Is dream recall frequency related to enhanced encoding, greater dream production, or both?

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Abstract

Research suggests there is a strong relationship between REM sleep and dreaming instances; evidenced through greater brain activity in the occipital and temporal regions during this sleep stage. Studies also indicate an intra-individual difference in dream recall frequency (DRF) upon awakening from sleep. The present study aimed to investigate these differences in DRF in a novel manner: through measuring objective sleep parameters between high recall dreamers and low recall dreamers. Literature identified three objective sleep parameters that may enable better encoding, greater dream production, or a combination of these two in high recallers. Hypotheses were formulated as following: $H_{1:}$ high frequency recallers (HFR) will exhibit greater REM density, which is speculated to be linked to PGO wave activity and thus production of dreams. $H_{2:}$ HFR will have more awakenings, and spend more time awake after sleep onset (WASO), which, according to arousal-retrieval model, explains DRF through better encoding into memory. H_3 HFR will exhibit greater production and recall, seen through greater REM density, more awakenings, and more wakefulness. The groups were matched according to demographic and screening outcomes ($N = 26$); state and trait measures, as well as a polysomnography, were used in data collection. Results: H_1 was insignificant. H_2 was retained, with awakenings ($p = .047$) and WASO ($p = .032$) reaching significance. H_3 could not be accepted by default. The study suggests that HFR encode more dreams due to awakenings/WASO; possibly caused by higher brain reactivity to their environment. As these differences exist across states of vigilance, it is possible to speculate that there is a functional difference in cerebral organization between HFR and LFR. More research with larger samples are required to further investigate this, and to uncover other possible phenomena related to DRF.

Keywords: dream recall frequency; dream encoding; dream production; REM density; awakenings; intra-sleep wakefulness; polysomnography.

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Introduction

Across species, sleep is a necessary process. It is established that it has a significant impact on cognitive and emotional functioning (Carskadon & Dement, 2011). In humans, sleep is characterized by two states: non-rapid eye movement (NREM) and rapid eye movement (REM) sleep (Carskadon & Dement, 2011; Dessielles, Dang-Vu, Sterpinich, & Schwartz, 2011). These two states alternate in a cyclical manner roughly every 90 minutes (Guilleminault & Kreutzer, 2003). Another characteristic feature of sleep is dreaming; however, in many ways it remains poorly understood, despite extensive research. The relationship between dreaming, dream recall frequency (DRF), and other physiological markers of sleep is one area of dream research where strong methodological studies are lacking. Investigating this relationship will not only contribute significantly to a better understanding of the mechanisms involved in dreaming, but can also provide important new insights into the biological function of certain distinct characteristics of sleep.

Physiologically, NREM and REM sleep have important distinctions: NREM is associated with low muscle tone and relatively synchronous electroencephalogram (EEG) patterns (Guilleminault & Kreutzer, 2003). In contrast, REM sleep is normally accompanied by muscle atonia (lack of muscle tone), rapid eye movements, and rapid, desynchronized EEG patterns (Abe, Ogawa, Nittono, & Hori, 2008). The unique neurophysiological markers and neural patterns of activation of REM sleep have been strongly linked to the occurrence of dreaming. The defining characteristic of REM sleep is the distinct rapid eye movements that occur during this period; a prominent physiological marker, yet little is known about the purpose of these eye movements. There is, thus, a notable gap in the literature in terms of methodologically sound studies investigating the purpose of these rapid eye movements, and other physiological aspects of sleep, and how they may be associated with the phenomenon of dreaming.

Dreaming

Although research has focused on the phenomenon of dreaming for many years, more studies are required to elucidate all the different possible functions of dreaming (Walker, 2008). Regardless of gaps in knowledge concerning dreaming, it has been found that the neural activation unique to REM sleep supports the occurrence of dreams during this sleep phase (Ogawa, Abe, Nittono, Yamazaki, & Hori, 2009). This neural pattern of activation facilitates both the vividness and bizarreness of REM dreams, as well as the presence of strong, salient emotions. Thus, despite debate regarding what it is that constitutes a dream,

most authors agree that dreams in general contain a strong visual component, and, in certain cases, intense emotions (Hobson & Friston, 2012).

It is important to note that dreaming can occur outside of REM sleep, and REM sleep can occur in the absence of dreaming (Solms, 2000). However, NREM dream reports typically do not contain the same vivacity of visual elements, nor are they necessarily associated with strong emotions (Nielsen, 2000; Stickgold, Pace-Schott, & Hobson, 1994).

REM Sleep and Dreaming

Evidence suggests that NREM and REM dreams are not only qualitatively different, but also show varying rates of dream recall: as much as 90% of REM sleep awakenings result in dream reports, compared to only 5-10% NREM awakenings (Dement & Kleitman, 1957; Goodenough, Shapiro, Holden, & Steinschriber, 1959; Solms & Turnbull, 2002). This provides further evidence for the strong link between REM sleep and dreaming.

Recent advances in neuroimaging have allowed for a more in depth study of neural activation during REM sleep. Studies have shown that there are consistent patterns of activity in the occipital and temporal cortices during REM sleep; similar to the high activity seen in waking states (Nir & Tononi, 2010). These findings could potentially account for the prominent visual and auditory elements of dreams reported during this stage of sleep (Braun et al., 1998; Nir & Tononi, 2010). Furthermore, activation in the limbic and paralimbic structures, such as the amygdala, hippocampus, and anterior cingulate cortex, provides a possible explanation for the strong emotional content of dreams (Desseilles et al., 2011; Nir & Tononi, 2010).

As mentioned above, REM sleep appears to have strong links not only to vivid dreaming itself, but also to the recall of dreams. Given that REM sleep is partly defined by the presence of rapid eye movements, it makes sense that investigations attempting to establish a link between REM sleep and dreaming have focused on this physiological marker (Corsi-Cabrera, Guevara, & del Rio-Portilla, 2008).

Rapid Eye Movements and Dreaming

The relationship between rapid eye movements and instances of dreaming has drawn attention for decades, with very few strong methodological studies addressing this issue directly. These eye movements, which occur in periodic bursts during REM sleep, have been compared to waking ocular movements (Ogawa et al., 2009). Although not identical, certain eye movements documented during REM sleep are similar to those seen in awake individuals

(Arnulf, 2011; Peigneux et al., 2001); this has inspired numerous theories surrounding a potential function of these rapid eye movements seen in REM sleep.

One theory concerning rapid eye movements suggests that the movements may be related to scanning visual elements of dreams (Leclair-Visonneau, Oudiette, Gaymard, Leu-Semenescu, & Arnulf, 2010). This is known as the scanning hypothesis. Several studies have examined this idea:

Initially, this hypothesis was investigated through the use of subjects with lifelong blindness, whom did not report having dreams containing visual components. Berger, Olley, and Oswald (1962) reported no instances of eye movements during REM sleep of blind subjects. However, subjects who had become blind in recent years, and whom still reported experiencing visual dream elements, did have rapid eye movements during REM sleep. Although this evidence seems to support the scanning hypothesis, the methodology is flawed: using blind subjects introduces other possible factors relating to eye movements during sleep; particularly in reference to the lifelong blindness subjects, the possibility of ocular muscle atrophy causing the reported absence of eye movements. Furthermore, studies that sought to replicate these results produced mixed findings (Amadeo & Gomez, 1966; Gross, Byrne, & Fisher, 1965).

Despite the initial use of flawed methodology, a more recent study has re-introduced the plausibility of the scanning hypothesis. Leclair-Visonneau et al. (2010) studied the direction of rapid eye movements during REM sleep in a population with REM sleep behaviour disorder (RBD), where individuals act out their dreams due to a lack of muscle atonia. Utilizing video monitoring in conjunction with polysomnography, the authors analyzed direction of eye movements in accordance with goal-directed behaviour exhibited during dreaming; for example, lighting and smoking a cigarette. The results indicated that the eye movements followed the movement of the limbs and head in an organized manner approximately 82% of the time.

Studies investigating the scanning hypothesis using alternative methodology have reported mixed findings (Arnulf, 2011); possibly due to the use of potentially flawed methodology in some instances. For example, Zhou and King (1997) found that 77.8% of horizontal eye movements in REM sleep lack a fixation point; meaning that the eyes are not scanning a single image, if they are indeed scanning images at all. However, the methodology employed in this study is outdated, and an animal sample was utilized. Additional studies employing retrospective dream reports and the association to the direction of the individual's gaze during their dream suggest that the correspondence in gaze direction of eye movements

and goal-directed behavior in dreams is no higher than chance (Moskowitz & Berger, 1969). Once again, the methodology employed could have introduced error; especially as retrospective dream reports are often regarded as relatively unreliable. Given this, it seems that the association between REM sleep, rapid eye movements, and dreaming requires a research methodology that could minimize these mixed results obtained through error. The REM sleep behaviour disorder study (Leclair-Visonneau et al., 2010) suggests that more methodologically sound experimental designs are possible in this research area.

Interspecies studies may have provided one possible solution to studying the proposed link between rapid eye movements and dreaming. Animal studies have found that, closely linked to bursts of rapid eye movements, are spikes of phasic activity in certain brain areas; most prominently, the pons, lateral geniculate nucleus, and occipital cortex (Peigneux et al., 2001). These are known as ponto-geniculo-occipital (PGO) waves. Most PGO wave studies are conducted using animal subjects, as this allows for more invasive brain activity monitoring (Abe et al., 2008). However, using a human population with Parkinson's Disease, Fernandez-Mendoza et al. (2011) identified clusters of sharp field potentials in sub-thalamic brain regions through the use of deep brain polysomnography, during pre-REM, REM, and post-REM sleep periods. Activation of the primary visual cortex, without visual input through the retina, during REM sleep offers additional support for the suggestion that PGO waves occur in the sleeping human brain (Miyauchi, Misaki, Kan, Fukunaga, & Koike, 2009).

Further findings state that these PGO wave clusters in the human brain can be time-locked to the eye movement occurrences during REM sleep (Miyauchi et al., 2009; Peigneux et al., 2001). The evidence of rapid eye movements and PGO wave bursts coinciding consistently has subsequently led to the acceptance of measuring PGO wave activity through the incidence of eye movements in REM sleep (Arnulf, 2011; Braun et al., 1998; Peigneux et al., 2001).

Research shows that not only are PGO waves time-locked to rapid eye movements, but clusters of these potentials are found in specific brain regions connected to visual imagery (Arnulf, 2011; Fernandez-Mendoza et al., 2011; Miyauchi et al., 2009); thus, there seems to be evidence that PGO waves possibly underlie visual components of dreams (Arnulf, 2011; Miyauchi et al., 2009).

The evidence proposing that PGO waves underlie dream imagery, and are also connected to the incidence of eye movements during REM sleep, could lead one to extrapolate that rapid eye movements are associated with dream imagery. Furthermore, the

aforementioned studies provide evidence that rapid eye movements could serve the function of scanning the visual imagery of dreams, given that the direction of eye movements has a high and significant concordance with goal-directed behaviour in dreams (Fernandez-Mendoza et al., 2011; Miyauchi et al., 2009).

Having established this connection between rapid eye movements in REM sleep and PGO spikes responsible for visual imagery, one can investigate new opportunities by which to study different aspects of dreaming during REM sleep. One interesting avenue of investigation concerns the relationship between the frequency of rapid eye movements (REM density), and the frequency of dream recall.

REM Density and Dream Recall

The high activation of certain brain regions during REM sleep is seen across most healthy individuals; however, some individuals still report more dreams than others (Nielsen, 2000; Watson, 2003).

Studies surrounding REM density and instances of dreaming have suggested connections between rapid eye movements, spontaneous activation of the striate cortex, and the vivid nature of dreams. Braun et al. (1998) reported that there was a positive correlation between REM density and extrastriate and hippocampal brain activation. These are areas associated with the visual elements of dreams, and the possible consolidation of dreams in memory. Further support for this hypothesis was revealed in the same study, where REM density also shared a positive relationship with dream recall upon awakening from REM sleep. Thus, there is evidence to propose that REM density is related to the likelihood of recalling dreams upon awakening, and by extension, also possibly with the production of dreams.

Based on this, three possibilities can be put forth to explain the variability in dream recall frequency (DRF): high recallers may produce more dreams than low recallers; or high recallers and low recallers may have similar amounts of dreams per night, with the difference pertaining to enhanced encoding, and subsequent recall, of these dreams; alternatively, it may be a combination of the two hypotheses (Eichenlaub, Bertland, Morlet, & Ruby, 2014a).

Producing More Dreams: REM Density's Association with Dream Production

The argument for dream recall as related to better memory encoding has been discussed briefly, but the possibility exists that high dream recall individuals also produce more dreams. As mentioned earlier, there is strong evidence in the literature that rapid eye

movements are associated with dream imagery, and that the generation of PGO waves, indexed through REM density, is one of the mechanisms through which this is achieved (Braun et al., 1998; Miyauchi et al., 2009). Therefore, one way of elucidating whether greater REM density is associated with higher DRF is to study rapid eye movements of high DRF individuals compared to low DRF individuals. As evidence suggests that rapid eye movements can index PGO activity, and PGO activity is related to the generation of dream imagery, one can investigate whether greater REM density inferentially equates to increased dream production. Investigating whether individuals with high DRF exhibit significantly greater REM density compared to low DRF, could provide strong evidence that some individuals not only recall more dreams, but have greater dream production too

Remembering/Recalling More Dreams: The Arousal-Retrieval Hypothesis

The arousal-retrieval model of dreaming is an influential theory when it comes to explaining the process of how instances of dreaming are translated into the recall of dreams. This model proposes that dream recall is possible only when an individual awakens from sleep whilst there is still a short-term memory trace of the dream; ultimately, this awakening enables the dream to be encoded into long-term memory, and subsequently recalled at a later stage (Eichenlaub et al., 2014a; Koulack & Goodenough, 1976). In essence, dream recall depends on intra-sleep awakenings shortly after dreaming in order to process the occurrence of the dream into memory storage (Koulack & Goodenough, 1976). Several studies have stated that high recall dreamers self-report, and exhibit, greater intra-sleep awakenings than low recall dreamers (Eichenlaub et al., 2014a; Ruby et al., 2013). Furthermore, these studies suggest that high recall dreamers have longer periods of intra-sleep wakefulness than their low recall counterparts; possibly due to a difference in the level of brain activation (Eichenlaub et al., 2014b; Ruby et al., 2013). Given this, one could suggest that there is a possibility that there might be functional differences in the cerebral organization of high frequency dream recallers compared to low frequency dream recallers.

Functional Cerebral Organization Associated with Dream Recall Frequency

Further studies have focused on other differences that may exist between individuals exhibiting either high or low DRF. A recent positron emission tomography (PET) scan study indicated that individuals with high recall frequency present higher regional cerebral blood flow (rCBF) in areas such as the temporo-parietal junction and the medial prefrontal cortex (Eichenlaub et al., 2014b); both of which are thought to be implicated in dream processes

(Solms, 2000). This neuroimaging finding exists both when individuals are awake, and during REM sleep (Eichenlaub et al., 2014b). Such findings provide strong support for the idea that the cerebral organization of high DRF individuals is functionally different to those whom exhibit low DRF; especially as these differences in rCBF are maintained in waking states as well as during sleep (Eichenlaub et al., 2014b). An additional study employed an auditory stimuli design in order to measure differences in evoked potentials between DRF groups: findings suggest that, across states of vigilance, high frequency recallers exhibit higher brain reactivity to stimuli in the external environment (Eichenlaub et al., 2014a).

In summary, there is empirical evidence supporting the premise that increased awakenings and amount of wakefulness after sleep onset is associated with increased DRF. In addition to this, there is strong theoretical grounds for the supposition that high frequency recall individuals not only recall more dreams, but possibly produce more dreams as well. Furthermore, based on neurophysiological and neuroimaging studies, the possibility exists that there is an intrinsic functional difference in cerebral organization underlying these observed differences in DRF.

Research Aim and Questions

There is convincing evidence in the literature that REM sleep is significantly linked to the occurrence of vivid visual and emotional dreams. Furthermore, it appears that REM sleep is also associated with higher incidence of recall of these dreams. Given that PGO waves, which underlie the visual components of dream activity in REM sleep, can be indexed by the presence of rapid eye movements, one can hypothesize that greater REM density possibly relates to increased dream production. Therefore, the main focus of this study is finding a novel way of testing the possibility that high frequency recall (HFR) individuals produce more dreams than low frequency recall (LFR) individuals. However, based on existing literature, other parameters associated with DRF must also be considered, for example, awakenings and intra-sleep wakefulness.

In summary, the rationale behind this study is that HFR individuals not only remember more dreams, but possibly also produce more dreams. One of the ways to empirically test this idea is to compare HFR with LFR on the basis of the following sleep variables: REM density values, number of awakenings, and time spent awake after sleep onset. Based on this, the hypotheses for this study can be formulated:

Hypothesis 1:

- HFR individuals will report more dreams due to increased production of dreams.
    a. Therefore, HFR individuals will exhibit increased REM density values.

Or:

Hypothesis 2:

- HFR individuals will report more dreams due to more fragmented sleep, and subsequent better encoding of dream memory traces into long-term memory.
    a. Therefore, HFR individuals will exhibit increased number of awakenings and experience increased wakefulness after sleep onset.

Or:

Hypothesis 3:

- HFR individuals will report more dreams due to better encoding of dream memory traces, and in addition, also produce more dreams when compared to LFR individuals.
    a. Therefore, HFR will present with more fragmented sleep, increased wakefulness, and greater REM density values.

Methods

Design and Setting

This study was conducted as a pilot study, forming part of a PhD examining the role of dreaming in memory processes and emotion regulation during sleep; therefore, the design formed one part of the larger investigative protocol. As part of a larger PhD study, the pilot study obtained ethical approval from the Psychology Department and Humanities Faculty Ethics Committees (see Appendix A).

This pilot study focused on the magnitude of REM density, and how this relates to DRF, as well as the potential differences between intra-sleep awakenings/wakefulness and how these may be associated with DRF.

This study had a quasi-experimental design, and was conducted over a number of phases. After a two-stage screening process, the data was collected at the University of Cape Town sleep laboratory.

Participants

The study included both female and male participants from the University of Cape Town student body (N=26). Both female and male participants were utilized so as to create a more representative sample.

The participants were divided into two groups; namely, HFR dreamers and LFR dreamers. The division was operationalized through the participants' self-reported number of dreams in the past month on two different occasions. Thus, those who recalled greater than three dreams per week formed the HFR group, and those who recalled fewer than two dreams per month formed the LFR group. This division was based on the protocol employed in Eichenlaub et al. (2014b) and Eichenlaub et al. (2014a). Participants were also given dream diaries to record their own dreams, but, even with frequent communications and reminders, compliance was low and responses were inconsistent.

The participants in each group were matched on all demographic and psychiatric factors, as well as sleep quality parameters, in order to ensure that the only difference between the groups was DRF.

Measures and Apparatus

Screening measures. In order to be selected for the study, potential participants underwent a thorough screening process that took place in two phases. Phase one included questionnaires that were completed as part of an online survey. These included demographic information, medical history, dream recall frequency, psychiatric history, The Michigan Alcoholism Screening Test (Selzer, 1971), as well as the Beck Depression Inventory-II (Beck, Steer, & Brown, 1996) and the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). If potential participants indicated that they either remember more than three dreams per week, or less than two dreams per month, and their questionnaire scores were within normal parameters, they were invited to participate in the second phase of the screening process.

In phase two of screening, participants gave written consent; subsequent to this the Shipley-2 IQ test (Shipley, Gruber, Martin, & Klein, 2009) was administered. Following this, the Mini International Neuropsychiatric Interview (Version 5; Shehaan et al., 1998) was conducted in order to cross-validate the survey results as well as screen for other major disorders. The different screening measures will be discussed in more detail below.

The Michigan Alcohol Screening Test (MAST; Selzer, 1971) was utilized to identify possible alcohol or substance abuse amongst individuals. This self-report test was quick, and consists of twenty-four questions. Individuals who obtained scores above 4 were excluded from participation. This measure has been used reliably in the South African context (Bekker & van Velden, 2003).

The Beck Depression Inventory-II (BDI-II; Beck et al., 1996) screened for potential depressive disorders. As depression can alter the sleep cycle of an individual (Argyropoulos & Wilson, 2005), it was important to note the potential presence of these disorders in the screening phases. Individuals who scored 14 or above, which indicates the presence of mild depression, were excluded from the study (Beck et al., 1996). This is a self-report questionnaire, and it has high internal consistency in both clinical and healthy populations (Richter, Werner, Andres, Kraus, & Sauer, 1998). In terms of cross-cultural use, studies conducted in South Africa have used this measure successfully (Seedat, Nyamai, Njenga, Vythilingum, & Stein, 2004).

The Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989) is a twenty-four item subjective measure of sleep quality, which focuses on sleep disturbances over a one-month time period. The measure has good reliability; thus, this was an acceptable way to identify reduced sleep quality amongst the potential participants. Participants with total scores exceeding 5 were excluded from participation.

The Shipley-2 IQ Test (Shipley et al., 2009) is a short, robust measure of cognitive functioning (Kaya, Delen, & Bulut, 2012). Composite B, which includes verbal and block tasks, assesses both fluid and crystallized intelligence (Kaya et al., 2012). The reason for including this measure pertains to matching groups on IQ, as this is standard practice when cognitive tests (the memory tasks forming part of the bigger study) are utilized.

The Mini International Neuropsychiatric Interview (MINI; Shehaan et al., 1998) is a diagnostic interview that follows a structured format. It is useful in screening for psychiatric disorders, and the most recently validated version corresponds to disorders as described in DSM-IV-TR. Additionally, it is short and easy to administer.

Exclusion criteria. In order to be eligible for this study, potential participants were asked to go through a thorough screening process (as mentioned above). This examined medical history, psychiatric history, medication and drug use, alcohol use, and subjective sleep quality. Specific criteria that led to exclusion from participation are listed below:

1) Individuals who showed signs of alcohol or drug abuse. Alcohol and drugs affect and alter sleep architecture in a multitude of ways (Carskadon & Dement, 2011; Zhang, Samet, Caffo, & Punjabi, 2006).
2) Individuals below the age of 20 and above the age of 40 were excluded from participation. This is due to the different sleep architecture found in adolescents and older adults (Carskadon & Dement, 2011).

3) Individuals who took chronic medication, or medications that could alter the natural sleep cycle (such as sleeping pills or sedatives) were excluded.
4) Individuals who had a history, or currently exhibited signs of insomnia, depression, anxiety, and other major axis I diagnoses. These conditions all have the potential to affect normal sleep architecture.

Figure 1 represents the reasons for excluding 807 individuals from the study, based on exclusion criteria and screening measures outcomes.

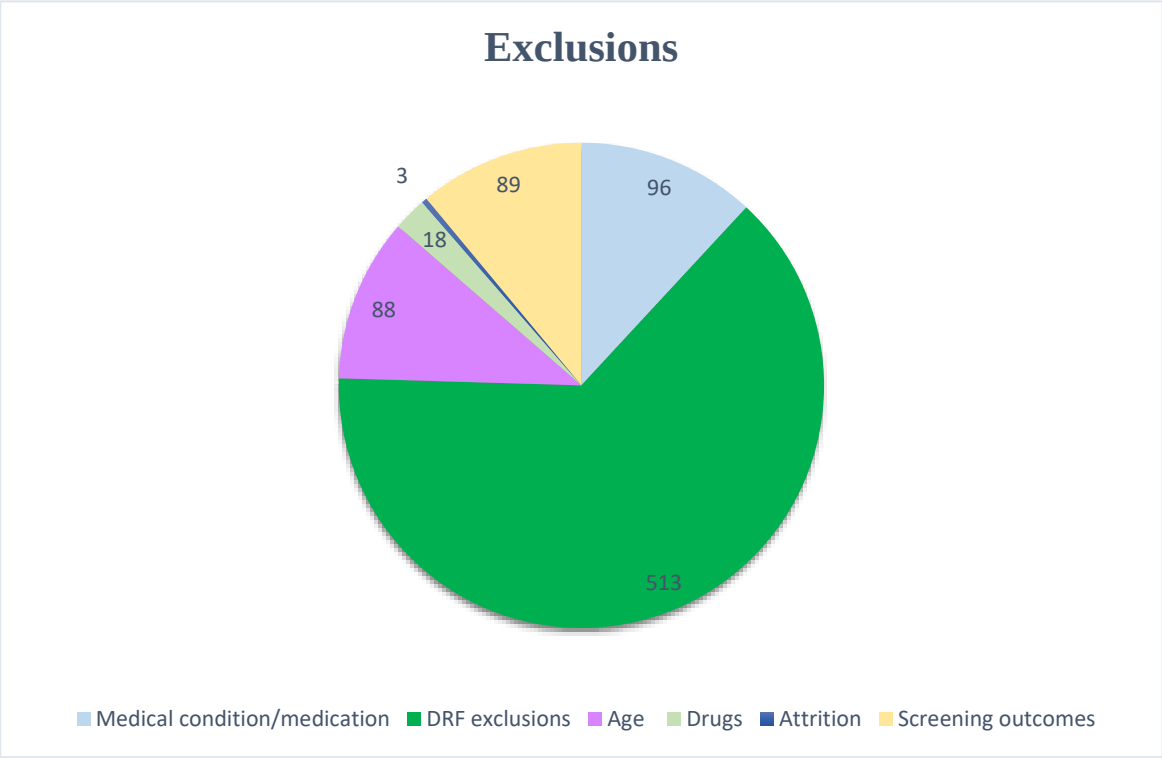

Figure 1. Reasons for Excluding Individuals from Participation. This figure presents the reasons for excluding approximately 807 individuals from the current study. DRF = dream recall frequency; here, exclusions were made when individuals reported dream frequency that did not meet the criteria previously stated for use in this study; screening outcomes = included individuals scoring above cut-off points on the BDI-II, PSQI, MAST, or MINI. Additionally, medication/medical conditions and drug use that may interfere with sleep architecture were excluded. Age = individuals below the required age of 20 and above the age of 40 were also excluded.

Table 1 reflects the demographic variables and screening outcomes from the eligible participants in this study. This shows that the HFR and LFR groups are adequately matched with the exception of the variable of interest: DRF.

Table 1

Participants: Demographic Data and Screening Outcomes

Variables	HFR	LFR	t/χ^2	*df*	*p*
Age	21.07	24.54	-1.93	13.56	.075
	(1.52)	(6.28)			
Highest level of education	12.38	13.46	-1.54	14.087	.146
	(1.05)	(1.94)			
Shipley IQ	106.85	105.38	.30	24	.765
	(13.16)	(13.30)			
PSQI	3.77	3.54	-.542	18.36	.595
	(1.35)	(1.05)			
BDI-II	5.31	3.77	1.51	19.20	.149
	(1.91)	(3.19)			
MAST	0.77	1.00	-.54	24	.593
	(0.70)	(1.35)			
Dream recall frequency	4.69	0.25	12.99	12	<.001**
	(1.11)	(0.01)			
Dream interest	3.38	2.92	1.36	24	.593
	(0.64)	(1.04)			
Awakenings			5.87[a]	1	.016*

Note. The test statistic was independent samples *t*-test. Highest level of education is presented in years of completed education. HFR and LFR columns reflect mean values with standard deviations in parenthesis. *df* = degrees of freedom. Dream interest was obtained through self-reported interest in dreams, from 1 (not interested) to 4 (very interested). For awakenings, chi square is reported as values were coded as categorical variables. Awakenings = Most Recent Dream Form (MRDF) administered upon awakening. This result indicates the differences between HFR and LFR groups with regards to reporting dreams upon awakening.

*$p < .05$; **$p < .01$.

[a] χ^2 (1) statistic reported.

Table 1 represents the groups as evenly matched on demographic variables and screening outcomes. Each group contained an equal number of females (n = 5) and males (n = 8). Notably, there is a significant difference between the self-reported DRF of the groups, as well as the objective dream recall upon awakening measure. The most recent dream form (MRDF), given to the groups upon awakening, indicates that 72.7% of HFR individuals recalled dreams compared to only 36.4% of LFR individuals; which supports the original division of the two groups according to DRF obtained through self-report.

Experimental measures. DRF has been studied in a number of ways across studies. Research states that certain state and trait factors, such as affect, personality and the thickness/thinness of boundaries[1], may be associated with an individual's DRF. For this reason, the following experimental measures were utilized:

The personality inventory utilized was the Ten-Item Personality Inventory (TIPI; Gosling, Rentfrow, & Swann, 2003). This is an easy to administer measure, and presents adequate reliability as a short measure of personality. The short measure was chosen in order to minimize the testing burden on the participant. It is structured around the factors of agreeableness, openness to experience, extroversion, emotional stability (conversely neuroticism), and conscientiousness (Gosling et al., 2003). This measure is based on the Big-Five personality dimensions (Gosling et al., 2003).

A short form of the Boundary Questionnaire (BQ-Sh; Rawlings, 2001) was employed to establish the differences in individuals' boundary thickness/thinness. This construct refers to the degree of closeness ('thinness') of an individual to their inner thoughts, feelings, and emotions, versus the degree of separateness ('thickness') of an individual to these inner components (Beaulieu-Prevost & Zadra, 2007; Hartmann, Elkin, & Garg, 1991). Thinness/thickness of boundaries also concern an individual's sense of identity: thin boundaries are associated with fluidity between the self and others, as well as between reality and fantasy, whereas thick boundaries are associated with clearly differentiated identity of the self from others, and a marked difference between reality and fantasy (Schredl & Erlacher, 2004). According to this construct, an individual's thinness/thickness of personality boundary may relate to DRF (Beaulieu-Prevost & Zadra, 2007). For this reason, the measure was included in examining characteristic differences in our sample.

[1] An example of 'thin' boundaries would be trusting people easily; being vulnerable; and being open. Examples of 'thick' boundaries include having distinct and clear ideas about time; being guarded around unknown people; and being careful (Rawlings, 2001).

The Positive and Negative Affect Schedule-Expanded version (PANAS-X; Watson & Clark, 1994) is a tool that for example, measures affective states, such as fear, hostility, sadness, shyness, joviality. The measure was administered before the participant went to sleep, and once more upon awakening in order to track any overnight changes that may occur. Including this measure in this fashion was exploratory.

Objective measures of sleep. *Polysomnography.* The UCT Sleep Sciences laboratory has all the necessary equipment to conduct a sleep study in a research setting. This includes an EEG, an electrooculograph (EOG), electrocardiograph (ECG), and an electromyograph (EMG). The EEG is sleep-adapted, and serves to measure brain activity during the night. The EOG measures eye movements throughout the sleep cycle; thus serving as an important measure of REM density in this study. The EOG placement was based on the Rechtschaffen and Kales (1969) method, which is a robust method of detecting horizontal eye movements. The EMG measured the muscle tone of the participant throughout the sleep cycle, and the ECG recorded the corresponding cardiac information. The data obtained through EEG, EOG, ECG, and EMG measures was scored according to the principles provided by the American Academy of Sleep Medicine (2015).

The sleep variables of interest in this study are as follows: REM density, total sleep time (TST), sleep onset latency (SOL), wake after sleep onset (WASO/WASO%), sleep efficiency (SE), stage 1 percentage (N1%), stage 2 percentage (N2%), stage 3 percentage (N3%), REM sleep percentage (REM%), total awakenings, N2 awakenings, N3 awakenings, and REM awakenings. Based on previously discussed literature (see Eichenlaub et al., 2014a; Eichenlaub et al., 2014b), there was a specific focus on awakenings and WASO%; this is due to the idea the arousal-retrieval model has put forth: differences in the amount and length of intra-sleep awakenings may be associated with differences in DRF.

Procedure

This study involved a number of phases. Phase one included distributing a recruitment e-mail to the University of Cape Town student body (see Appendix B). The recruitment e-mail was distributed to other individuals in the Cape Town area via numerous forms of social media. This e-mail invited individuals to participate, and included a link for those who were interested. This link led to the phase one screening measures, including: demographic forms, medical history forms, psychiatric history forms, MAST, BDI-II and PSQI. It also included an online consent form (see Appendix C).

If eligible after phase one screening, individuals were invited to the sleep laboratory for the second phase of screening. Phase two required participants to fill out a consent form in person (see Appendix D), and involved the Shipley-2 IQ test and the MINI. After scoring all the measures, potential participants were informed whether they were eligible to continue. If they agreed to participate, the adaptation night and testing night were scheduled non-consecutively at the UCT Sleep Sciences laboratory.

An adaptation night was included in the protocol to allow participants to acclimatize to the sleep laboratory environment and to the use of the polysomnography equipment. This aspect of the study design is beneficial in that it acts to eliminate or reduce the first night effect, which is a recognized bias in polysomnography data (Le Bon et al., 2001). This is due to a number of factors, including a strange sleep environment and the initial discomfort of the polysomnography equipment (Le Bon et al., 2001). Due to the possibility of this effect lasting more than one night (Le Bon et al., 2001), or that testing night data may be biased by the presence of recovery sleep, the testing night never followed the adaptation night consecutively. During the adaptation night, the participants were attached to the polysomnography; however, they did not undergo any other forms of testing except for completing the MRDF upon awakening in the morning.

Following this, the sleep-testing phase took place. As previously noted, this never took place on a consecutive night. The participant was attached to the polysomnography, identical to the adaptation night; however, they were required to complete the PANAS-X, the TIPI, and the BQ-Sh. In addition to this, participants completed three memory tasks and a heart rate counting task that formed part of the larger study's protocol. Upon awakening, participants filled in the MRDF, the PANAS-X, and the recognition component of the memory tasks.

After the sleep-testing phase, debriefing occurred and the participants received their compensation.

Statistical Analysis

The independent variable for all levels of the analyses is the group condition: HFR dreamers (n = 13) and LFR dreamers (n = 13). There are three main sets of analyses in this study: the first involves the PANAS-X, BQ-Sh, and TIPI as the dependent variables; the second analysis involves the sleep variables listed above as the dependent variables; and the third analysis involves REM density as the dependent variable. In addition to these three

analyses, a correlation analysis was conducted to identify whether there was a significant relationship between the dependent variables.

REM density was analyzed in terms of frequency and amplitude. Rapid eye movements were measured through application of EOG electrodes on two points surrounding the eyes. These measured the horizontal eye movements (Rechtschaffen & Kales, 1969). The EOG channel was set at 50Hz notch filtered; additionally, bandpass filtered from 0.3-30Hz. The double-threshold eye movement detection method was utilized to determine the presence of a horizontal rapid eye movement, with a high threshold of 30uV and a low threshold of 10uV. Due to digital computers, EEG and EOG activity data were analyzed in a manner that extracted and quantified information regarding frequency, amplitude, and sleep phase with more accuracy than traditional, or manual scoring methods (Pivik et al., 1993). In addition to this quantitative analysis, the entire dataset was also manually inspected so that REM state data corresponding to noisy sections of EOG waveforms could be deleted from the spreadsheet generated by the MATLAB program (MathWorks, 2015) following analysis. Within each REM stage, REM density was calculated through a process, which was based on a method employed by Stanford's Center for Sleep Sciences (Moore, Mignot, Shenoy, Widrow, & Woodward, 2013): firstly, REM density for each 30 second epoch was calculated by dividing this epoch into 2 second mini-epochs, and by using the double threshold method. Each of these mini-epochs was analyzed for rapid eye movements. There needed to be at least one eye movement in each 2 second mini-epoch to conclude that an eye movement had taken place within that mini-epoch; any more than one eye movement was still recorded as a single movement within a mini-epoch.

The value of REM density was calculated for each 30 second epoch as a percentage of 2 second mini-epochs that contain eye movements. If a participant had a REM sleep cycle exceeding 30 seconds, then additional REM density values would be generated. Thus, longer REM sleep cycles produced several REM density values, which depend on the number of 30 second epochs constituting that stage. Total REM density value for each participant per night was calculated by finding the mean percentage of the frequency of rapid eye movements for every 30 second epoch for the entire duration of every REM cycle. This was calculated for each eye channel, where they were subsequently added together and averaged; producing the ultimate REM density value per participant. To detect whether HFR individuals have higher REM density values in comparison to LFR individuals, a series of independent *t*-tests were conducted. Similarly, independent *t*-tests were conducted in the other analyses, too. All collected data was analyzed using SPSS software (Howell, 2004).

Results

Characteristics of the Sample

As depicted in Table 1, the HFR and LFR groups were matched on all demographic and screening variables, with the only difference being DRF. DRF was measured by self-report, while dream reports obtained upon awakening were also recorded in order to objectively investigate whether differences in DRF exists between groups. Both subjective [$t(12) = 12.99$, $p < .001$] and objective [$\chi^2 (1) = 5.87$, $p = .016$] values reached significance. As previous research has found an association between DRF and dream interest, self-reported interest in dreams and DRF group was investigated (Beaulieu-Prevost & Zadra, 2007). In order to identify whether there is a difference in the interest in dreams between the HFR group ($M = 3.38$, $SD = 0.64$) and the LFR group ($M = 2.92$, $SD = 1.04$), a *t*-test was conducted, $t(24) = 1.36$, $p = .593$. This further indicates that the HFR and LFR groups were matched on all demographic variables, screening outcomes, and interest in dreams; DRF was the only significant exception between the groups.

Data relating to the personality, boundary, and positive/negative general emotions of the HFR and LFR groups were collected using the TIPI, BQ-sh, and PANAS-X. This was used to see if there are differences in personality factors, boundary thickness/thinness, and general affect between individuals who have high DRF versus those who have low DRF. A series of independent *t*-tests were run; these results are summarized and presented in Table 2.

Table 2

State and trait characteristics of the sample

	HFR *M (SD)*	LFR *M (SD)*	*t*	*df*	*p*	*ESE*
TIPI Extroversion	4.96 (1.55)	4.23 (1.45)	1.24	24	.226	.25
TIPI Agreeableness	5.54 (0.90)	4.38 (0.85)	3.52	24	.002**	.58
TIPI Conscientiousness	5.73 (1.09)	5.73 (1.03)	<.01	24	.1.00	.002
TIPI Emotional Stability	5.85 (1.17)	5.77 (0.86)	.22	24	.414	.005
TIPI Openness	5.77 (0.97)	5.69 (0.99)	.20	24	.422	.04
BQ-Sh Total Score	69.92 (14.31)	60.62 (10.36)	1.90	24	.035*	.36
PANAS Night GPE	28.85 (9.09)	28.23 (8.78)	.17	24	.865	.04
PANAS Night GNE	11.46 (2.17)	13.23 (5.51)	-1.07	24	.294	.21
PANAS Morning GPA	25.08 (9.40)	27.08 (9.14)	-.54	24	.595	.11
PANAS Morning GNE	10.85 (3.03)	11.69 (2.78)	-.98	17.75	.840[a]	.20

Note. TIPI = Ten-Item Personality Inventory; BQ-Sh = Boundary Questionnaire Shortform; PANAS-X GPE = Positive and Negative Affect Schedule- Expanded Version General Positive Emotion; PANAS-X GNE = Positive and Negative Affect Schedule- Expanded Version General Negative Emotion; *ESE* = effect size estimate, calculated using Cohen's *d.*

A one-tailed *t*-test was run for the BQ-Sh, TIPI openness to experience, and TIPI emotional stability, as previous literature suggests there may be an association between DRF and these constructs. BQ-Sh higher scores indicate 'thinner' boundaries.

Two-tailed *t*-tests were conducted for the remaining variables.

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

[a]As Levene's Test was significant, a non-parametric independent samples test was run to determine significance more accurately.

As one can see from Table 2, some significant differences were found between HFR and LFR groups. For instance, the TIPI personality measure of agreeableness, $t(24) = 3.52$, $p = .002$, ESE = .58.

The BQ-sh, which measures the boundary construct, also revealed a significant difference between HFR and LFR individuals, $t(24) = 1.90$, $p = .035$, ESE = .36.

A paired-samples *t*-test was conducted to identify if there were any significant differences between the PANAS-X night/morning conditions within HFR and LFR groups. Table 3 reflects the results of comparing the PANAS-X night condition (general positive and negative emotion) with the morning condition (general positive and negative emotion) within each group.

Table 3

Paired Samples Test: PANAS-X

		N	*M (SD)*	*t*	*df*	*p*
Pair 1 HFR	PANAS Night GPE & PANAS Morning GPE	13	28.85 (9.42) 25.08 (9.78)	1.65	12	.124
Pair 2 HFR	PANAS Night GNE & PANAS Morning GNE	13	11.46 (2.22) 10.85 (1.41)	1.43	12	.180
Pair 1 LFR	PANAS Night GPE & PANAS Morning GPE	13	28.23 (8.78) 27.08 (9.14)	.53	12	.604
Pair 2 LFR	PANAS Night GNE & PANAS Morning GNE	13	13.23 (5.51) 11.69 (2.78)	1.58	12	.139

Note. PANAS-X GPE = General Positive Emotion; PANAS-X GNE = General Negative Emotion. Degrees of freedom presented under *df*. Two-tailed, paired sample *t*-test, $*p < .05$.

The results in Table 3 show that there were no significant differences within each group, with regards to the PANAS-X night/morning measures.

Testing Hypothesis 1 and 2: Objective Sleep Parameters

In order to assess hypothesis 1 (HFR individuals will have greater REM density values compared to LFR individuals) and hypothesis 2 (HFR individuals will experience more awakenings, as well as spend more time awake after sleep onset compared to LFR individuals) independent *t*-tests were conducted to analyze potential differences with regard to the following sleep variables: REM density, number of awakenings, and WASO%. In addition, other common sleep variables were also included in the analyses in order to detect any other differences in sleep architecture: total sleep time (TST), sleep onset latency (SOL), sleep efficiency (SE), N1%, N2%, N3%, REM%, N1 awakenings, N2 awakenings, N3 awakenings, and REM awakenings. Results from the independent *t*-tests can be seen in Table 4.

Table 4

Objective Sleep Parameters

	HFR *M (SD)*	LFR *M (SD)*	*t/U*	*df*	*p*	*ESE*
REM density	38.54 (26.42)	33.70 (11.10)	.610	16.11	.420[a]	.15
TST	369.08 (96.81)	380.19 (1.21)	-.39	14.47	.840[a]	.11
SOL	34.92 (21.83)	24.08 (16.34)	1.43	24	.165	.28
WASO%	14.81 (10.12)	8.63 (4.32)	2.03	16.23	.032*[a]	.50
SE	85.29 (11.76)	88.94 (5.94)	-1.00	24	.164	.20
N1%	11.83 (5.31)	12.36 (8.19)	-.19	24	.848	.04
N2%	58.16 (18.05)	59.13 (8.62)	-.17	24	.863	.04
N3%	13.74 (7.89)	13.33 (4.76)	.16	24	.873	.03
REM%	11.80 (6.23)	15.18 (5.01)	-1.53	24	.070	.30
Total awakenings	28.31 (12.03)	21.62 (6.81)	1.75	24	.047*	.34
Wake N2	19.46 (10.97)	12.00 (6.19)	2.14	24	.043*	.40
Wake N3	2.62 (1.26)	2.62 (1.85)	<.01	24	1.00	<.001
Wake REM	6.08 (3.75)	7.15 (4.10)	-.70	24	.491	.14

Note. HFR = high frequency recall; LFR = low frequency recall. HFR and LFR reflect mean values with standard deviations in parenthesis.

TST = total sleep time; SOL = sleep onset latency; WASO/% = wake after sleep onset measured in minutes; SE = sleep efficiency; N1% = percentage of sleep time spent in stage 1 sleep; N2% = percentage of sleep time spent in stage 2 sleep; N3% = percentage of sleep time spent in stage 3 sleep; REM% = percentage of sleep time spent in REM sleep; Wake N2 = number of awakenings in stage 2; Wake N3 = number of awakenings in stage 3; Wake REM = number of awakenings in REM sleep.

ESE = effect size estimate, calculated using Cohen's *d*.

*$p < .05$. [a]Levene's Test was significant for REM density, and thus a non-parametric, independent samples Mann-Whitney *U* test was run to determine exact significance. This test was one-tailed.

A one-tailed *t*-test was used for WASO%, total awakenings, and REM density, as it was hypothesized that there would be a difference between the groups. Two-tailed *t*-tests were employed for the other variables.

Table 4 illustrates that WASO% produced a significant difference between the HFR and LFR groups $U = 2.03$, $p = .030$, $d = .50$. Additionally, total awakenings differed significantly between the groups, $t(24) = 1.75$, $p = .047$, $d = .34$. Furthermore, there was a

significant difference between the amount of N2 awakenings between HFR and LFR groups, $t(24) = 2.14$, $p = .043$, $d = .40$.

Table 4 does not reflect a significant difference between REM density and DRF group, however, the means do suggest that the direction of the trend in the data corresponds with our hypothesis.

Figure 2 reflects the mean REM density values of the HFR and LFR groups.

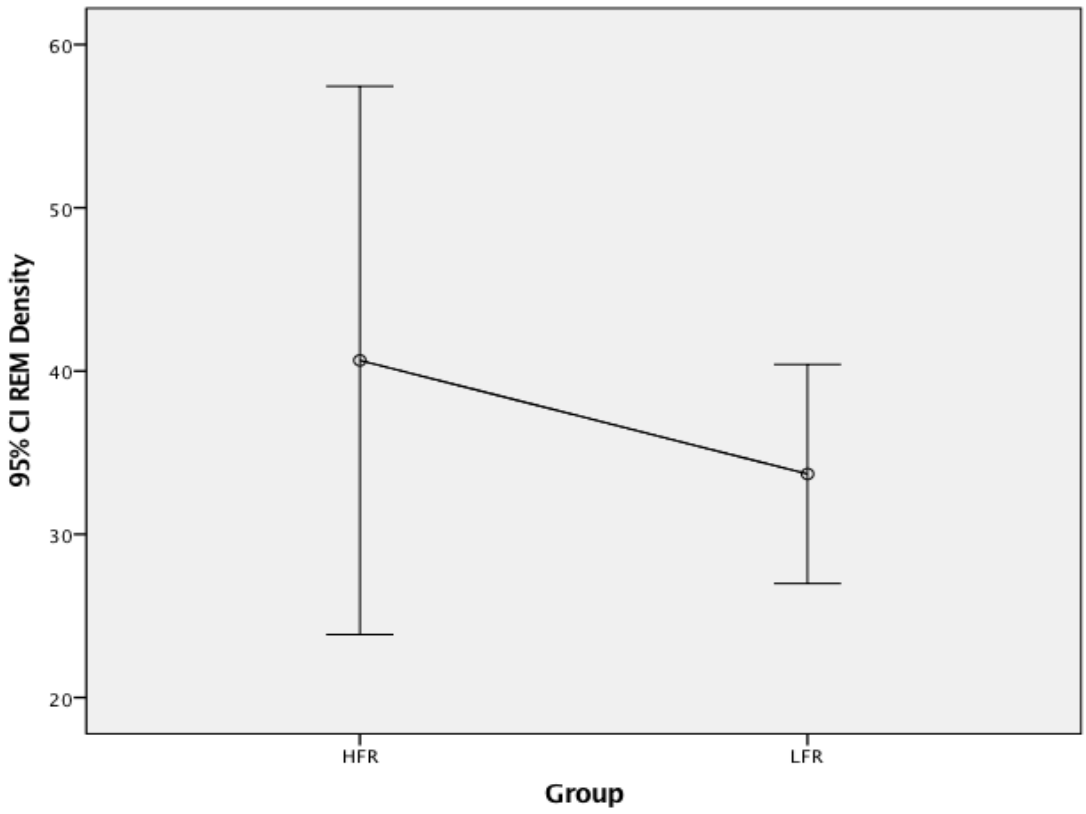

Figure 2. A Graphical Representation of the Group Mean Data for REM Density. Error bars represent 95% confidence interval. HFR = High frequency recall; LFR = Low frequency recall.

A series of correlational analyses were conducted on selected variables to ascertain whether or not the previous results were a function of associations between other variables. This was conducted in order to strengthen support for the results from the initial analyses. These correlations can be seen in Table 5.

Table 5

Correlations

		Age	PSQI	BDI	BQ-Sh	WASO%	Total Awakenings	Wake N2
Age	Pearson Correlation	-	.09	-.13	-.10	.13	-.11	-.09
	Sig. (2-tailed)		.656	.543	.622	.542	.603	.647
PSQI	Pearson Correlation	.09	-	.12	.02	.17	.04	.09
	Sig. (2-tailed)	.656		.549	.927	.407	.840	.651
BDI	Pearson Correlation	-.13	.12	-	-.001	.26	.18	.33
	Sig. (2-tailed)	.543	.549		.997	.208	.382	.098
BQ-Sh	Pearson Correlation	-.10	.02	-.001	-	-.03	.19	.12
	Sig. (2-tailed)	.622	.927	.997		.894	.349	.560
WASO%	Pearson Correlation	.13	.17	.26	-.03	-	.13	.30
	Sig. (2-tailed)	.542	.407	.208	.894		.543	.142
Total Awakenings	Pearson Correlation	-.11	.04	.18	.19	.13	-	.91
	Sig. (2-tailed)	.603	.840	.382	.349	.543		<.001**
WAKE N2	Pearson Correlation	-.09	.09	.33	.12	.30	.91	-
	Sig. (2-tailed)	.647	.651	.098	.560	.142	<.001**	

Note. PSQI = Pittsburgh Sleep Quality Index; BDI-II = Beck Depression Inventory-II; BQ-Sh = Boundary Questionnaire Shortform; WASO% = Wake after sleep onset; Wake N2 = stage 2 awakenings.

**$p < .01$ (2-tailed).

As the literature suggests variables such as age and BDI-II score may affect sleep architecture, this study investigated the correlational relationships between these variables; additionally, correlations were conducted to determine whether self-reported sleep quality was related to the objective parameters employed in this study. One can see that there was no significant relationship between age and the selected sleep variables: WASO% [$r(24) = .13$, $p = .542$], total awakenings [$r(24) = -.11$, $p = .603$], and N2 awakenings [$r(24) = -.09$, $p = .647$]. Furthermore, BDI-II scores were not significantly correlated with the sleep variables: WASO% [$r(24) = .26$, $p = .206$], total awakenings [$r(24) = .18$, $p = .382$], and N2 awakenings

[$r(24)= .33$, $p = .098$].

The only significant correlation result found was between total awakenings (M = 24.96; SD =10.17) and N2 awakenings (M= 15.73; SD = 9.52), $r(24) = .91$, $p < .001$. However, this result is to be expected, as N2 awakenings form part of the total awakenings recorded and that sleep variables tend to be correlated with each other. Sex was not included in the analyses as groups were perfectly matched in this regard.

Discussion

Previous research supports the idea that although dreaming may occur in NREM sleep, there is a stronger association between REM sleep and dreams. However, studies have presented mixed findings and explanations for the notable intra-individual differences in DRF. This could be due to the varying methodologies employed across studies, and to the use of retrospective or subjective measures of dream recall. Due to this, very little is known about intra-individual differences in dream recall, and whether this difference is associated with enhanced memory encoding (and therefore recall) of dreams, greater production of dreams, or if it is a combination of the two. Before these hypotheses can be addressed, results pertaining to the sample characteristics must be discussed.

Sample Characteristics

A notable and considerable strength of this study is the homogeneity of the sample utilized. Through very stringent exclusion criteria and screening measures, 807 (97%) of individuals who applied to participate in this study were excluded; this left a sample of 26 eligible participants that made up the HFR and LFR groups for the pilot study. Although this sample size is small, it was necessary in order to obtain a ‘clean’ homogenous sample that would not bias the data. Furthermore, HFR and LFR groups were matched on all screening outcomes and demographic variables; which highlights the only difference between the two groups: the independent variable of DRF. DRF was operationalized in two ways to control for error: firstly, participants provided a self-report of how many times they recall dreaming in the last month on two separate occasions, and secondly, obtaining objective dream reports upon awakening in the morning. This was achieved by administering the MRDF to participants upon awakening on both the adaptation and testing nights. The result from the MRDF shows that the self-report measure was accurate in statistically discerning between the

two groups, as 72.7% of the HFR group reported a dream upon awakening versus 36.4% of the LFR group.

State and Trait Characteristics of the Sample

Previous literature focusing on explaining why individuals differ on DRF has often centred on the state and trait characteristics of the sample. For instance, Schredl, Ciric, Gotz, and Wittmann (2003) reported a significant relationship between DRF, thinness of boundaries, emotional stability (also known as neuroticism), as well as openness to experience. In addition to this, there has been extensive research on the potential bias of positive or high interest in dreaming on the recorded dream recall of an individual (Beaulieu-Prevost & Zadra, 2007; Schredl et al., 2003).

The results in the present study reflect a significant difference between the two groups with regards to the boundary construct (p = .035); which replicates findings in previous studies (see Beaulieu-Prevost & Zadra, 2007; Schredl et al., 2003). As previously stated, the groups did not differ in reported interest in dreams (p = .593); nor was there a significant finding with regards to emotional stability (p = .414) and openness to experience personality dimensions (p = .873).

Although these results replicate previous findings, in which thin boundaries have been significantly associated with higher DRF, the present study presents contrasting findings with regards to an association between dream recall and thinness of boundary with interest in dreams: Schredl, Kleinferchner, and Gell (1996) stated that thin boundaries are not only positively correlated with DRF, but with the interest shown in dreams. If one takes into account that the boundary construct suggests that thin boundary individuals are more sensitive, vulnerable and prone to fantasy (Hartman et al., 1991), one could argue that the differences in the literature with regard to DRF are trait-related. In other words, the frequency with which individuals report dreams is a product of having thin boundaries, and not the result of better encoding or production of dreams. Some studies suggest that the difference in DRF is related to this trait in another way: Beaulieu-Prevost and Zadra (2007) propose that thinness/thickness of boundaries may dictate DRF differences, as individuals with thin boundaries have the tendency to overestimate their dream frequency, and individuals with thicker boundaries have the tendency to underestimate dream frequency. Essentially, if this hypothesis is true, then one could suggest that boundaries do not provide evidence of a direct association with DRF; instead, this construct could be more related to the differences in

individuals regarding personal tendencies to over- or under-report occurrences of dreaming, regardless of how often they objectively have, or recall having, dreams.

However, if one looks at boundaries in the context of DRF in neurophysiological and neuroimaging studies, it is also possible to argue that DRF is not a product of having thin differences (and thus, over-estimating dream occurrences); instead, it may be the case that possessing thin boundaries is an expression of the functional cerebral organization underlying higher DRF.

Differences in Functional Cerebral Organisation

This difference in functional cerebral organisation is supported within two dimensions. The first study used an evoked potential paradigm, which indicated that HFR individuals exhibited higher brain reactivity to different auditory stimuli compared to LFR individuals, both when awake and when asleep (Eichenlaub et al., 2014a). This reactivity to environmental stimuli is thought to underlie the greater amount of awakenings seen in HFR individuals, which, in turn, may facilitates better encoding of dream memory traces. Furthermore, it may also explain why HFR individuals have longer intra-sleep wakefulness: the high reactivity of HFR brains suggests that these individuals are more prone to reacting to external stimuli; culminating in longer periods of wakefulness after sleep onset (Eichenlaub et al., 2014a). This objective dissimilarity between the two groups suggests that there may be a neurophysiological difference that promotes increased DRF (Eichenlaub et al., 2014a).

A neuroimaging study also examined possible differences in functional cerebral organisation between DRF groups using positron emission tomography (PET) scans: results show that regional cerebral blood flow (rCBF) in a collection of brain areas associated with the default-mode network (DMN) was higher in HFR individuals than LFR individuals; specifically, when HFR individuals reported that their minds were wandering (Eichenlaub et al., 2014b). Once more, these difference existed both when individuals were awake and asleep. This provides strong support for Domhoff's (2011) proposition that the neural substrate of dreaming could function as a subsystem of the DMN (Eichenlaub et al., 2014b). The evidence for this proposition, in part, emerges from the areas of the DMN that show this increased rCBF: in REM sleep, the tempo-parietal junction of HFR individuals was significantly more active than LFR individuals (Eichenlaub et al., 2014b). As mentioned in previous sections, it has been postulated that this area of the brain in REM sleep is connected to dreaming activity (Braun et al., 1998; Domhoff & Fox, 2015).

These two studies together provide strong evidence for the proposition that there are neurophysiological and functional anatomical differences underlying DRF in individuals. Not only does this finding provide support for the hypothesis that an intrinsic difference in cerebral functional organization exists between the DRF groups, but it also may suggest why HFR individuals are associated with having thinner boundaries, and yet other undetermined phenomena.

Objective Sleep Measures

The findings regarding differences between HFR and LFR individuals in terms of objective sleep parameters reflects interesting results. The implications of these findings shall be discussed with regards to the originally stated hypotheses.

Hypothesis 1: Dream production. It was originally postulated that HFR individuals would report more dreams due to a greater production of dreams compared to LFR individuals, and that this would be inferentially confirmed through significantly greater REM density values in the HFR group. However, this idea was not supported by the findings of this study. Despite this, there is a mean trend in the data that corresponds to the stated hypothesis. It should be acknowledged that areas of the study design may have impacted the results in this particular analysis: not only is the sample size small, but the analysis method employed for REM density is relatively recent, and requires refining. However, evidence from neuroimaging studies suggests that the dream production hypothesis could be explored further in future research; not only through the connections between eye movements, PGO waves, and visual imagery of dreams, but also through greater investigation into existing findings that indicate the presence of increased rCBF in areas of the brain thought to be involved in the dreaming process (Domhoff & Fox, 2015).

Hypothesis 2: Dream encoding. Hypothesis 2 postulated that HFR individuals exhibit higher DRF because they encode more dreams. This was operationalized as HFR individuals exhibiting greater intra-sleep awakenings, as well as longer periods of wakefulness after sleep onset. Results in this study suggest that this hypothesis can be retained.

Awakenings. Findings reflect that HFR individuals exhibited significantly more intra-sleep awakenings than LFR individuals, $p = .047$. This has also been found in previous research: Eichenlaub et al. (2014a) found that higher DRF was associated with more self-reported and objectively measured intra-sleep awakenings. This study also reported that HFR individuals exhibited higher brain reactivity across vigilance states; which could possibly

explain why they experience these awakenings. Additional evidence confirms that there is a higher level of brain activity in high recallers, and that this stable brain state may lead these individuals to be more reactive to the external environment, even when asleep (Eichenlaub et al., 2014a; Eichenlaub et al., 2014b). Using the arousal-retrieval model, it could be argued that these awakenings, due to a higher level of brain reactivity, allow HFR individuals to transfer dreams to long-term memory storage, and thus increase DRF.

Wakefulness after sleep onset. The findings regarding wakefulness after sleep onset were also significant in this study, $p = .032$. As previously discussed, this suggests that higher brain reactivity in HFR individuals enhances awareness and reaction to the external environment during sleep (Eichenlaub et al., 2014a; Ruby et al., 2013). In concordance with previous research, these once more suggest that there is an intrinsic difference in the cerebral functional organization of HFR individuals; thus, allowing them to better encode, and subsequently recall, more dreams.

N2 awakenings. An interesting result obtained in this study concerns a significant difference in N2 awakenings between the DRF groups, $p = .043$. This was not expected in the context of this study, and the significance of this is beyond the scope of the present study; however, there are previous studies that suggest N2 sleep may be more open to processing and reacting to external stimuli (Ermis, Krakow, & Voss, 2010).

Hypothesis 3: Dream production/encoding combination. As discussed above, hypothesis 1 was insignificant, and was thus rejected in the context of this study. Therefore, regardless of the significance obtained in hypothesis 2, hypothesis 3 cannot be retained at this stage by default. It is important to note that the lack of significance of REM density values between the DRF groups does not necessarily indicate that there is no difference in dream production between individuals; as this idea remains unconfirmed, further research is warranted in the future.

Limitations and Future Directions

This study faced a couple of limitations, which may have influenced the reported findings. Firstly, the sample size was relatively small. This was due to the limited time frame in which this study needed to be completed, as well as the very stringent exclusion criteria and measures. However, this exclusion process benefitted the study through creating a more homogenous sample; additionally, the added adaptation nights strengthened the study design regardless of the additional time required. Given this, future research should employ a larger

sample size, but not at the cost of the study design and homogeneity of the sample, which add strength to the present study.

Another limitation of this study pertains to the method used to analyse REM density: as it is fairly novel in this context, there is little information regarding standardization and it is in need of refinement. Given the limited time frame in which this study took place, this refinement was not feasible.

Conclusion

Intra-individual differences in DRF have been attributed to numerous states, traits, and characteristics in the past (Schredl et al., 2003); however, there have been few studies investigating the relationship between DRF and objective sleep parameters. It was therefore the principle aim of this study to find a novel manner in which to investigate whether differences in DRF are due to production of dreams, encoding of dreams, or if it is a combination of these two.

Hypothesis 1 utilized REM density as an indication of dream production between the DRF groups; with greater REM density suggesting greater dream production. However, these findings were not significant, and thus this hypothesis could not be confirmed. Notably, the limitations of the study design in this area may have impacted findings, and thus, rejecting this idea should be seen as preliminary until further research is conducted.

Hypothesis 2, which adopted the arousal-retrieval model in speculating that greater awakenings and longer wakefulness will facilitate dream encoding and subsequent recall in the HFR group, proved to be significant in both awakenings, and in wakefulness after sleep onset. The suggestion that HFR individuals exhibit higher brain reactivity leading to these awakenings, and subsequent encoding of dreams, indicates that there may be an underlying functional difference in cerebral organization between the groups. Future research is required to develop and examine these potential neurophysiological differences further.

The findings in this study are thus an important contribution to previous literature; especially as they provide support for existing research using a novel manner of investigating dream recall. In addition to this, the present study by, for example examining boundary thickness, may have unexpectedly added the theoretical possibility that there are other unknown phenomena associated with the underlying functional cerebral organization evident in HFR individuals; suggesting that future research is imperative to further our understanding of the relationship between intra-individual differences in DRF, objective sleep parameters, and possible differences in functional organization of the human brain.

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Appendix A

Ethics approval form

DEPARTMENT OF PSYCHOLOGY

REPORT OF THESIS COMMITTEE

Student Name: Mariza van Wyk

Student #:

Degree: PhD

Title (as proposed) The role of dreaming in memory processes and emotion regulation during sleep

Supervisor: Prof Mark Solms

Co-supervisor:

Committee members: DR F. BOONZAIER
DR L. SCHRIEFF
DR S. MALCOLM-SMITH
DR P. NJOMBORO

WE:

1. Approve the proposal, and recommend that the student continue with the research.

(2.) Approve the proposal, and recommend that the student may continue with the research. However, we recommend that change(s), as noted below, be incorporated in the research, to the satisfaction of the supervisor.

3. Approve the proposal in terms of its ethical implications. If necessary, explanatory notes appear below.

4. Find the proposal unsatisfactory, for the reason(s) listed below. The student is hereby requested to re-present the proposal to a departmental thesis committee by _____.

UNIVERSITY OF CAPE TOWN

FACULTY OF HUMANITIES

DC: HUM /

PROPOSAL APPROVAL FORM

DOCTORATE (A research proposal must accompany this form)	RESEARCH MASTERS (A research proposal must accompany this form)	C/W MASTERS

SECTION A: (To be completed by candidate)
Please complete this form and return it to the Faculty Office once you have obtained the signatures of the supervisor(s) and Head of Department.

Surname	van Wyk				First Name(s)	Maiza	
Title	Mr.	Ms.	Mrs.	Miss	Student No	VWYMAI015	
Address	6 Hillside road, Tamboerskloof, Cape Town						
Telephone(Home					Work/Cell	0835656190	

Note: Your UCT Email address is the default email address for all official communication – make sure that you access it regularly.

Department	Psychology
Title of Dissertation:	The Role of Dreaming in Memory Processes and Emotion Regulation during Sleep

Qualifications held			
Degree/Diploma	Major(s) &) Subjects	Month/Year awarded	University
BA Humanities	Psychology, Afrikaans	2009, December	Stellenbosch University
Psychology Honours	Neuropsychology	2010, December	UCT
MA in Psychological Research	Neuropsychology	2013, June	UCT

Signature of candidate: Maiza Date: 24/04/14

SECTION B:

	Name	Signature	Date
Supervisor	Prof M. Solms		25/4/2014
Co-supervisor (if applicable)			
HOD	Prof. M. Solms		24/4/2014
Deputy-Dean: Research			
Ethics approval obtained where applicable	on behalf of Departmental Ethics Committee		24/4/2014

Appendix B

Online recruitment e-mail

You are invited to participate in a sleep study

We are looking for participants to take part in a sleep study at the UCT sleep laboratory. This study is about how dreaming relates to memory and emotion regulation. If you are eligible you will be required to spend 2 nights at the sleep lab, while we record your sleep and ask you to a couple of memory tasks. This study has been ethically approved by the Department of Psychology.

Are you between the ages of 20 and 40 years?
Are you a regular sleeper?

If you answered yes to all these questions and are interested, please click on the link below so that we can obtain additional information from you to determine if you are eligible.

Appendix C

Online consent form

1. Sleep Studies at UCT
Online consent form

This is a survey used for initial screening for sleep studies being carried out at the University of Cape Town (UCT). This online survey should take less than 15 minutes and will assess you on various aspects of your sleep routine and other qualities that affect sleep.

Taking part in this survey is completely voluntary, and you may withdraw at any time without incurring any penalties. The information you provide will be kept strictly confidential. This means that your digital data will be kept in secure computer files, and will only be shared with the researchers of these studies. Any information that is released to the public will not include your name or any personal details that may be used to identify you.

Please take this survey in a single session, and without consulting outside sources of information. This survey is intended to collect responses in a specific manner, and outside sources of information or activities between answering the questions may impact on the results. In order to control this to some degree, the survey must be completed in less than 20 minutes for the results to be considered.

There are no benefits or payments for completing this survey, however, if your responses indicate you are eligible, you may be contacted to meet with a researcher to participate in a second, short screening interview. This screening will determine if you are eligible for the sleep study, for which you will receive payment upon completion.

By continuing with this survey, you agree to supply personal information that is correct to the best of your knowledge.

if you do not agree, please close the page on your web-browser and do not continue.

If you have any questions, please contact sleep.dreamstudy@gmail.com

Appendix D

Information sheet and consent form

Information Sheet

PARTICIPATION IN UNIVERSITY OF CAPE TOWN RESEARCH STUDY INFORMATION SHEET

Name of Participant: _____
Title of research study: The Role of Dreaming in Memory Processes and Emotion Regulation During Sleep
Name of principal researcher: Mariza van Wyk
Department/research group address: Psychology Department, Faculty of Humanities, University of Cape Town
Contact number: 0835658190 (Mariza van Wyk)
Email: mariza.v.w@gmail.com

Dear Participant

You are invited to take part in a research study conducted by the Psychology Department at the University of Cape Town. This study is interested in looking at the relationship between dreaming, memory and emotion regulation. Please note that you participation is completely voluntary and that you may withdraw from the study at any time without any negative consequences for yourself. Any information collected will only be used for research purposes.

What's involved?
Sleep study
For the sleep study, you will be asked to come to the UCT Sleep Sciences laboratory on two non-consecutive nights (this will be scheduled at your convenience). In preparation for this, you will be asked to not sleep at all during the day on the days you will be coming to the sleep lab. You will also be asked to not drink any caffeine containing drinks (e.g. coffee) before coming to the hospital. For each night, you will be asked to arrive at the sleep lab at 8pm. Please eat at home before arriving as supper will not be provided for you.

At the sleep lab, you will be given your own private room to sleep in. There are bathroom facilities in the sleep laboratory and you will be given an opportunity to change into your sleeping clothes (please bring these with you). A technician will then hook you up to a polysomnograph machine. This is a machine that records your sleep. It consists of a box (which will be placed on your bedside table) that has leads attached to it. These leads have small pads on the end that will then be attached to various parts of your head to measure your brainwaves during sleep, and to your chest and stomach to measure your breathing during sleep. These pads are attached with a simple sticky substance, this does not hurt at all and we do not have to shave your hair, and they can easily be removed in the morning without any pain. It takes approximately 45 minutes for all the leads to be attached.

Once the leads have been attached, you will be asked to lie down in the bed. The technician will turn the machine on and test whether everything is working correctly. We will then turn

off the lights and ask you to sleep as you would normally at home. You will be left alone in your own room, but the researcher will be just outside the room monitoring your brainwaves on a computer. While we will be able to hear you if you call out something, you will also be giving a button to press if you need anything during the night. If you need to go to the bathroom during the night, we will simply unplug the machine and then plug in back in when you return.

For both nights, the technician will turn the lights on and wake you up at 6am in the morning. All the leads will then be taken off. This takes approximately 20 minutes. After that, you are able to go home.

Memory Testing
On the second night that you come to the sleep laboratory, we will ask you to complete three memory tasks. Completing these tasks will take approximately 30 minutes. You will complete similar tasks the following morning.

What information will we be using?
All the information that we collect from you during the two screening phases, during memory testing, as well as the data from the sleep testing nights will only be used for research purposes. It will be used as part of the principal researcher's PhD thesis and will also be used in future research publications. Complete confidentially will be maintained at all times, i.e. your information will be used, but your name will not appear on anything and all identifying information will be left out. Personal information will be kept completely private and stored on password-protected computers and locked filing cabinets.

Are there any risks?
There are no major risks associated with this study. The only minor risk is the slight possibility that you could fall out of bed. We will, however, make sure that you are completely comfortable. The researcher will be there for every step of the study, and should you feel uncomfortable at any time you may ask the researcher any questions and you may withdraw from the study at any time without any negative consequences for yourself.

Are there any benefits?

There are no direct benefits for participating in this study as this study is for research purposes only. However, if any sleep disorder is detected in the sleep laboratory, this information will be given to your doctor.

Is there any payment?
As you will be giving up a lot of your time, you will be paid for the nights that you spend in the sleep laboratory. For each night in the sleep laboratory, you will receive R150. Thus, if you complete the full two nights in the sleep laboratory, you will be paid R300.

PARTICIPATION IN UNIVERSITY OF CAPE TOWN RESEARCH STUDY CONSENT FORM

Title of research study: The Role of Dreaming in Memory Processes and Emotion Regulation During Sleep
Name of principal researcher: Mariza van Wyk
Department/research group address: Psychology Department, Faculty of Humanities, University of Cape Town
Contact number: 0835658190 (Mariza van Wyk)
Email: mariza.v.w@gmail.com

I, _____, confirm that I have read and agree to all the information in the information sheet provided for me and that I agree to take part in this study.

I hereby give permission for the researcher to use the information collected in the screening phases and the sleep study for research purposes. I acknowledge that all this information will used for research purposes, will be kept for future research purposes, may be used in future research publications, and will only be used if my name and all identifying information is omitted.

I agree to a monetary compensation of R150 for every night that I spend in the sleep laboratory.

I am aware that my participation is completely voluntary and that I may withdraw from this study at any stage without any negative consequences for myself.

Name of Participant: _____

Signature of Participant: _____

Date: _____

Name of Researcher: _____

Signature of Researcher: _____

Date: _____