The Role of Sleep in the Consolidation of Autobiographical Memories

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Abstract

There is compelling support in literature that there is a relationship between sleep and memory processing. Research shows firstly that sleep promotes the consolidation of memory and secondly it significantly protects memories from degradation. Slow wave sleep (SWS) and rapid eye movement (REM) sleep are implicated in the consolidation of memories through active systems consolidation and synaptic consolidation. However, what remains uncertain is an assessment of the types of memory that benefit from consolidation during sleep. Autobiographical memory (AM) is one type of memory that is under-represented in studies investigating sleep and memory. Using a quasi-experimental cross sectional design, this study aimed to assess the role of sleep in the consolidation of AM. The Autobiographical Memory Test (AMT), 1 night of polysomnographic sleep data and a period of being awake was used to investigate this association. Participants were recruited, screened and subsequently allocated to two conditions of day and night which entailed an 8 hour wake period and an 8 hour sleep period. Although several dimensions related to content and emotion were measured using the AMT, only one variable, verb retention per word , showed significant between-group differences, indicating that sleep rather than wake promotes AM. Sleep latency showed trend level significance for predicting verb retention indicating that there is preliminary evidence that sleep quality may predict AM consolidation. The preliminary findings suggest that memory processing benefits from sleep based consolidation process. However this relationship still needs to be investigated further in future research.

Key words: Autobiographical Memory Test, Autobiographical memory, sleep, wake, polysomnography, memory consolidation

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Sleep has been posited to provide individuals with many benefits that cannot be achieved during the waking state. For example, many cognitive processes profit from an 'off-line' state with a cessation of new stimuli or input (Romcy-Pereira et al., 2009). Regarding these benefits, a clear relationship has been described between sleep and memory processing. Sleep is known to promote the consolidation of memory and to significantly protect memories from degradation (Diekelmann & Born, 2010; Walker, 2009). The central role of sleep in memory processing is well described in the literature. However, there is still some clarification required regarding the types of memory that benefit from consolidation during sleep (Wagner & Born, 2008). One such specific memory system that is under-represented in studies of sleep and memory is autobiographical memory (AM). AM refers to memory for an event that actually occurred in a person's life at a specific place and time (Rubin, 1998). AM further encompasses a recollection of past experienced events that are personal in nature (Murre et al., 2014). AM is an important aspect of memory as it plays a critical function in personality development and aids in the sustenance of a coherent self over time (Holland & Kensinger, 2010).

Healthy sleep in individuals

As a counterpart for wakefulness, sleep has been noted to perform many vital functions that are either cognitive or related to emotional functioning (Walker, 2009). The sleep state can be distinguished by two distinct features that include the loss of behavioral control and consciousness (Diekelmann & Born, 2010). In a single sleep cycle, individuals first go through four stages of non-rapid eye movement (NREM) sleep, followed by rapid eye movement (REM) sleep. The progression of NREM to REM sleep forms a cycle which repeats itself every 90 minutes (Walker, 2009). Stage three and four NREM (collectively known as slow-wave sleep (SWS) dominates the first part of the night and REM sleep dominates the second half of the night (Walker, 2009).

Different memory systems: Declarative, episodic and autobiographical memory

Different kinds of memory systems are relevant to our understanding of the relationship between sleep and memory. Past studies indicate that both procedural and declarative memories are strengthened by sleep (Diekelmann & Born, 2010) Procedural memories pertain to recollections for skills that are a result of repeated practice such as driving a car or playing an

instrument (Diekelmann & Born, 2010). Here we focus on declarative memory, reviews of procedural memory functioning are found elsewhere (Backhaus & Junghanns, 2006).

Declarative memory is a long-term flexible memory system that pertains to conscious recollections that are acquired regularly through facts or episodes such as learning a word or vocabulary list or remembering events that have a temporal component (Brancack, Platt & Riedel, 2009; Diekelmann & Born, 2010). This type of memory is typically explicitly encoded and noted to engage regions such as the hippocampus, medial temporal lobe structures and neocortical regions for long term storage (Diekelmann & Born, 2010).

Declarative memories are made up of two types of memories namely, episodic memories and semantic memories. Episodic memories relate mainly to events that are specific and contain information that is detailed and perceptual in nature. On the other hand semantic memories comprise of memories that are general such as information on facts (Parkin, 1999; Soderlund et al, 2014). AM is therefore a form of episodic memory because it has a content aspect and a temporal aspect. In contrast semantic memories have a content aspect but lack a temporal aspect.

Considering AM is a type of declarative episodic memory (Brancack, Platt & Riedel, 2009), such memories are therefore also explicit and thus dependent on the hippocampus as evidenced through imaging studies (Diekelmann & Born, 2010).

AM also has emotional content or emotional descriptors. This means it constitutes knowledge about oneself which encompasses an integration of knowledge about one's emotions, personal goals and personal meanings (Holland & Kensinger, 2010). Therefore to a certain extent, AM represents a subjective reconstruction of one's personal life which is rich in meaningful life experiences (Piefke et al; 2003). Often the recollection of autobiographical memories evokes past emotions and entails the actual re-experiencing of some events; this is usually accompanied by a significant degree of feelings of vividness, sensory and perceptual detail (Holland & Kensinger, 2010).

Autobiographical memories are important to individuals because they contribute to individual uniqueness (Brown et al., 2013). They also contribute to an individual sense of self both presently and in the envisioned future self; they are vital in equipping individuals to apply themselves in problem solving and further inform individual behavior in social situations (Brown et al., 2013).

Sleep stages and its contribution to memory

Sleep has been noted to serve an important memory function, that of consolidation of both declarative and procedural memories that were encoded or retrieved in the awake state (Diekelmann & Born, 2010). The process of consolidation involves strengthening memories that were encoded whilst awake so that they are represented in neutral networks in a stable manner (Diekelmann & Born, 2010). This process of consolidation is important as newly encoded memories are susceptible to deterioration (Wagner & Born, 2007).

SWS has been widely cited as critical to memory consolidation (Walker, 2009). SWS is characterized by slow oscillations generated by frontal regions of the brain. These result in a synchronous pattern of neuronal firing between the neocortex and the hippocampus meaning that information encoded by the hippocampus and stored there temporarily is disseminated to other networks of knowledge stored in the neocortex (Diekelmann & Born, 2010). These networks of knowledge are thus updated with new information ensuring that the hippocampus is revitalized to encode new input the next day (Diekelmann & Born, 2010). This process is termed systems consolidation.

Similarly, REM sleep also contributes to memory consolidation. This stage of sleep is characterized by waveforms that reflect higher frequency synchronous activity. This activity is characterized by phasic waveforms originating in regions such as the pons, lateral geniculate nuclei of the thalamus and the occipital cortex (Walker, 2009). REM sleep contributes to memory consolidation through synaptic consolidation which involves the strengthening of representations at the synaptic level (Diekelmann & Born, 2010). This is achieved through expression of immediately early genes (IEG) which results in long-term potentiation (LTP) (Diekelmann & Born, 2010). LTP occurs during sleep in regions that are essential for memory storage and ensures that synaptic connections last longer. This stage of sleep thus serves to strengthen the memory traces that were encoded.

SWS has been noted to be essential for laying the foundation for synaptic consolidation (Walker, 2009). REM sleep promotes synaptic consolidation through the stabilizing and strengthening of synapses that were reorganizing during SWS (Diekelmann & Born, 2010). Therefore the progression of SWS to REM is important for memory consolidation.

Sleep and autobiographical memory

Although many studies have been conducted on sleep and its role on memory consolidation, the primary focus of these studies has been on neutral declarative memory. When assessing declarative memory consolidation, participants are usually required to learn a list of associated word pairs or stories; after which free recall is assessed (Diekelmann, Wilhelm, & Born; 2009). The neutral nature of the methods used to investigate declarative memories in these studies is in contrast with AM whose distinctive nature is of being personal as well as time and space specific (Magnussen et al., 2007).

There have however been few studies that have focused on sleep and its role on AM consolidation as such there is very little evidence regarding how sleep may benefit AM consolidation. The few studies that have investigated this benefit must be interpreted with some caution. For example Murre, Kristo & Janssen, 2014, were interested in investigating the impact of the interaction between sleep quality and sleep length on recalling autobiographical memories. Their design investigated this over a specific range namely 2 to 46 days at most. They hypothesized that participants who experienced good sleep over a longer period of time were more likely to have better AM. Their results concluded that poor quality of sleep contributed to worse AM when a memory is to be retained over a longer number of days (Murre et al., 2014). Their analysis only reported a small effect of sleep quality on AM. More concerning however, are some methodological short-comings of this study. The study was internet based and as such relied on participants to report on their sleeping habits. It also lacked objective measures of sleep and thus the interpretation of sleep results relied on participants subjective reports on their sleep.

An examination of other literature reveals that AM is reliant on the hippocampus. Sleep studies have further revealed that the hippocampus is active during consolidation in sleep (Diekelmann & Born, 2010; Walker, 2009). It is therefore reasonable to consider that AM is also strengthened by sleep. Thus, the expectation is that describing the relationship between AM and sleep will elaborate our understanding of how sleep benefits memory processing systems.

Research Aim and Hypotheses

The study aimed to investigate whether AM is consolidated during sleep, rather than waking.

We hypothesized that (1) Sleep, rather than waking improves memory consolidation, (2) Sleep quality serves to predict the level of AM consolidation that occurs

Methods

Design and setting

To investigate whether AM is preferentially consolidated during sleep rather than wake we followed a quasi-experimental cross-sectional design for our study. The major predictor variable was group status with participants assigned to either the day (wake) or night (sleep) group. The outcome variables are measures of sleep quality and autobiographical memory test (AMT) performance. The study procedures took place at the University of Cape (UCT) Sleep Sciences laboratory.

This study had two independent groups; one experienced the day condition and the other the night condition. The decision to utilize a design encompassing two independent groups rather than a repeated measures design, which would be better suited to investigate the stated hypotheses, is motivated by the challenges in adapting AM testing for a repeated measures design. The instrument that is available to measure AM, described in full below, has no parallel form and comprises of 15 items not suited to adaptation across two time periods. The use of two independent groups will ensure that the measure of AM performance utilizes a reliable instrument to investigate this type of memory.

Participants

We recruited participants using convenience sampling for our study. The initial recruitment was done through the UCT's Student Research Participation Programme (SRPP) which recruits Psychology undergraduate students to participate in research that is being conducted in the Department of Psychology. In conjunction with the SRPP, fellow sleep researchers who had a surplus of participant interest referred interested parties to the study for screening. We thereafter assigned eligible participants to the day condition or the night.

This study sample comprised of 23 participants between the ages of 18-24 made up of 5 males and 18 females. Participants were assigned to the day condition (n = 10) or the night condition (n = 13).

The power calculation for this study revealed that 36 participants were required in order for the study to have sufficient power. This calculation utilised a Cohen's d = 1.15 which is equivalent to eta squared of 0.25 (this effect size has been reported in previous sleep studies conducted at UCT Psychology Department). However, in the context of this research, recruiting

a sample of 36 participants presents with some practical challenges because of the demanding nature of sleep studies. The scope of the current research combined with the demands of conducting sleep research only allowed us to recruit 23 participants.

Considering our sample size is likely to be too small to evidence significant between-group differences the current study represents a pilot study to help indicate whether a full study of the benefits of sleep for AM would be warranted.

Eligibility criteria. Participants were eligible if they:

1. Fell between the ages of 18 – 24. This is because sleep cycles differ across different age groups such as between children, young adults, middle aged and the elderly. This means that choosing a sample within a fairly narrow age range is important to ensure that observed between-group differences are those related to study manipulations and not age-related sleep changes. Furthermore, aging is associated with mild memory decline (McEwan, 1999). The narrow age range eliminated the possibility of mild memory decline impairing performance in memory tasks or potentially favoring a group with younger participants.
2. Did not present with any psychiatric disorders as having a psychiatric diagnosis is associated with disrupted sleep patterns. Individuals that are diagnosed with psychiatric disorders are noted to report the most number of complaints in sleeping patterns (Benca, 1996). Depressed individuals, for example, are noted to have short, shallow fragmented sleep with redistributions of sleep stages (Gillin et al, 1981).
3. Did not utilize sedative or psychotropic medications as sleep assisting medication alters natural sleep patterns (see Goldsmith & Casola, 2006).
4. Do not smoke as smoking can alter sleep architecture (Conway et al, 2008; Zhang, 2006). Individuals who smoke are noted to experience longer stage 1 sleep and shorter SWS. Subjective sleep measures also confirm that smokers are reported to complain about difficulties in maintaining sleep (Conway et al, 2008).
5. Did not have any neurological conditions such as traumatic brain injury or epilepsy as these conditions may influence the findings of the study. For example, in a review of studies that investigated mild traumatic brain injury and sleep a

decrease in sleep efficiency and an increase in the length and number of awakenings after sleep was noted (Orff, Ayalon & Drummon, 2009).

Measures

Instruments for screening. The *Mini International Neuropsychiatric Interview* Version 6.0 (MINI 6.0; Appendix A) is a brief structured interview that assesses for any Axis I - psychiatric disorders that are found in the DSM-IV. This test has been shown to be highly valid and reliable using Cohen's alpha (Sheehan, 1998). This screening tool was used to exclude participants with Axis I psychiatric disorders.

The *Beck Depression Inventory – Second Edition (BDI II*; Appendix B*)* is a standardized self-report measure for depression in adults. This test contains 21 groups of statements that assess participants' feelings over the past two weeks. This test assesses an individual's level of depression or severity of depression (Dozois, Dobson, & Ahnberg, 1998). This test is noted to be highly valid and reliable and has been used successfully in sleep studies in South Africa. Participants with a score of 14 or greater were not considered for participation in the study.

The *Wechsler Abbreviated Scale of Intelligence* (WASI) is a screen for IQ. Four subtests combine to provide a reliable estimate of IQ (Laher & Cockcroft, 2013). This instrument will be used to evaluate participants' cognitive functioning to ensure that no significant between-group differences in cognitive ability impact the results. We used 85 as a cut-off score.

The *Pittsburgh Sleep Quality Index* (PSQI; Appendix C) is a self-rated questionnaire which assesses the level of sleep quality and sleep disturbance that individuals may experience over a one month period (Buysse, Reynolds, Monk, Berman & Kupfer, 1988). This questionnaire contains 15 items, 9 of which use a Likert scale to score subjective sleep patterns (Buysse et al., 1988).The test has been noted to be highly valid and reliable with an internal validity and was used to determine whether participants are healthy sleepers. In order for participants to be classified as good sleepers they need to obtain a score of less than or equal to 5 (Buysse et al., 1988).

Experimental instruments. The *Autobiographical Memory Test* (AMT; Appendix D) is the only widely available reliable test of autobiographical memory. The test contains 15 cues words which are made up by 5 positively valenced words, 5 negatively valenced words and 5 neutral words. This version of the AMT has been adapted by Williams & Broadbent (1986). The

test responses to each word were scored across five categories namely, *specific*, *extended, categoric*, *semantic association,* or *omission.*

The *Karolinska Sleepiness Scale* (KSS; Appendix E) is used to evaluate subjective sleepiness. This is a 9 point scale that assesses for participants level of alertness (Reyner & Horne, 1999). This test is used in order to control for tiredness effects as we will be seeing each group of participants at different parts of the day. This is important as tiredness can impact on participants' level of performance in the AMT. On this scale 1= Extremely alert and 9= Very sleepy, great effort to keep awake, fighting sleep.

The *Pittsburgh Sleep Diary (Appendix H)* is a diary instrument that is used to quantify subjective measures of sleep and waking behaviors. This instrument comprises of two separate components namely a bedtime component and a wake time component. The bedtime component involves a subjective report of the night preceding the sleep and the wake time component involves a report on the sleep period that has just been completed (Monk et al., 1993). This instrument was utilized in order to briefly log the activities that the day condition participants were involved in.

Sleep laboratory equipment. Sleep adapted EEG, also termed polysomnography (PSG) was used to measure sleep objectively. The PSG comprises of several component parts: EEG electrodes measure brain activity; the electrocardiograph (ECG) electrodes measure heart rate while electrooculograph (EOG) electrodes monitor eye movements. Lastly, the electromyograph (EMG) electrodes are used to measure muscle tone. All these measurements are necessary to objectively score sleep.

We recorded sleep measures using a 16-channel Nihon Kohden NeuroFax EEG9000. We used a bipolar referential montage, including the following bipolar derivations: F3-A2, C3-A2, P3-A2 and F4-A1, C4-A1, P4-A1. We placed electrodes according to the international 10-20 placement system. Standardized filters for recording sleep were employed for the EEG and EOG (0.5-35 Hz), EMG (10-70 Hz) and ECG (1-70 Hz) leads to ensure signal integrity in each of the channels.

Procedure

Participants were screened to ensure that they were eligible for the study using the screening measures outlined previously. Figure 1 below provides a diagrammatic explanation of

the procedure for this study. The screening was done in a private room in the Department of Psychology (P D Hahn Building). We obtained written informed consent (Appendix F) from the participants prior to screening and ensured that participants understood the content of this document. Eligible participants were assigned to the day or night group and then notified about their eligibility.

Once participants arrived for either the day (the standard time was 9.00am) or night condition (which was 2 hours before their usual bedtime) we first administered the KSS, to control for tiredness effects, and then the AMT. We termed this administration of the KSS and AMT the immediate recall (IR) session. During AMT (IR) administration, we gave participants three practice words and thereafter, participants were presented with 15 cue cards with words from the AMT. The 15 words were ordered so that the words followed a positive, negative and neutral sequence until all the words were administered.

Once the AMT was complete during the day condition participants were asked not to have any caffeine in any form or engage in any form of sleep so that they experience 8 hours of waking. The participants were also given the Pittsburgh Sleep Diary (Appendix H) so that they could record times where they may have engaged in certain activities during the 8 hour wake period (e.g. noting the time they had lunch). During the night condition, after participants completed the AMT (IR), they were prepared and attached to the PSG and thereafter experienced 8 hours of sleep.

After both the day and night groups completed either 8 hours of waking or 8 hours of sleep respectively, participants then completed another trial of the KSS and the free recall of the AMT. This administrating of the KSS and AMT was termed the delayed recall (DR) session. During the free recall (DR), participants were asked to remember their specific memories related to the cue words they had seen in the first session. However no cues were provided with this administration.

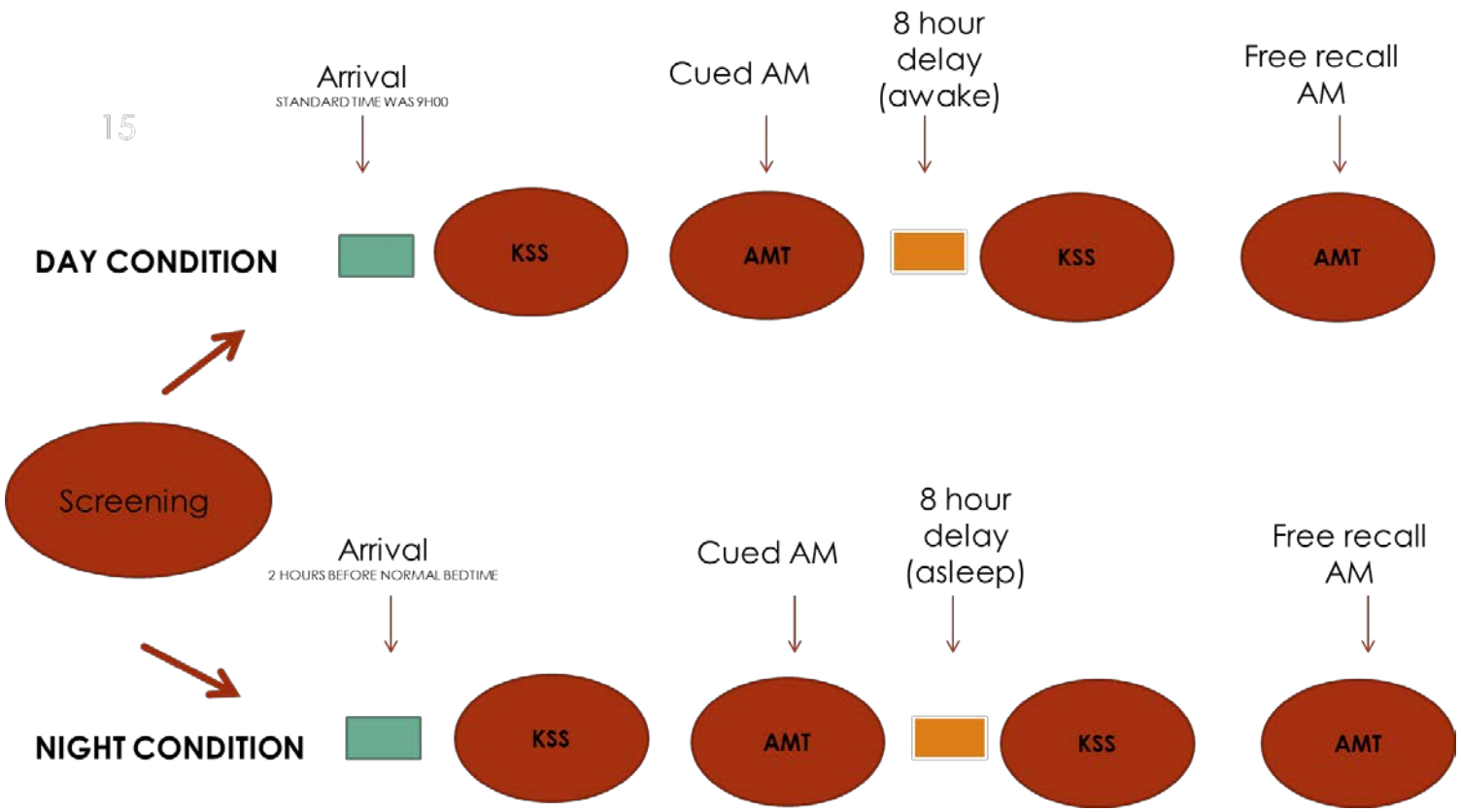

Figure 1: Diagram portraying procedure of study

Data Management and Statistical analysis

Scoring and deriving variables. The initial step in deriving outcome variables for memory consolidation involved scoring participant's responses to each item of the AMT. These were coded as either *specific*, *extended*, *categoric*, *semantic association*, or *omission*, using these criteria:

1. Specific: a memory specific to 1 day or less.
2. Extended: a memory that lasted longer than 1 day.
3. Categoric: a memory that referred to a type of event (e.g., 'every time I drive my car').
4. Semantic association: a memory that provided a definition of the cue word, rather than a memory (e.g., 'Tender is when you are soft or kind-hearted').

Omission: no memory could be recalled within 60 seconds. We excluded AM data that was scored as being *sematic*, *categoric* or *omission* as this indicates that participants have failed to retrieve an autobiographic memory.

Thereafter, we assessed the word count, nouns, verbs and emotionality of autobiographical memories using the Linguistic Inquiry and Word Count program (LIWC) (Pennebaker, Chung, Ireland, Gonzales, & Booth; 2007). LIWC is a text analysis software program that is used to analyse transcribed verbal text that is stored in Microsoft Word or other similar word processing software files (Pennebaker et al., 2007). The transcribed AMT responses were run through this software in order to determine the number of words and the percentage of verbs, nouns and emotional words used by participants for each of the 15 AMT words during the IR and DR session A retention score (DR/IR) was thereafter calculated for the individual words in order to derive a measure of how much participants were able to recall. The decision to utilize a retention score was so that we could determine how much information was retained over a delay of either wake or sleep period. We used the retention score to evaluate the level of consolidation after a delay while also taking into account the IR responses.

The overall AMT data was then grouped into broad to more specific test score categories. The categories were total score, affect score and individual words categories. Figure 2 below provides a diagrammatic breakdown of the categories. The total scores category and the affect category also included a sublevel that we termed the total scores "per word" category. The "per

word" category only included the retention score for AMT words that were recalled in the DR session. For example, if a participant had 15 AM responses in the IR session and 9 AM responses in the DR session, the total scores category would include the all this data. The "per word" category however would include 9 IR scores and 9 DR scores. This "per word" category more accurately compares information in the DR with what was remembered in the IR, as it does not include words that were not recalled in the DR.

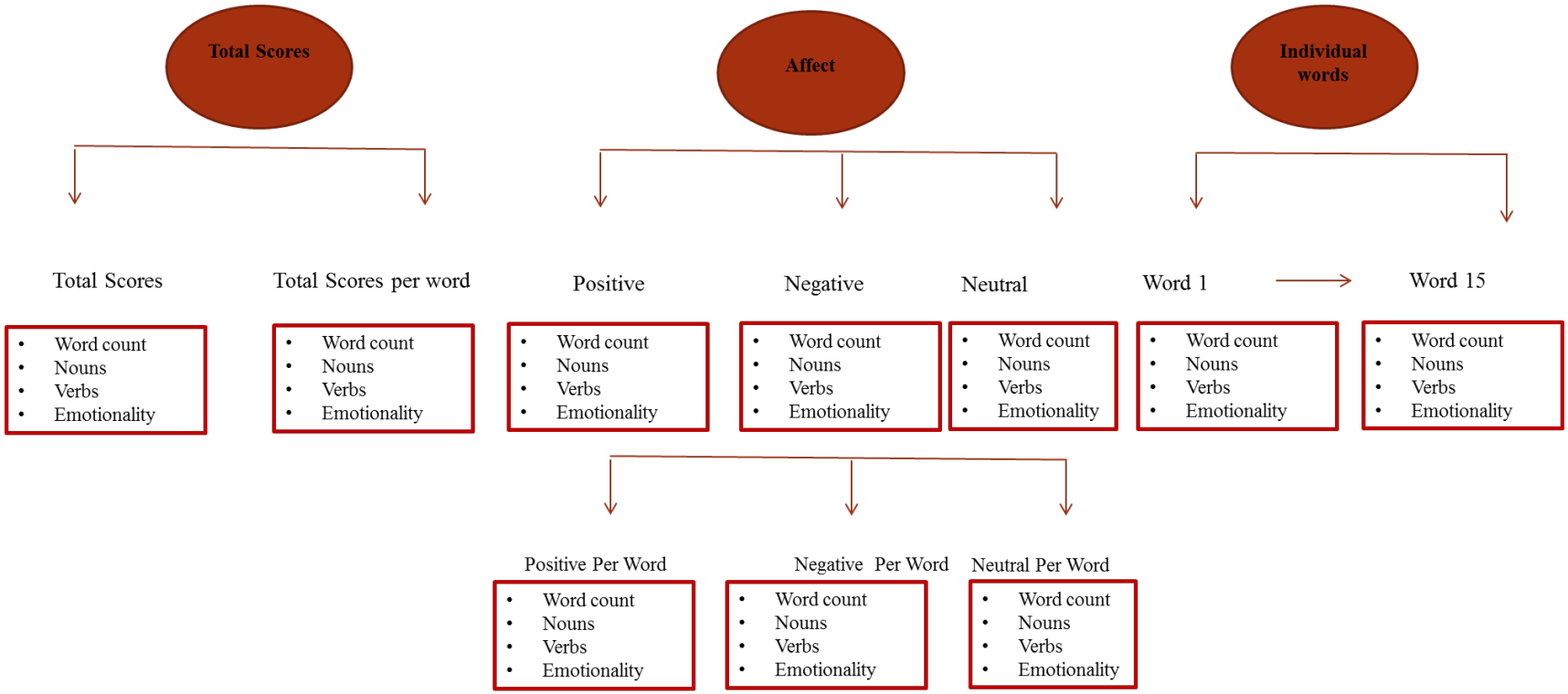

Figure 2: Diagram displaying data categories

We used the sleep data we collected from the PSG readings to derive the following measures: sleep latency (minutes taken for sleep onset to occur), number of awakenings (a period of waking after sleep onset that is more than 1.5 minutes in duration), WASO (minutes spent awake after sleep onset), sleep efficiency (percentage of time spent asleep during an 8-hour span), NREM 1, NREM2 and NREM 3 percentages (percentage of time spent in these NREM stages of sleep) and REM percentage (percentage of time spent in REM sleep).

The Statistical Package for the Social Sciences (SPSS) database was used to assist in the analysis of the data.

Testing hypothesis 1 between group comparison of AM variables. We used t-tests to test hypothesis 1. T-tests investigate the difference between means in our context independent sample *t-tests* were used. The use of multiple t-tests requires a Bonferroni correction and this was calculated for each of the 3 categories. The Bonferroni corrected significance was calculated by dividing the conventional alpha level by the number of t-tests that were conducted ($\alpha = .05$). Therefore the Bonferroni corrected significance was $0.05/8 = p < 0.006$ for the total scores category, $0.05/24 = p < 0.002$ for the affect category and $0.05/60 = p < 0.0008$ for the individual words category.

Testing hypothesis 2 - Predicting AM performance using sleep variables. We began testing this hypothesis by running a correlation analysis between the sleep variables and AMT outcome variables for which significant between group differences were detected. We subsequently ran a general linear model (GLM) to evaluate whether specific sleep variables can predict AMT performance for the significant between group AMT variables

Ethical considerations

Consent, voluntary participation and confidentiality. This study was approved by the Ethics Committee of the University of Cape Town to commence. Written informed consent from our participants was sought (Appendix B). To ensure confidentiality participants were assured of anonymity and, that research records and information collected would be kept in a secure place where only a few designated people can access it.

Results

Sample Characteristics

We screened 60 participants for eligibility. Of these participants 37 were excluded leaving a final sample size of 23. Reasons for exclusion included poor reported sleep, the presence of psychiatric conditions or use of psychotropic medication and IQ scores that were below the cut-off score. Of the final sample 13 completed the night condition and 10 completed the day condition. From the night condition, 3 participants did not have PSG data due to experimental error. Regarding the entire sample, the mean age was 20.78 years (*SD* = 1.48, range = 19 – 24), the mean PSQI score was 3.3 (*SD* = 1.49) the mean BDI II score was 5.30 (*SD* = 3.15) and the mean WASI IQ score was 104.70 (*SD* = 9.11, range = 88.0 – 124).Table 1 shows the group characteristics across age, gender, PSQI, BDI II scores and IQ scores. Regarding gender the sample had a higher proportion of females, (*n* = 17, 74%); males were fewer (*n* = 6, 26%). However, the chi-square reveals that there are no between group differences that can be attributed to gender. The groups were well matched for PSQI, BDI-II scores, gender and IQ. However, an analysis of age, showed a statistically significant result indicating that Wake group was older than the Sleep group. However, this significance is not meaningful as the means of both groups are similar and the standard deviations do not deviate largely from the mean. The small difference in age between the wake and the sleep group is unlikely to impact on sleep architecture and AMT performance. Age will therefore not be used as a covariate in subsequent analyses.

We ran a repeated measures ANOVA to evaluate whether time of day effects that could impact on the level of alertness between the groups. There were no between group differences with respect to alertness or interaction effects between time and group status indicating that levels of alertness did not differ between the sleep or wake group. However, time had a significant effect indicating that both groups were more tired in the DR session, $F(1,21)= 5.63$, $p = .027$. The mean alertness for the DR session was 4.78 (*SD* = 2.26), while the mean alertness for the IR session was 3.61 (*SD* = 1.47). Although the mean alertness for both groups in the DR was higher, alertness levels were not below average.

Table 1

Sample Demographic, IQ, Psychiatric and Alertness Characteristics (N=23)

	Group				
	Sleep (n = 13)	Wake (n = 10)	F/t /X^2	p	ESE
Age	20.15 (1.48)	21.60 (1.35)	- 2.62	.008	1.02
Sex			0.14	.708	
Male	3	3			
Female	10	7			
PSQI	3.23 (1.59)	3.400 (1.43)	- 0.26	.397	0.11
BDI II	5.30 (3.45)	5.30 (2.91)	- 0.01	.498	0.00
WASI	104.30 (9.96)	105.20 (8.39)	- 0.23	.411	
KSS	3.61 (1.47)	4.78 (2.26)	1.66[a]	.211	0.07
IR	3.85 (1.82)	3.30 (0.82)			0.39
DR	5.54 (2.03)	3.80 (2.25)			0.57

Note. For all variables except Sex, means are presented with standard deviations in parentheses. For Sex, raw numbers of participants are given. ESE = effect size estimate (in this case, either Cohen's *d (*for t-tests), eta squared η^2 (for *F* tests), or Crammers *d* (for χ^2 tests); PSQI = Pittsburgh Sleep Quality Index; BDI-II = Beck Depression Inventory – Second Edition; WASI = Wechsler Abbreviated Scale of Intelligence Full subset; KSS = Karolinska Sleepiness Scale; IR= Immediate recall; DR= Delayed recall.

[a]*df* = 1,21; the reported statics are for the interaction between *Group status* and *Time*

Testing assumptions for the data

We began with testing the underlying assumptions of independent sample t-tests namely those related to normality and homogeneity of variance for the outcome variables. Independence of observations is upheld as the study utilizes two independent groups for the night and day condition. The majority of the outcome variables upheld the assumptions of normality and homogeneity of variance. However, 4 of the AMT variables violated normality and 10 of the AMT variable violated homogeneity of variance. Parametric tests such as t-tests are noted for being robust to violations of normality and homogeneity of variance (Field, 2009), therefore we proceeded to analyse the data using t-tests. Appendix J provides a tabulated list of the Shapiro-Wilk statistic and Levene's test for homogeneity of variance statistic for the outcome variables being investigated.

Testing Hypothesis 1: Between Group Comparison – AM variables

This hypothesis investigated whether sleep rather than waking improves autobiographical memory consolidation. To test the AM outcome variables we grouped the variables in three categories namely; total scores category, affect category and AMT individual words categories. Each category was evaluated using the sublevels namely word count, number of nouns and verbs and emotionality.

Total scores categories. Table 2 shows the results of the t-tests conducted on the total scores of the AMT variables. The analyses produced a statistically significant result after using a Bonferroni correction of $p < .006$ for the AMT outcome variable Total verb retention score per AMT word (TotalVerb RT PW).This suggests that there are between group differences in terms of AMT performance between the wake and sleep groups for this variable. Specifically it suggests that those in the sleep group are more likely to perform better with regard to verb recall per word ($M = 95.17$, $SD = 25.77$) compared to the wake e group ($M = 33.63$, $SD = 17.48$).

Affect categories. For the total affect category Appendix I shows that there are no statistically significant between group differences after a Bonferroni correction of $p < .002$. Appendix I further displays the non-significant findings for the AMT variables.

Individual words category. Appendix I shows that tests for the individual words in the AMT revealed that there are no statistically significant findings after a Bonferroni correction of $p < .0008$. Appendix I further displays the non-significant findings for the AMT variables.

In summary, although the majority of analyses were non-significant, one t-test showed that there is some significant difference to note between the sleep and wake group when investigating AMT performance. Total verb retention per word is statistically significant in the predicted direction and will therefore be used in our subsequent analysis to investigate whether this group difference can be attributed to specific sleep variables.

Table 2

AMT performance between the day and night condition (N=23)

Variable	Group: Sleep (n = 13)	Group: Wake (n = 10)	t	p	ESE
Total Scores Category					
Total Verb Retention Per Word	95.18 (25.77)	33.63 (17.48)	6.48	<.001*	2.79

Note For all variables means are presented with standard deviations in parentheses. ESE = effect size estimate (in this case Cohen's *d* for t-tests)

*$p < .006$ (statistically significant after a Bonferroni correction for Total Scores Category)

Testing Hypothesis 2: Predicting AM Performance Using Sleep Variables

This hypothesis investigates whether sleep quality serves to predict the level of AM consolidation that occurs. In order to test this hypothesis, we performed a correlation analysis to determine the sleep variables that are associated with AMT performance, with the aim of using significantly correlated sleep variables to build a GLM. Although our sample is conventionally considered too small for model building, we decided to proceed with the analysis as this research is exploratory, with the intention to show whether it is feasible to run bigger studies of this nature in future. We only added sleep variables that have a significant correlation with AM variables (not, for example, trend-level correlations). Total verb retention per word was the only AM outcome variable used to investigate this hypothesis as this was where significant between group differences were located.

The correlation analysis (Appendix J) revealed a statistically significant negative correlation between sleep latency and *total verb retention per word* (r = -.58, n = 10, p = .038). The effect size (r = .58) shows a moderate correlation. This finding indicates that shorter sleep latency is associated with better retention of verbs.

The GLM (see Table 3 below) shows that sleep latency is a trend-level predictor of AMT performance for total verb retention per word. Although the results show a trend towards predicting AMT using sleep latency, the result is non-significant possibly due to the small sample size used.

Table 3

Results of the General Linear Model for Sleep latency (N=10)

Dependent Variable: Total Verb retention per word

	Type III SS	*df*	MS	*F*	*p*	*ESE*
Corrected model	5710.946	8	713.868	99.674	.077	.999
Sleep Latency	5710.946	8	713.868	99.674	.077	.999
Error	7.162	1	7.162			
Total	84230.627	10				
Corrected Total	5718.108	9				

Note. SS = sums of squares; MS = mean square; ESE = effect size estimate; in this case, η^2. For the overall model, η^2 =.99

*p< .05. **p< .01. ***p< .001.

Discussion

The study set out to investigate whether AM is preferentially consolidated during sleep compared to wake period. Our interest in this research question is based on findings from literature which indicate that there is a beneficial relationship between sleep and memory consolidation (Walker, 2009; Diekelmann & Born, 2010). Based on this knowledge we made two predictions. Our first prediction was that sleep rather than waking improves AM consolidation. Secondly, we predicted that the level of AM consolidation would be explained by PSG-recorded sleep quality variables.

To test our predictions we used the AMT to collect autobiographical memories from participants. We examined participants' memories according to their total scores on the test, the valences of the AMT words (positive, negative or neutral) and further examined them according to each word of the AMT. We also focused on *word count, nouns, verbs* and *affect* to strengthen our evaluation of the quality of memory.

Hypothesis 1: Findings regarding AMT performance between the day and night condition

Overall, the statistical analyses conducted did not confirm hypothesis 1. This means that there were no significant group differences in AMT performance between the day and night groups with a few exceptions. One possible reason for our lack of significant findings can be attributed to the small sample size. Another possible explanation is that contrary to our hypothesis, sleep does not strengthen AM consolidation. However, there is at least one variable that shows a significant relationship in the predicted direction. We then discuss our findings according to our stated categories.

Total scores categories. This category revealed that total verb retention per word was statistically significant. This means this memory variable met the predicted pattern. This predicted pattern suggests that the sleep group performed better in AMT performance for verb content; inferring improved AM consolidation. This improvement in verb retention reflects a strengthening of memory recall associated with AM content. Literature shows that neutral (non-affective) declarative memory is consolidated with sleep. Although AM is personal, content aspects of AM may benefit from a similar type of consolidation akin to neutral declarative information (Marshall & Born, 2007). Literature also informs us that AM is episodic in nature

which denotes memory that it is filled with event specific moments. Studies that have investigated the temporal aspects of memory note that there is a significant impairment in the consolidation of the content event specific moments when sleep does not precede a consolidation phase (Walker, 2009).

Affect categories. The adjusted Bonferroni significance level yielded no statistically significant results. This indicates that the positive, negative and neutral affect categories of the AMT did not produce significant between group differences and the small sample may contribute to this. There is general consensus in literature that emotional events are remembered better than neutral ones (Diekelmann, Wilhelm & Born, 2009; Holland & Kensinger, 2010; Walker, 2009). Sleep studies give strong indications that sleep strengthens the retention of emotional events (Diekelmann et al, 2009). These studies base their conclusions on observations of the amygdala which is the center for emotional content; they note that the amygdala becomes highly activated particularly in REM sleep compared to wake periods and that this activation is related to the degree of emotional memory consolidation (Vandekerckhove & Cluydts, 2010) These studies further note that REM deprived people remember less emotional content with no comparative loss in neutral memories (Diekelmann et al, 2008).

Individual words category. When we assessed all the 15 AMT words for recall none showed significant results. This may indicate that the groups performed too similarly for between group differences to be noted.

Summary of findings. Our data suggests that verb content is preferentially consolidated during sleep suggesting that the content of personal memory takes preference over elements associated with affect. Verb content represents neutral content that does not convey affect. Research however indicates that affective memory is consolidated preferentially over neutral memory during sleep (Diekelmann et al, 2008; Hu, Stylos-Allan, M. & Walker, 2006). Our findings are therefore discrepant with the majority of the literature. We do however note that these findings may be limited by our small sample.

Hypothesis 2: Findings regarding AMT performance and sleep predictors in the night condition

Since total verb retention per word was the only AMT outcome variable that produced significant results for between group differences, this was the only variable utilised for

subsequent analyses. We set out to explain this variance in verb retention per word using sleep variables. To test our predicted pattern, which stated that variations in memory performance between the groups can be explained by our sleep variables, we first conducted correlations. The correlation analysis noted a significant association between sleep latency and verb retention per word and this association was negative. The negative correlation between sleep latency and total verb retention per word suggests that the shorter the time it takes one to fall asleep, the greater memory retention.

While noting the small size of our sample (n=10 with PSG data) we decided to proceed with the analysis and ran a GLM with the intention to show whether a predictive association between sleep latency and total retention per word can be observed. The model produced by the GLM disconfirmed the assumption that the relationship between verb content and sleep quality is predictive in nature. The GLM result showed trend level significance ($p = 0.077$). Although caution must be applied in interpreting the results because the sample is small and the prediction is not significant; there is however some preliminary support with regard to the predictive value of sleep quality for AM performance. The large effect size (see Table 3) should be interpreted with caution as only one predictor was entered into the model.

Literature concedes that sleep quality is highly subjective and so there is some difficulty in defining it objectively. This is partly because sleep quality encapsulates different aspects of sleep; one of which is sleep latency defined as the time it takes for sleep onset to occur (Richardson, Carskadon, Flagg, Hoed, Dement & Mitler, 1978).We can speculatively note that falling asleep quickly may equate to better sleep quality. However, taking a long time to fall asleep is one criteria for insomnia and people with insomnia are noted to have difficulties with the consolidation of neutral declarative memory (Backhaus & Junghanns, 2006). Sleep latency is a useful criterion for noting sleep pathology and this usefulness may be extended to the domain of memory. We can suggest that taking longer to fall asleep may be detrimental for the consolidation of neutral declarative memory and more especially for AM consolidation. While helpful in evaluating pathological patterns of sleep, literature is not clear on its connection to memory processing specifically verb retention. We can only make inferences namely that the shorter sleep latency the greater memory retention and link this to the already documented

process of memory consolidation that is strengthened by sleep for declarative memory. We note however that this is likely a novel area and requires more research.

Strengths and Limitations

The study had many methodological strengths particularly regarding the exclusion criteria in order to try to control for confounding effects that can affect the significance of the findings. For example, a particular age range was utilised in order to control for the difference in sleep architecture associated with different age ranges. The study also took into account tiredness effects that could impact on AMT performance as there was a day and night condition in the study design. Additionally, the study controlled for psychiatric diagnoses, psychoactive medication, alcohol and substance use.

The study also addressed an underrepresented area of research namely sleep and AM and the associated interactions. The study also evaluated AM in a more nuanced manner to investigate the association between sleep and AM. Lastly, the study in being a pilot study makes a significant and unique contribution as it highlights the possible direction that future studies could investigate regarding sleep and AM.

There were, however, limitations of the current study, one of which is the small sample size. The trends found in the data suggest that a larger sample size may be needed to detect significant effects, also in order to detect significant between group differences in AMT as well as significant within subject factors in the night condition.

Another limitation is the use of two independent groups. This design does not allow for the elimination of personal characteristics that may confound the trends seen. Regarding the night condition, it would have been ideal to have an adaptation night in the sleep lab followed then subsequently followed by the experimental night. Regarding the day condition, there were no objective means to ensure that participants did not have daytime naps or caffeine for example.

Directions for future research

We suggest that future empirical research should make attempts to clarify the association described with a larger sample size. Future research could also investigate the association between sleep and AM in a repeated measures design in order to eliminate personal unique between group characteristics that may confound the results.

Future studies could also analyse the AMT responses by using a broad content category that combines nouns and verbs into a single category.

Conclusion

The current study did not show an overall difference in AM consolidation between the groups. However, the recollection of verbs seems to benefit from a period of sleep. The preliminary findings within the sleep group also suggest that sleep latency predicts content consolidation at the trend-level. Although the results yielded few significant relationships, we note the importance of sleep for AM consolidation. The association between sleep and AM is noteworthy as memories impact on how we define ourselves and also influence our behavior (Steven, 2003). AM is especially relevant as this type of memory is specifically linked to personal memories about oneself. Therefore research on the important role for consolidation of AM may be helpful in understanding the development of a healthy self-concept. Our findings show some limited and preliminary support for the relationship between sleep and AM, which can be elaborated on by future research.

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ID#

SAMS____

Appendix F

Informed Consent Document

The Importance of Sleep in the Consolidation of Autobiographical Memories.

You are being asked to take part in a research study. This form provides you with information about the study and seeks your authorization for the collection, use and disclosure of your sleep architecture patterns, cognitive performance data and autonomic arousal data as well as other information necessary for the study. The Principal Investigator (the person in charge of this research) or a representative of the Principal Investigator will also describe this study to you and answer all of your questions. Your participation is entirely voluntary. Before you decide whether or not to take part, read the information below and ask questions about anything you do not understand.

Title of Research Study

"The Importance of sleep in consolidation of autobiographical memories"

1. Principal Investigators and Telephone Number(s)

Phumelele Ngubane

University of Cape Town (UCT)

Contact number: 07 99513821

Vakele Gama

University of Cape Town (UCT)

Contact number: 072 038 0652

2. What is the purpose of this research study?

This research aims to investigate whether sleep helps in the consolidation of autobiographical memories (AM). AM refers to memories that are personal in nature, they are memories on events that occurred in a person's life at a specific place and time.

3. What will be done if you take part in this research study?

Before commencing on the actual study (phase two), you will undergo phase one of the study which is a screening process. The Principal Investigators listed in # 2 of this form, will administer a number of short psychiatric questionnaires and an IQ test. The psychiatric questionnaires will ask about your mood and your patterns of behaviour. These questionnaires are research instruments that allow us to identify certain patterns of interest. During this

screening the researcher will also inform you in detail about the design of the study and the research questions we hope to address with this study. We will also take a brief medical history from you where we will ask you to provide us with details of any medication you are currently on and any other things we should be aware of. All participants in the study are expected to refrain from indulging in foods that contain caffeine (e.g. coffee, Red bull, caffeinated sports/energy/soft drinks, tea, cappuccino, expresso, chocolate) at least 24hours prior to and during participation and in the day or night condition.

During phase two, you will be randomly assigned to either a day or night session. You will therefore take part in one of these sessions and not both. Random assignment means that you have an equal chance of being assigned to the day or night condition. This is to ensure that that the two groups (day group and night group) are equal and that the investigators preferences or your personal preferences do not influence which group you will be assigned to.

For the day session you will be expected to come in twice. Firstly, you will be asked to come to UCT (PD Hahn building) at 9.00am in the morning for a study session of approximately 2 hours. During this session a memory test will be administered. You will be presented with some information that is part of a memory task. You will be requested to stay awake and to return 8 hours later for the administration of the memory test again.

For the night session, you will be asked to come in about 2 hours before your normal bed time. During this session a memory test will be administered. Thereafter, you will be hooked up to a polysomnograph (PSG) which is an EEG machine designed to monitor your sleep patterns. Electrodes will be placed on your head, chest, near your chin and temples; these are completely safe and present no danger whatsoever to your health. They are designed to transmit physiological indications of the stage of sleep you are experiencing at a given point in time, to a computer monitor. A trained researcher will be at the lab with you throughout the night for assistance at any time. In the morning the memory test will be administered again. All the equipment will then be removed, you will be remunerated and then free to leave.

At the end of each study session, you will be debriefed about the study. You will also have the opportunity to ask questions and thus learn more about psychological research. If you have any questions now or at any time during the study, you may contact the Principal Investigators listed in #3 of this form.

4. Consent to be Voice Recorded:

The memory test that will be utilised will ask you to retrieve specific personal memories that are related to a word. The administration of the memory task has a temporal aspect. As such, your responses to the memory task will be audio recorded.

5. If you choose to participate in this study, how long will you be expected to participate in the research?

Screening and interview session: approximately 2 hours (phase 1). Study sessions: morning session 2 hours, you will be required to stay awake and return 8 hours later for testing; night session – spending a night at the Sleep Laboratory at UCT.

6. How many people are expected to participate in the research?

20

7. What are the possible discomforts and risks?

During the initial screening you may be asked specific questions regarding your current psychological functioning. Sleeping in an environment other than your own bedroom might feel strange and uncomfortable at first. Precautions will be taken to ensure your safety and comfort. The sleep laboratory at UCT is situated in a secure building with sufficient security. It is fully equipped with a proper bed, clean bedding, and restrooms. Attempts will be made to familiarise you with the PSG and the electrodes used will be padded and lubricated so as to be as non-intrusive as possible.

8. a. What are the possible benefits to you?

You may or may not personally benefit from participating in this study. Participation in this study may, however improve your understanding of some of the benefits of healthy sleep.

8. b. What are the possible benefits to others?

The information from this study may help improve our understanding of the importance of sleep. This study aims to elaborate on current knowledge of the benefits of sleep on memory consolidation. This study will focus on the consolidation of AM.

9. If you choose to take part in this research study, will it cost you anything?

Participating in this study will not cost you anything.

10. Will you receive compensation for taking part in this research study?

You will receive 4 SRPP points for the screening phase of the study.

If you are eligible and take part for phase 2, you will receive financial compensation of the amount of R150 after the study session.

11. a. Can you withdraw from this research study?

You are free to withdraw your consent and to stop participating in this research study at any time. If you do withdraw your consent, there will be no penalty.

If you have any questions regarding your rights as a research subject, you may phone the Psychology Department offices at 021-650-3430. You may also contact Rosalind Adams at 0216503417 or email: rosalind.adams@uct.ac.za.

11. b. If you withdraw, can information about you still be used and/or collected?

Information already collected may be used.

12. Once personal and performance information is collected, how will it be kept secret (confidential) in order to protect your privacy?

Steps will be taken to ensure that the information collected is kept confidential. Information collected will be stored in locked filing cabinets or in computers with security passwords. A limited number of people will have access to these research records. These people include the researchers for this study and certain University of Cape Town officials.

13. What information about you may be collected, used and shared with others?

This information gathered from you will be demographic information, information on depression, records of your sleep architecture, performance on cognitive tests, and scores on the IQ test and psychiatric inventory. If you agree to be in this research study, it is possible that some of the information collected might be copied into a “limited data set” to be used for other research purposes. If so, the limited data set may only include information that does not directly identify you. For example, the limited data set cannot include your name, address, telephone

number, ID number, or any other photographs, numbers, codes, or so forth that link you to the information in the limited data set.

14. How will the researcher(s) benefit from your being in the study?

The Principal Investigators may benefit if the results of this study are presented at scientific meetings or in scientific journals. This study is being undertaken for the Principal Investigators' Honors degree.

15. Signatures:

As a representative of this study, I have explained to the participant the purpose, the procedures, the possible benefits, and the risks of this research study; and how the participant's performance and other data will be collected, used, and shared with others:

Signature of Person Obtaining Consent and Authorization: _____

Date _____

You have been informed about this study's purpose, procedures, possible benefits, and risks; and how your performance and other data will be collected, used and shared with others. You have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time.

You voluntarily agree to participate in this study. You hereby authorize the collection, use and sharing of your performance and other data. By signing this form, you are not waiving any of your legal rights.

Name of Participant:

_____

Signature of Participant: _____ Date _____

I hereby give my consent to being voice recorded as part of participating in the above cited research study.

Name of Participant

_____

Signature of Participant: _____ Date _____

Signature of Person Obtaining Consent and Authorization

_____ Date _____

Please indicate below if you would like to be notified of future research projects conducted by our research group:

_____ (initial) Yes, I would like to be added to your research participation pool and be notified of research projects in which I might participate in the future.

Method of contact:

Phone number: _____

E-mail address: _____

Mailing address: _____

_____

_____

Appendix G

Advert for the SRPP

Dear Students

You are being invited to participate in a study on the role of sleep in autobiographical memory consolidation.

Sleep has been noted to provide many benefits to our functioning one of which is related to memory. This study wants to investigate the role of sleep and the impact it has on one's ability to remember personal life events.

What does participation entail?

Phase one of the study is a screening session that will take 1.5 to 2 hours of your time for **1 SRPP point for next semester**.

Phase two of the study involves participation in the sleep study for remuneration of R 150, 00. Participants that are found to be eligible during the screening session (phase 1) will take part in this phase. In phase 2, you will be asked to perform a memory task, followed by an 8 hour delay period and then a memory task once again. The 8 hour delay period will either be your normal day to day activities or a night in UCT's sleep laboratory.

In order to take part for the study, you must:

a. **Be between the ages of 18 – 24** as sleep cycles differ across different age groups.
b. **Not be a smoker** as this effects normal sleep patterns
c. **Not use medication to assist in sleeping or psychotropic medication**(medication used to treat psychiatric conditions) as these alters natural sleep patterns
d. **Not suffer from a psychiatric disorder** as these themselves impact on sleep patterns
e. **Not have had any neurological condition or injuries** as this affects your sleep patterns and may influence memory ability.

If this study has interested you, please contact the researchers on this email sleepandremember@gmail.com for any questions, queries or information.

Participation in this study is entirely voluntary and you are free to withdraw from this study at any point during the process. Information that is provided to the researchers will be kept confidential and known only to the researchers. The results from this study will not link to individuals in any manner.

Appendix H

Pittsburgh Sleep Diary

Name: _____ #ID: _____

Fill out this part after the memory task

Time: Date:

Went to bed last night at:	
Lights out at:	
Minutes till you fell asleep:	
Finally awoke at:	
Awakened by (circle one):	Alarm clock Asked someone to wake me Noises Just woke
Number times you woke up during the night (circle one)	0 1 2 3 4 5 6 7 8 9 10
Total number of minutes awake:	0 1 2 3 4 5 or more
Woke to use bathroom (circle # times)	0 1 2 3 4 5 or more
Awakened by noises/children/bed partner (circle # times)	0 1 2 3 4 5 or more
Awakened due to pain or discomfort (circle # times)	0 1 2 3 4 5 or more
Just woke (circle # times)	0 1 2 3 4 5 or more
Sleep Quality	0 (very bad) 1 2 3 4 5 6 7 8 9 10 (very good)
Mood upon awakening	0 (very tense) 1 2 3 4 5 6 7 8 9 10 (very calm)
Alertness upon awakening	0 (very sleepy) 1 2 3 4 5 6 7 8 9 10 (very alert)

Fill out this part during the course of the day

Time: Date:

When did you have these meals…?	Breakfast		
	Lunch		
	Dinner		
How many caffeinated drinks did you have today?			
How many cigarettes?			
How many alcoholic drinks?			
Which medications did you take today?	Name	Dose	Time Taken
What exercise did you do today? If nothing tick here:	Start time	End time	Type of exercise
How many daytime naps did you take and when? If none tick here:	Start time	End time	

Did you take the actigraph off today at all?	Time off	Time back on

Appendix I

AMT performance between the day and night condition

Table A

AMT Performance between the day and night condition (N=23)

Variable	Group		*t*	*p*	ESE
	Sleep	Wake			
	(*n* = 13)	(*n* = 10)			
Total scores category					
Total Word Count Retention	37.61 (16.86)	38.20 (16.82)	-0.08	.467	-0.04
Total Word Count Retention Per Word	84.43 (49.40)	81.74 (49.32)	0.13	.449	0.05
Total Noun Retention	45.44 (19.63)	49.40 (22.51)	-0.45	.328	0.19
Total Noun Retention Per Word	102.44 (18.32)	102.16 (22.90)	0.03	.488	0.18
Total Verb Retention	52.43 (15.17)	51.56 (21.36)	0.11	.455	0.01
Total Emotionality Retention	46.41 (15.92)	49.06 (23.49)	-0.322	.376	0.63
Total Emotionality Retention Per Word	108.25 (25.79)	129.69 (53.58)	-1.27	.109	1.41
Affect category					
Total Positive Word Count Retention	60.53 (30.55)	41.55 (21.46)	1.67	.055	2.62
Total Positive Noun Retention	62.49 (18.41)	63.09 (36.75)	-0.05	.48	0.72
Total Positive Verb Retention	73.38 (43.00)	55.23 (35.81)	1.08	.147	0.26
Total Positive Emotionality Retention	68.62 (21.74)	70.69 (35.23)	-0.17	.432	0.46
Total Negative Word Count Retention	33.75 (19.45)	40.96 (27.28)	-0.74	.2335	1.56

Total Negative Noun Retention	55.73 (29.18)	45.08 (22.21)	0.96	.175	0.57
Total Negative Verb Retention	51.26 (26.5)	54.47 (27.38)	-0.29	.389	0.23
Total Negative Emotionality Retention	45.69 (32.4)	43.27 (24.46)	0.20	.423	0.31
Total Neutral Word Count Retention	18.03 (24.1)	27.85 (18.02)	-1.07	.148	0.8
Total Neutral Noun Retention	21.43 (29.18)	44.55 (45.10)	-1.49	.076	0.17
Total Neutral Verb Retention	19.19 (17.33)	45.12 (33.44)	-2.42	.012	-0.97
Total Neutral Emotionality Retention	13.20 (19.36)	37.49 (35.92)	-2.06	.027	-0.09
Total Positive Word Count Retention Per Word	102.85 (63.63)	76.02 (20.06)	1.37	.096	1.22
Total Positive Noun Retention Per Word	98.64 (23.14)	131.07 (64.21)	-1.45	.090	1.27
Total Positive Verb Retention Per Word	128.20 (111.95)	98.06 (56.05)	0.74	.234	0.59
Total Positive Emotionality Retention Per Word	112.57 (29.56)	109.51 (34.90)	0.22	.415	0.57
Total Negative Word Count Retention Per Word	71.38 (59.86)	87.60 (61.02)	-0.63	.269	0.44
Total Negative Noun Retention Per Word	130.46 (109.80)	89.97 (33.02)	1.12	.138	0.26
Total Negative Verb Retention Per Word	112.36 (79.26)	106.07 (35.29)	0.232	.409	0.40
Total Negative Emotionality Retention Per Word	94.40 (44.29)	73.34 (32.33)	1.25	.113	0.11
Total Neutral Word Count Retention Per Word	67.48 (43.56)	72.08 (47.77)	-.21	.419	0.84
Total Neutral Noun Retention Per Word	93.31 (25.24)	103.86 (24.69)	-.87	.199	0.80
Total Neutral Verb Retention Per Word	100.15 (41.87)	101.22 (19.52)	-.07	.474	0.85
Total Neutral Emotionality Retention Per Word	71.07 (59.12)	103.51 (70.91)	-1.00	.167	0.50
Individual words category					
Retention Word Count Devoted	0.40 (0.42)	0.06 (0.12)	2.21	.028	1.10

Retention Noun Devoted	0.68 (0.66)	0.29 (0.64)	1.07	.155	0.60
Retention Verb Devoted	0.55 (0.53)	0.21 (0.46)	1.21	.126	0.69
Retention Emotionality Devoted	0.84 (0.79)	0.00 (0.00)	3.03	.009	1.50
Retention Word Count Failure	0.17 (0.32)	0.29 (0.45)	-0.72	.242	0.31
Retention Noun Failure	0.22 (0.41)	0.38 (0.61)	-0.72	.241	0.31
Retention Verb Failure	0.28 (0.51)	0.30 (0.52)	-0.13	.448	0.03
Retention Emotionality Failure	0.28 (0.61)	0.34 (0.59)	-.23	.412	0.10
Retention Word Count Guilt	0.32 (0.43)	0.40 (0.47)	-0.43	.337	0.18
Retention Noun Guilt	0.52 (0.64)	0.60 (0.64)	-0.28	.391	0.13
Retention Verb Guilt	0.42 (0.50)	0.51 (0.54)	-0.38	.354	0.18
Retention Emotionality Guilt	0.33 (0.39)	0.33 (0.42)	-0.01	.495	0.00
Retention Word Count Happy	1.07 (1.10)	0.44 (0.39)	1.34	.099	0.76
Retention Noun Happy	0.92 (0.58)	0.56 (0.46)	1.34	.099	0.69
Retention Verb Happy	1.23 (1.85)	0.56 (0.49)	0.85	.203	0.50
Retention Emotionality Happy	1.16 (0.91)	0.93 (1.04)	0.48	.319	0.24
Retention Word Count Helpless	0.34 (0.49)	0.98 (1.28)	-1.26	.124	0.66
Retention Noun Helpless	0.37 (0.60)	0.47 (0.49)	-0.370	.358	0.18
Retention Verb Helpless	0.36 0.51)	0.90 (0.91)	-1.43	.095	0.73
Retention Emotionality Helpless	0.41 (0.65)	0.29 (0.31)	0.47	.323	0.24
Retention Word Count Joy	0.76 (0.38)	0.58 (0.38)	1.12	.139	0.47
Retention Noun Joy	0.90 (0.41)	1.23 (1.43)	-0.74	.234	0.31

Retention Verb Joy	0.89 (0.38)	0.68 (0.60)	0.98	.172	0.40
Retention Emotionality Joy	0.91 (0.45)	0.76 (0.47)	0.70	.247	0.33
Retention Word Count Library	0.31 (0.50)	0.07 (0.16)	1.01	.166	0.65
Retention Noun Library	0.44 (0.61)	0.21 (0.48)	0.74	.236	0.42
Retention Verb Library	0.33 (0.44)	0.27 (0.60)	0.222	.414	0.11
Retention Emotionality Library	0.43 (0.81)	0.10 (0.21)	0.90	.192	0.56
Retention Word Count Rejected	0.56 (0.48)	0.26 (0.35)	1.30	.108	0.71
Retention Noun Rejected	0.96 (0.58)	0.48 (0.69)	1.39	.094	0.75
Retention Verb Rejected	0.78 (0.46)	0.47 (0.60)	1.08	.150	0.58
Retention Emotionality Rejected	0.94 (0.49)	0.49 (0.72)	1.35	.100	0.73
Retention Word Count Relieved	0.63 (1.54)	0.27 (0.36)	0.73	.237	0.32
Retention Noun Relieved	0.35 (0.52)	0.54 (0.96)	-0.61	.275	0.25
Retention Verb Relieved	0.33 (0.50)	0.46 (0.62)	-0.54	.298	0.23
Retention Emotionality Relieved	0.38 (0.65)	0.51 (0.69)	-0.45	.330	0.19
Retention Word Count Rhythm	0.12 (0.28)	0.32 (0.39)	-1.30	.105	0.59
Retention Noun Rhythm	0.18 (0.42)	0.46 (0.53)	-1.22	.120	0.59
Retention Verb Rhythm	0.24 (0.60)	0.47 (0.52)	-0.77	.226	0.41
Retention Emotionality Rhythm	0.32 (1.12)	0.59 (0.95)	-0.46	.325	0.30
Retention Word Count Sad	0.41 (0.28)	0.67 (0.66)	-1.25	.112	0.51
Retention Noun Sad	1.04 (0.67)	0.85 (0.83)	0.59	.280	0.25
Retention Verb Sad	0.83 (0.45)	0.80 (0.54)	0.16	.439	0.06

Retention Emotionality Sad	0.73 (0.67)	0.54 (0.61)	0.68	.252	0.30
Retention Word Count Shoes	0.05 (0.18)	0.08 (0.17)	-.26	.398	0.17
Retention Noun Shoes	0.10 (0.35)	0.21 (0.46)	-0.52	.305	0.27
Retention Verb Shoes	0.07 (0.25)	0.21 (0.47)	-0.80	.219	0.37
Retention Emotionality Shoes	0.13 (0.47)	0.19 (0.42)	-.22	.415	0.13
Retention Word Count Tender	0.33 (0.41)	0.79 (0.19)	-2.39	.040*	1.44
Retention Noun Tender	0.31 (0.39)	1.13 (0.49)	-2.63	.014*	1.85
Retention Verb Tender	0.48 (0.59)	0.87 (0.12)	-1.82	.051	0.92
Retention Emotionality Tender	0.64 (1.00)	0.85 (0.54)	-.27	.396	0.26
Retention Word Count Tree	0.11 (0.28)	0.23 (0.26)	-.94	.179	0.44
Retention Noun Tree	0.12 (0.27)	0.64 (0.73)	-1.92	.045	0.94
Retention Verb Tree	0.15 (0.35)	0.47 (0.57)	-1.41	.093	0.59
Retention Emotionality Tree	0.20 (0.68)	0.67 (0.91)	-1.21	.123	0.36
Retention Word Count Uncle	0.35 (0.67)	0.59 (0.67)	-0.70	.246	0.63
Retention Noun Uncle	0.38 (0.51)	0.75 (0.66)	-1.24	.118	0.35
Retention Verb Uncle	0.42 (0.68)	0.63 (0.49)	-0.64	.265	0.35
Retention Emotionality Uncle	0.29 (0.52)	0.86 (0.64)	-1.61	.067	0.98

Note For all variables means are presented with standard deviations in parentheses.

*$p < .006$ (statistically significant after a Bonferroni correction for Total Scores Category), **$p < .002$ (statistically significant after a Bonferroni correction for Affect Category), ***$p < .0008$ (statistically significant after a Bonferroni correction for Individual words Category)

Appendix J

Test of underlying assumptions for variables

Levene's test for homogeneity must be run between-groups. The Shapiro-Wilk test of normality, was run to analyse normality for the AMT outcome variables. This is due to a need to check the distribution of data for violations of these assumptions

Table B

Between group factors: Results for the Shapiro Wilk test of normality

Variable	Group	
	Sleep (n = 13)	Wake (n = 10)
Age	.023*	.198
PSQI	.088	.268
BDI II	.307	.525
WASI	.291	.682

Note. Data are *p*-values

*$p < .05$

Table C

AMT outcome Variables: Results for the Shapiro Wilk test of normality (N = 23)

Variable	Group	
	Sleep (n = 13)	Wake (n = 10)
Total Word Count Retention	.637	.826
Total Word Count Retention Per Word	.690	.175
Total Noun Retention	.657	.081
Total Noun Retention Per Word	.693	.983
Total Verb Retention	.575	.417
Total Verb Retention Per Word	.944	.387
Total Emotionality Retention	.546	.621
Total Emotionality Retention Per Word	.969	.186

Total Positive Word Count Retention	.745	.877
Total Positive Noun Retention	.308	.333
Total Positive Verb Retention	.313	916
Total Positive Emotionality Retention Per Word	.993	.006**
Total Negative Word Count Retention	.042*	.330
Total Negative Noun Retention	.066	.871
Total Negative Verb Retention	.534	.240
Total Negative Emotionality Retention	.487	.529
Total Neutral Word Count Retention	.073	.670
Total Neutral Noun Retention	.675	.198
Total Neutral Verb Retention	.129	.387
Total Neutral Emotionality Retention	.088	.744
Total Positive Word Count Retention Per Word	.332	.872
Total Positive Noun Retention Per Word	.108	.050
Total Positive Verb Retention Per Word	.326	.023*
Total Positive Emotionality Retention Per Word	.775	.726
Total Negative Word Count Retention Per Word	.477	.622
Total Negative Noun Retention Per Word	.468	.691
Total Negative Verb Retention Per Word	.522	.898
Total Negative Emotionality Retention Per Word	.557	.206
Total Neutral Word Count Retention Per Word	.801	.085
Total Neutral Noun Retention Per Word	.621	.444
Total Neutral Verb Retention Per Word	.001**	.540
Total Neutral Emotionality Retention Per Word	.166	585

Note. Data are *p*-values

*$p < .05$, **$p < .01$,

Table D

AMT Outcome Variables: Results for Levene's test of homogeneity of variance(N=23)

Variable	Levene's *p*
Total Word Count Retention	.855
Total Word Count Retention Per Word	.689
Total Noun Retention	.984
Total Noun Retention Per Word	.693
Total Verb Retention	.059
Total Verb Retention Per Word	.597
Total Emotionality Retention	.106
Total Emotionality Retention Per Word	.127
Total Positive Word Count Retention	.471
Total Positive Noun Retention	.073
Total Positive Verb Retention	.815
Total Positive Emotionality Retention	.482
Total Negative Word Count Retention	.315
Total Negative Noun Retention	.375
Total Negative Verb Retention	.974
Total Negative Emotionality Retention	.458
Total Neutral Word Count Retention	.659
Total Neutral Noun Retention	.084
Total Neutral Verb Retention	.058
Total Neutral Emotionality Retention	.063
Total Positive Word Count Retention Per Word	.036*
Total Positive Noun Retention Per Word	.011*
Total Positive Verb Retention Per Word	.506
Total Positive Emotionality Retention Per Word	.448
Total Negative Word Count Retention Per Word	.786
Total Negative Noun Retention Per Word	.276
Total Negative Verb Retention Per Word	.507

Total Negative Emotionality Retention Per Word	.270
Total Neutral Word Count Retention Per Word	.731
Total Neutral Noun Retention Per Word	.754
Total Neutral Verb Retention Per Word	.363
Total Neutral Emotionality Retention Per Word	.550
Retention Word Count Devoted	.012*
Retention Noun Devoted	.805
Retention Verb Devoted	.511
Retention Emotionality Devoted	.006**
Retention Word Count Failure	.138
Retention Noun Failure	.138
Retention Verb Failure	.959
Retention Emotionality Failure	.927
Retention Word Count Guilt	.804
Retention Noun Guilt	.990
Retention Verb Guilt	.926
Retention Emotionality Guilt	.891
Retention Word Count Happy	.346
Retention Noun Happy	.879
Retention Verb Happy	.415
Retention Emotionality Happy	.918
Retention Word Count Helpless	.007**
Retention Noun Helpless	.634
Retention Verb Helpless	.024*
Retention Emotionality Helpless	.071
Retention Word Count Joy	.958
Retention Noun Joy	.164
Retention Verb Joy	.026*
Retention Emotionality Joy	.798
Retention Word Count Library	.112

Retention Noun Library	.184
Retention Verb Library	.787
Retention Emotionality Library	.194
Retention Word Count Rejected	.614
Retention Noun Rejected	.679
Retention Verb Rejected	.091
Retention Emotionality Rejected	.203
Retention Word Count Relieved	.168
Retention Noun Relieved	.243
Retention Verb Relieved	.236
Retention Emotionality Relieved	.703
Retention Word Count Rhythm	.173
Retention Noun Rhythm	.226
Retention Verb Rhythm	.741
Retention Emotionality Rhythm	.804
Retention Word Count Sad	.074
Retention Noun Sad	.264
Retention Verb Sad	.316
Retention Emotionality Sad	.751
Retention Word Count Shoes	.712
Retention Noun Shoes	.354
Retention Verb Shoes	.120
Retention Emotionality Shoes	.785
Retention Word Count Tender	.027*
Retention Noun Tender	.943
Retention Verb Tender	.006**
Retention Emotionality Tender	.494
Retention Word Count Tree	.538
Retention Noun Tree	.001**
Retention Verb Tree	.033*

Retention Emotionality Tree	.236
Retention Word Count Uncle	.938
Retention Noun Uncle	.782
Retention Verb Uncle	.641
Retention Emotionality Uncle	.799

Note. (*) indicate a significant violation of the assumption of homogeneity of variance.
*$p < .05$, **$p < .01$

Appendix K

Correlation analysis between sleep predictors and total verb retention per word

Table E

Correlation analysis between sleep predictors and total verb retention per word

		Sleep Latency	Spontaneous awakenings	Wake upon sleep onset	Sleep Efficiency	NREM 1	NREM 2	NREM 3	REM	Total Verb Retention Per Word
Total Verb Retention Per Word	Pearson Correlation	-.583*	-.044	-.235	.419	.232	-.341	-.452	.274	1
	Sig. (1-tailed)	.038	.452	.257	.114	.260	.168	.095	.222	
	N	10	10	10	10	10	10	10	10	23

*. Correlation is significant at the 0.05 level (1-tailed).