	X

KAROLINSKA SLEEP LOG **Participant ID: _____**
Date:_____

1. At what time did you go to bed and turn the light off last night? _____PM or AM
2. At what time did you arise this morning? _____PM or AM
3. How long did you sleep? _____hours and _____minutes
4. How long did it take you to fall asleep? _____hours and _____minutes
5. How many awakenings did you have last night? _____
6. How many total minutes were you awake after falling asleep last night? _____minutes

(Don't include time in bed before falling asleep)

7. Did you have any caffeine this morning? yes no If yes, describe quantity: _____

Circle one per question only:

7. How did you sleep?

1	2	3	4	5
Very Poorly				Very Well

8. Did you feel refreshed after you arose this morning?

1	2	3	4	5
Not at all				Completely

9. Did you sleep soundly?

1	2	3	4	5
Very Restless				Very Soundly

10. Did you sleep throughout the time allotted for sleep?

1	2	3	4	5
Woke up much too early				Slept thru the night

11. How easy was it for you to wake up?

1	2	3	4	5
Very Easy				Very Difficult

12. How easy was it for you to fall asleep?

1	2	3	4	5
Very Easy				Very Difficult

13. How much did you dream last night?

1	2	3	4	5
None				Much

Post-Task Interview

1. Did you notice anything interesting or unusual about the stimuli?

2. Did you notice any kind of pattern, structure or systematic relationship between the different stimuli or the different types of stimuli? If yes, please elaborate.

KAROLINSKA SLEEP LOG
MODIFIED FOR AFTERNOON NAP

Participant ID: _____
Date:_____

1. How long did you nap for? _____hours and _____minutes
2. How long did it take you to fall asleep? _____hours and _____minutes
3. How many awakenings did you have during your nap? _____
4. How many total minutes were you awake after falling asleep? _____minutes

(Don't include time in bed before falling asleep)

Circle one per question only:

5. How did you sleep?

1	2	3	4	5
Very Poorly				Very Well

6. Did you feel refreshed after woke up?

1	2	3	4	5
Not at all				Completely

7. Did you sleep soundly?

1	2	3	4	5
Very Restless				Very Soundly

8. Did you sleep throughout the time allotted for your nap?

1	2	3	4	5
Woke up after a short time				Slept for 90 min or more

9. How easy was it for you to wake up?

1	2	3	4	5
Very Easy				Very Difficult

10. How easy was it for you to fall asleep?

1	2	3	4	5
Very Easy				Very Difficult

11. How much did you dream during your nap?

1	2	3	4	5
None				Much

Western

DEBRIEFING FORM

Project Title: Studies of sleep and language learning

Principal Investigator:
Dr. Laura Batterink
Department of Psychology, University of Western Ontario
Telephone: [redacted]
Email: [redacted]

Thank you for your participation in this study. The purpose of this study was to examine how sleep contributes to the consolidation and retention of new linguistic information. Sleep has been shown to play an important role in memory consolidation, and also in the generalization and abstraction of hidden patterns or overarching rules in the environment. Our main hypothesis is that sleep contributes to the consolidation and strengthening of many different aspects of language, such as learning of sound patterns and vocabulary acquisition. We hypothesize that sleep may play an especially important role in generalization aspects of language learning, such as grammatical rule generalization. We are also interested in testing which—if any—aspects of language processing can occur during sleep, by assessing how the brain responds to different types of linguistic stimuli presented at non-awakening thresholds during sleep.

By having you complete different tasks, we were able to assess what you learned, consolidated, and retained about the language-related stimuli that you were presented with. We also recorded your brain activity to monitor how your brain responds to different types of stimuli, and how these brain responses relate to overall learning success. By recording your brain activity while you were given the opportunity to nap, we were also able to see how long you slept, and what stages of sleep you were in. Your data will help us understand how different sleep mechanisms contributes to memory consolidation in a language-learning context. Your participation and responses are much appreciated.

As part of this experiment, you may have been in an experimental condition in which auditory stimuli were presented at low volumes while you were asleep. We did not inform you about this possibility prior to your nap, because expecting that auditory sounds may be presented can make it more difficult to fall asleep, and may also lead to differences in processing the stimuli during sleep, potentially leading to greater likelihood of arousal. If this makes you uncomfortable you are free to withdraw your data from our sample.

If you would like to learn more, here are some interesting references on the role of sleep in memory consolidation and language:

- Schreiner, T., & Rasch, B. (2017). The beneficial role of memory reactivation for language learning during sleep: A review. *Brain and Language*, *167*, 94–105.

- Diekelmann, S., & Born, J. (2010). The memory function of sleep. *Nature Reviews Neuroscience,* 11, 114–126.

- Walker, M. P., & Stickgold, R. (2010). Overnight alchemy: Sleep-dependent memory evolution. *Nature Reviews Neuroscience*, 11, 218–219.

- O'Neill, J., Pleydell-Bouverie, B., Dupret, D., & Csicsvari, J. (2010). Play it again: Reactivation of waking experience and memory. *Trends in Neurosciences*, 33, 220–229.

Your results are confidential to the experimenters and all results are published anonymously as group data. If you have any further questions about this study please contact Sarah Hollywood ([redacted]) or Dr. Laura Batterink (email: [redacted] office: [redacted], phone: [redacted]).

If you have questions about your rights as a research participant, please contact the Director of the Office of Research Ethics at [redacted]

Appendix D: Implicit Memory Task Wordlist

Practice Trial	
Animal	Word
Aardvark	Adventure
Baboon	Castle
Bison	Charm
Crocodile	Explore
Mouse	Grow
Pigeon	Initiative
Salamander	Party
Wasp	Quick

Task				
Animal	Directly-Stated	Related	Control Story	Unrelated
Alligator	Advice	Affair	Attack	Camaraderie
Ant	Answer	Betray	Avenger	Closeness
Antelope	Awake	Conflict	Barbeque	Contentment
Ape	Bed	Deception	Campus	Engaging
Armadillo	Brain	Domestic	Cape	Extroverted
Badger	Burn	Embarrass	Costume	Foreign
Bear	Cab	Flirt	Cream	Innocent
Beaver	Call	Friend	Dean	Legitimate

Beetle	Cigarette	Frustrated	Elusive	Peaceful
Buffalo	Closet	Guilt	Embellishment	Pride
Butterfly	Countenance	Hesitant	Flannel	Public
Cat	Drink	Honorable	Journalism	Satisfy
Cheetah	Forearm	Husband	Latin	Secure
Chicken	Gray	Jealous	Letter	Silence
Cow	Hair	Secret	Library	Stability
Crab	Hand	Suspicious	Mask	Support
Crow	Headache	Trust	Newspaper	Uplifted
Deer	Home	Uncertain	Nuance	Vacation
Dog	Late	Vulnerable	Pastry	Wholesome
Dolphin	Lost	Worry	Pie	
Donkey	Neurotic		Prize	
Dove	Night		Question	
Duck	Phone		Reporter	
Eagle	Read		Rumour	
Eel	Relax		Scene	
Elk	Situation		Sensation	
Emu	Slip		Shoulder	
Falcon	Stew		Spirit	

Ferret	Stoic		Story	
Fish	Tough		Student	
Flamingo				
Frog				
Gazelle				
Gerbil				
Goat				
Goldfish				
Gorilla				
Grasshopper				
Hamster				
Hawk				
Hedgehog				
Hippo				
Hornet				
Horse				
Iguana				
Jaguar				
Jellyfish				
Junebug				
Kangaroo				
Koala				
Leopard				
Lion				

Lizard				
Llama				
Lobster				
Lynx				
Minnow				
Mongoose				
Moose				
Mosquito				
Moth				
Mule				
Newt				
Nightingale				
Octopus				
Opossum				
Ostrich				
Otter				
Owl				
Panda				
Peacock				
Penguin				
Pig				
Porcupine				
Quail				
Rabbit				

Rat				
Raven				
Reindeer				
Rhinoceros				
Salmon				
Sheep				
Skunk				
Snail				
Squirrel				
Swan				
Termite				
Toad				
Tuna				
Turkey				
Turtle				
Vole				
Vulture				
Walrus				
Weasel				
Wolf				
Woodpecker				
Worm				
Yak				
Zebra				

Appendix E: Explicit Memory Task

1. Please summarize the story using as many details as you can remember.

2. How much did you like this story?

Like a great deal	Like somewhat	Neither like nor dislike	Dislike somewhat	Dislike a great deal

3. Did you feel engaged with this story?

Was engaged with the entire story	Was engaged more than half the time	Was engaged half the time	Was engaged less than half the time	Was not engaged at all

4. Have you ever heard this story before?

Yes	Maybe	No

5. Was the narrator a male or female?

Male	Female	I don't know

6. What were the names of the two men in the story?

Lee and Arthur	Louis and Alan	I don't know

7. Why did Arthur call Lee?

Because Joanie didn't come home, and he wanted to know if Lee noticed when she left	Because Joanie didn't come home, and he wanted to know if she was at Lee's house	I don't know

8. What did Arthur worry Joanie was doing?

He thought Joanie was cheating on him	He thought Joanie was drunk	I don't know

9. What did Lee say Joanie was probably doing?

He said that Joanie probably went with the Ellenbogens to another place	He said that Joanie probably didn't find a cab and waited for a ride back home	I don't know

10. What did Lee advise Arthur to do?

To get in bed and relax	To keep calling the Ellenbogens	I don't know

11. What did Lee think was Arthur's problem?

That he was torturing himself and being paranoid	That he was drinking too much and losing his judgment	I don't know

12. What did Arthur ask Lee towards the end of their FIRST conversation?

If he could come over to Lee's place	If the two of them could go out for a drink	I don't know

13. What did Lee tell Arthur to do?

That it was better for Arthur to be there, when Joanie came back home	To go out looking for Joanie	I don't know

14. What did the girl ask after Lee hung up?

"What did he say?"	"What's wrong with him?"	I don't know

15. What did Arthur tell Lee in the SECOND phone call?

That Joanie just came home	That he wanted to come over	I don't know

16. What did Arthur say about why Joanie had come back home so late?

She went to drink to help her friends	She was with another man	I don't know

17. How does Arthur end the SECOND phone call with Lee?

Arthur tells Lee he wants to go to sleep	Arthur tells Lee he has a headache

18. What does Arthur do after he hangs the phone at the end of the story?

Reaches for a cigarette	Goes to sleep

Curriculum Vitae

Name:	Sarah Hollywood
Post-secondary Education and Degrees:	University of Guelph Guelph, Ontario, Canada 2012-2018 B.A. The University of Western Ontario London, Ontario, Canada 2018-2020 M.Sc.
Honours and Awards:	Ontario Graduate Scholarship 2018-2019 Natural Sciences and Engineering Research Council (NSERC) CGS-M 2019-2020
Related Work Experience	Teaching Assistant The University of Western Ontario 2018-2020
Conferences and Workshops	Visceral Mind Bangor University, Wales 2019 Association for the Scientific Study of Consciousness (ASSC) The University of Western Ontario 2019 EEG Workshop Brock University 2019