Thesis Presented for the Degree of
DOCTOR OF PHILOSOPHY
In the Faculty of Humanities

The Functional Neurophysiological Sequelae Associated with High Frequency Dream Recallers

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July 2017

Declaration

I hereby declare that this dissertation is my own unaided work, both in concept and execution. To the best of my knowledge and belief this dissertation contains no material written by another person, except where due acknowledgement has been made in the text. Neither the substance nor any part of the above thesis has been submitted in the past, or is being, or is to be submitted for a degree at this University or at any other university, except where the methods reported in this dissertation overlap with other projects coming from our laboratory (e.g. the configuration of electrodes used in the polysomnographic studies).

Signed

06/07/2017

Mariza van Wyk

Date

"Dreaming is not only an act of communication; it is also an aesthetic activity, a game of the imagination, a game that is a value in itself. Our dreams prove that to imagine… is among mankind's deepest needs."

-Milan Kundera, The Unbearable Lightness of Being-

"It is a dreamless sleep throughout which we remain awake"

-Fernando Pessoa, The Book of Disquiet-

Acknowledgements

Writing and concluding this thesis represents but a small facet of the PhD process. Support from many people and organisations have enabled me to embark on and persist in this journey:

First and foremost, my supervisor, Professor Mark Solms, from the Department of Psychology. Thank you for your guidance, mentorship, and enthusiasm over the years. Working with you has not only been an intellectually enlightening experience, but it has also been a thoroughly enjoyable one.

My co-supervisor, Dr Gosia Lipinska, from the Department of Psychology. We have worked closely together for several years, you have taught me so much and have been instrumental in the development of my ideas. Thank you for your innumerable contributions.

To my partner, Ashleigh Beddow, an honorary sleep scientist and neuropsychologist. Thank you for spending countless evenings with me on the balcony formulating and refining my thoughts and theories. Your fierce and unrelenting belief in me is one of the greatest gifts I have received whilst on this PhD journey. Thank you for walking alongside me.

Lester John from Elemedic, who spent considerable time with me developing methods for studying the microstructure of sleep. Your contribution has been an integral part of this study and will form part of the legacy of our sleep laboratory, thank you.

Dr Ridwana Timol, my mentor and friend, you are the reason sleep research is being conducted in the Department of Psychology, and I am immensely grateful for your intellectual and personal contributions in this regard. Thank you for all your guidance over the years.

My family and friends who have been cheering me on since I started my undergraduate studies in 2007. This achievement I share with, and owe to all of you – I have been incredibly lucky to have your unconditional love and support. Thank you for keeping me grounded and motivated, and highlighting the importance of having fun along the way.

Thank you to the members of the ACSENT (Applied Cognitive Science and Experimental Neuropsychology) Team at the Department of Psychology. You have provided me with access to intellectual, technical and financial resources that were instrumental in the completion of this PhD.

To the National Research Foundation for invaluable financial support, as well as the Oppenheimer Memorial Trust whose financial contribution made an immeasurable difference especially in the late phases of this PhD.

To everyone who participated in my study, thank you for your time and contributions.

Abbreviations

ACC	Anterior cingulate cortex
BDI-II	Beck Depression Inventory – 2nd Edition
BQ-Sh	Boundary Questionnaire – Shortform
CAP	Cyclic alternating pattern
CBF	Cerebral blood flow
DMN	Default mode network
DRF	Dream recall frequency
DRFQ	Dream recall frequency quantified
ECG	Electrocardiograph
EDM	Emotional declarative memory
EEG	Electroencephalogram
EMG	Electromyograph
ERP	Event-related potential
EOG	Electrooculograph
fMRI	Functional magnetic resonance imaging
GPE	General positive emotion
GNE	General negative emotion
HFR	High frequency recall
HPA axis	Hypothalamic-pituitary-adrenal axis
LFR	Low frequency recall
LMT	Logical Memory Test
MAST	Michigan Alcoholism Screening Test

MINI	MINI International Neuropsychiatric Interview
mPFC	Medial pre-frontal cortex
MTL	Medial temporal lobe
NREM	Non-rapid eye movement sleep
NREM1	Non-rapid eye movement sleep stage 1
NREM2	Non-rapid eye movement sleep stage 2
NREM3	Non-rapid eye movement sleep stage 3
PC	Predictive coding
PET	Positron emission tomography
PD	Parkinson’s disease
PGO	Ponto-geniculo-occipital waves
PSG	Polysomnography
PSQI	Pittsburgh Sleep Quality Index
RAVLT	Rey Auditory Verbal Learning Test
RBD	REM sleep behaviour disorder
rCBF	Regional cerebral blood flow
REM	Rapid eye movement sleep
REMs	Rapid eye movements (during REM sleep)
SWS	Slow-wave sleep
TIPI	Ten-Item Personality Inventory
TPJ	Temporo-parietal junction
UCT	University of Cape Town
WASO	Wake after sleep onset

Table of Contents

List of Tables

List of Figures & Illustrations

Abstract

Background: Dreaming is a universal experience, yet there is considerable inter-individual variability with regard to dream recall frequency (DRF). Research on DRF has been prolific leading to the development of various models delineating possible processes involved in dream recall. One such model is the 'arousal-retrieval' model positing that intra-sleep wakefulness is required for dream traces to be encoded into long-term storage, essentially proposing increased DRF as a product of a better *memory* for dreams. Results from recent studies support this model by demonstrating longer periods of intra-sleep wakefulness in high frequency recallers (HFRs) compared to low frequency recallers (LFRs). Furthermore, results showed heightened brain reactivity, as well as increased regional cerebral blood flow in areas in the brain associated with dream production. These results are indicative of the existence of a functional neurophysiological trait innate to HRs, while also supporting the premise that apart from a better memory for dreams, HRs also may *produce* more dreams. Awakenings from rapid eye movement (REM) sleep yield the highest dream recall rates, rendering REM sleep as a reasonable starting point for studying rates of dream production. Furthermore, increased dream production during REM sleep might also affect related processes, for example, leading to enhanced overnight emotional memory consolidation and emotion regulation. **Hypotheses:** The current study investigated the functional neurophysiological sequelae associated with HFRs in a design where HFRs are compared to LFRs. Hypotheses include: (1) HFRs will score significantly higher on certain personality dimensions; (2) HFRs will experience significantly more awakenings, as well as longer periods of intra-sleep wakefulness; (3) HFRs will have significantly higher rates of dream production as measured by the frequency of eye movements (REM density) during REM sleep; and (4) increased dream production during REM sleep will lead to enhanced overnight emotional memory consolidation and emotion regulation in HFRs. **Methods:** The study consisted of two groups of healthy young adults: high frequency recallers (*n* = 19) and low frequency recallers (*n* = 17) who underwent polysomnographic recordings on two non-consecutive nights. Memory tasks and affective questionnaires were completed before and after a night of sleep. **Results:** (1) HFRs scored significantly higher on the ‘agreeableness’ personality dimension and on the Boundary Questionnaire; (2) HFRs experienced significantly more awakenings, especially from stage 2 non-rem (NREM) sleep, as well as significantly longer periods of intra-sleep wakefulness; (3) no significant between-group differences with regard to REM density, nor (4) overnight emotional memory consolidation and emotion regulation were found. **Conclusion:** Results support, firstly, the proposition that certain personality traits, differences in sleep architecture, and increased DRF are an expression of a functional neurophysiological arrangement innate to HFRs. Secondly, the findings suggest that NREM sleep, as opposed to REM sleep, is important in relation to DRF in this specific population. This is the first study to not only replicate existing findings, but to also contribute to the extant literature by illuminating additional characteristics and features associated with HFRs.

CHAPTER ONE: INTRODUCTION

Both dreaming and sleep have intrigued philosophers, scientists, and clinicians throughout the course of human history. Over the last century, research into sleep and dreaming has been prolific as new and advanced technology enabled scientists to not only study the phenomenology of dreaming, but also its neurobiological underpinnings. What is evident throughout the literature, is that not only is the dream experience varied across individuals, but there is also considerable inter-individual variability with regard to how often dreams are recalled.

In light of this, several models have been developed in an attempt to explain the variation in dream recall frequency (DRF) across individuals. One such model posit that periods of intra-sleep wakefulness are required for dream traces to be encoded into long-term storage in order to be recalled at a later stage. In addition to the development of different models, many studies have focused on creating psychological and personality 'profiles' of individuals with high DRF. This has led to the common belief that possessing certain psychological characteristics and/or personality traits lead to an increased interest in dream mentation and subsequent better recall of dreams.

However, recent neurophysiological and neuroimaging studies (Eichenlaub et al., 2014a; 2014b) have cast doubt on the directionality of the above assertion. Authors from these studies propose that there is a difference in the functional neurophysiological arrangement in the brains of high dream recall frequency (HRF) individuals compared to low dream recall frequency (LRF) individuals. This raises the possibility that, instead of increased DRF being a result of possessing certain personality traits, both certain personality traits and increased DRF might in fact be an expression of a specific functional neurophysiological arrangement innate to HFR individuals.

Furthermore, results from the Eichenlaub et al. (2014a) study provide empirical support for the arousal-retrieval model of dream recall by demonstrating that HFR individuals experiences longer periods of intra-sleep wakefulness enabling dream traces to be encoded into long-term storage. Therefore, these results provide support for the premise that HFR individuals have better *memory* for dreams. However, the neuroimaging study by Eichenlaub et al. (2014b) found increased regional cerebral blood flow in areas in the brain associated with dream production. This raises the possibility that HFR individuals not only remember more dreams, but also possibly *produce* more dreams. In order to test this assertion, a measure must be employed that is capable of objectively and reliably measure rates of dream production. One such measure relates to studying the frequency of rapid eye movements (REM density) during rapid eye movement (REM) sleep. Awakenings from REM sleep yield the highest rates of dream recall (up to 90%), and therefore serves as a good starting point for studying rates of dream production across the night.

In light of this, I will start off by reviewing different models of dream recall, as well as the literature on the psychological and personality profiles of HFR individuals. This will be followed by a discussion of studies adopting a neurobiological approach to studying features associated with HFR individuals, as well as the possibility that HFR individuals produce more dreams. Within this context I will discuss different methods of measuring rates of dream production during REM sleep. Finally, I will review the possible effects that increased dream production during REM sleep might have on neurobiologically-related process. These processes include overnight emotional memory consolidation and emotion regulation.

CHAPTER TWO: LITERATURE REVIEW

Sleep is a recurring phenomenon common to most species that is characterised by a reversible state of altered consciousness. In humans, sleep is not only vital in terms of restoring physiological homeostasis, but it is also plays an imperative part in mental well-being and optimal cognitive functioning. Normal sleep is characterised by two states: non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep (Carskadon & Dement, 2005). These two states alternate in a cyclical manner roughly every 90 minutes, from NREM sleep (stages 1-3) to REM sleep. Stage 1 (NREM1) sleep is also known as light sleep and is regarded as a transitionary state between wakefulness and stage 2 sleep (NREM2). Humans spend the majority of the night in stage 2 sleep. Stage 3 (NREM3) sleep, is also known as slow-wave sleep (SWS) and is characterised by a dramatic decrease in awareness of, and response to, external stimuli. The final sleep stage, REM sleep, is characterised by intense central activation that co-occurs with inhibition of sensory input and motor output (Jones, 1991). The first part of a typical night of sleep is characterised by the predominant occurrence of NREM sleep, while the second part is characterised by the predominant occurrence of REM sleep (Carskadon & Dement, 2005).

Sleep and Dreaming. An integral part of sleeping is the occurrence of dreaming. Although the majority of dreams occur during REM sleep (up to 90% of awakenings yield a dream report), dreaming also takes place during NREM sleep, albeit at a variable, but much lower rate (e.g. 10-54%) (for reviews, see Nielsen, 2000; Nielsen, 2004; Schredl, Barret, & McNamara, 2007; Stickgold, Pace-Schott, & Hobson, 1994). Furthermore, there is also a qualitative difference between REM and NREM dreams: REM dreams tend to be more vivid, bizarre, and often contains strong and salient emotions (Ogawa, Abe, Nittono, Yamazaki, & Hori, 2009; Hobson & Friston, 2012), while NREM dreams tend to be more thought-like and often lack the same vivacity of visual representations so characteristic of REM dreams (Nielsen, 2000; Stickgold, Pace-Schott, & Hobson, 1994).

Dream Recall Frequency. Apart from varying rates of dream recall from different sleep stages across the night, recall rates also vary considerably between individuals (Schredl, Barret, McNamara, 2007). Some individuals hardly ever recall any dream mentation, while others retain detailed information about dream content almost every morning. Multiple models have been developed over the last couple of decades in an attempt to explain inter-individual variability with regard to DRF. The most influential ones will be discussed below.

Models of Dream Recall Frequency. One of the earliest models of dream recall is the Repression Hypothesis outlined by Freud (1900). This model postulates that repression as a defense mechanism influences DRF. Freud proposed that there are two dimensions with regard to dream content: the manifest content and the latent content. The manifest content relates to the dream mentation an individual is conscious of and remembers experiencing during the recall process. This includes actual images, characters, thoughts, and emotions. The latent content refers to the ‘hidden meaning’ of dreams, i.e. an individual is not always directly aware of the meaning of dreams as the unconscious mind suppresses any content that is threatening or difficult to cope with. In the context of DRF, complete repression of manifest dream content occurs when distressing latent content is not sufficiently censored and poses a threat to the individual if it was to permeate consciousness. In this instance, and through this process, dream traces are rendered completely inaccessible to recall. The difficulty with this model is that it is problematic to test empirically due to the unfeasibility of measuring latent dream content (Schredl, 1999).

Despite this assertion, empirical evidence for the Repression Hypothesis can be found in the literature. For example, Köhler and Prinzleve (2007) conducted an experiment based on the premise that free association relating to ‘forgotten’ elements of dreams would be met with increasing levels of resistance. This study consisted of two experiments, in the first experiment 25 participants were asked to freely associate in relation to five elements based on notes from their own dreams, as well as five stimuli from someone else's dreams. The second experiment entailed the participants returning one week later undergoing recognition testing for the previously reported dream elements. Skin conductance responses (SCR) were measured during recognition testing. In relation to the first experiment, the authors found that associations based on participants' own dream material elicited greater SCRs. Results from the second experiment showed that when compared to material identified during recognition testing, unrecognised aspects of dreams provoked greater SCRs. These findings support Freud's theory that 'forgetting' dreams possibly relates to dream content being repressed.

Another model of DRF is the Lifestyle Hypothesis developed by Schonbar (1965). This model proposes that dream recall forms part of a general lifestyle and/or possessing certain personality characteristics. This particular lifestyle typically involves increased creativity, florid fantasy, a tendency towards introversion and introspection, as well as divergent thinking. In its essence, this model emphasizes the 'trait' aspect of DRF in the sense that there are certain innate characteristics that are associated with high DRF in certain individuals. DRF in relation to trait aspects will be discussed in more detail in subsequent sections.

The Salience Hypothesis (Cohen & MacNeilage, 1974) and the Interference Hypothesis (Cohen & Wolfe, 1973) are both derived from classical memory theory. These models state that if the salience of a dream is enhanced, and if there are minimal interferences present during the recall process, recall will be improved. In other words, these two models form part of a complimentary process, for example, a dream with strong emotional content is more likely to be encoded due to its salience, and better remembered if the recall process is uninterrupted by competing memory traces/stimuli. As opposed to the lifestyle hypothesis, the abovementioned hypotheses emphasise the importance of state factors in relation to DRF. Parke and Horton

(2009) provided some empirical support for both the Salience and Interference hypotheses. Results from this study demonstrated that in the absence of an interference condition upon awakening, participants tended to produce longer dream reports, as well as ascribing higher levels of salience to their dream content.

The arousal-retrieval model (Koulack & Goodenough, 1976) is arguably one of the most comprehensive models, while it is also firmly rooted in empirical evidence compared to the others. This model proposes a two-stage memory theory in relation to DRF: The first stage relates to the processing of the target material, in this instance, dream traces. The authors propose that information processing must take place when the dream traces are still in its short-term form, as this promotes encoding into long-term storage. If the encoding process succeeds in taking place, it is believed to enhance subsequent retrieval from long-term storage. The process of retrieval constitutes the second stage of the model.

Sleep is thought to interfere with this information processing process during the first stage of the model in the sense that it prevents the target material from being encoded into long-term storage. This failure renders the dream traces inaccessible for recall at a later stage. It is important to note that this model emphasises that salience and the lack of interference are essential factors for retrieval to be successful, and therefore, integrates elements of both the Salience and Interference hypotheses discussed above.

There is strong empirical evidence in the literature providing support for the arousal-retrieval model of dream recall in both patient and healthy populations. With regard to a patient population, Schredl, Schafer, Weber, & Heuser (1998) studied DRF in individuals with insomnia and compared them to healthy controls. Individuals with insomnia reported an increased number of nocturnal awakenings, while they also demonstrated higher rates of DRF. An increased number of nocturnal awakenings potentially affords an individual with the opportunity of encoding dream traces into long-term storage (for a review on sleep disorders in relation to DRF, see Shredl, 2009).

Although the abovementioned study is based on self-reports of disturbed sleep, objective evidence in support of fragmented sleep in insomnia does exist. For example, a study utilising polysomnography[1] (PSG) provided evidence for sleep maintenance problems in insomnia – they found an increased number of awakenings as well as increased wakefulness after sleep onset (WASO) (Terzano et al., 2003). Furthermore, sleep maintenance problems in insomnia is a well-documented phenomenon and is reflected in the diagnostic criteria for insomnia in the International Classification of Sleep Disorders (American Academy of Sleep Medicine, 2014). Therefore, one could surmise that the sleep maintenance problems associated with sleep disorders like insomnia, i.e. increased awakenings and wakefulness, facilitates the encoding of dream traces into long-term storage in a manner compatible with the arousal-retrieval model (Shredl, 1999).

Apart from findings related to DRF in a patient population, a recent study provided direct and objective support for the arousal-retrieval model of DRF in healthy individuals. The study by Eichenlaub et al. (2014a) investigated sleep architecture via polysomnography in high frequency recall (HFR) individuals compared to low frequency recall (LFR) individuals[2]. They found a significant difference with regard to 'intra-sleep wakefulness', i.e. individuals with high rates of DRF spent significant more time awake following sleep onset. Again, as above, these findings are consistent with the arousal-retrieval model as wakefulness is thought to promote encoding of dream traces into long-term storage leading to better recall at a later stage.

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[1] A polysomnogram measures multiple parameters related to characterising sleep architecture. These parameters include brain activity, eye movements, muscle tone and movements, heart rate and respiratory parameters.

[2] The operationalisation of DRF was based on an adaptation of the Dream Recall Frequency Scale developed by Schredl (2002), HFRs recalled > three dreams per week, and LFRs < two dreams per month. Group demarcation by earlier studies include, for example, HFRs 'recalling dreams every morning with rare exception', and LFRs recalling 'two dreams a month or less' (Fitch & Armitage, 1989). More recent studies have used the mean of DRF across participants to differentiate between HFRs and LFRs (Dumel et al., 2015).

In summary, several models have been developed in an attempt to explain inter-individual variability with regard to DRF. There are some methodological difficulties with testing the Repression Hypothesis, as well as the Salience and Interference Hypotheses, as direct measurement of original dream content is not feasible. On the other hand, the arousal-retrieval model appears to be the most comprehensive, as well as being firmly rooted in empirical evidence. Nonetheless, taken together, these early models made an important contribution in terms of outlining the multi-dimensionality of the dream recall process from different theoretical perspectives. Based on this knowledge, more recent research has shifted focus from dream recall in general, to specifically studying distinct personality traits associated with HFR individuals.

Trait Profiles of High Frequency Dream Recall Individuals. Schredl & Montasser (1996-97a, b) published an extensive review outlining the different factors contributing towards increased DRF. These factors include certain personality dimensions such as 'openness to experience', having 'thin' boundaries[3], elevated levels of creativity, increased visual memory ability, as well as an increased interest in dream activity/positive attitude towards dreams. In addition, it is thought that the personality dimensions neuroticism[4] and extroversion[5], might also be influential in relation to increased DRF (Blagrove & Akehurst, 2000; Suzuki & Matsuda, 2012).

The review by Schredl & Montasser (1996-97a, b) was instrumental in terms of identifying factors in the literature that are associated with increased DRF in the preceding

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[3] The thickness of boundaries relates to how 'permeable' a person is to external influences, i.e. people with thin boundaries demonstrate a fluid sense of self, they are often sensitive, vulnerable, and sometimes fail to distinguish between fantasy and reality. Conversely, individuals with 'thick' boundaries have a distinct sense of self separate from others, can clearly distinguish between fantasy and reality, and are often guarded, and meticulously careful in their actions.

[4] Neuroticism as a personality dimension refers to the tendency to experience negative emotions, for example anxiety, sadness and depression. It is also related to having a low tolerance for stress, and is sometimes referred to as an indication of emotional instability.

[5] Extroversion as a personality dimension is demonstrated by a strong and energetic engagement with the outside world. People scoring high on this dimension are frequently perceived as being enthusiastic, assertive and verbally engaging.

decades. However, at the time, no other study had attempted to investigate all of the abovementioned domains simultaneously and within one sample. In order to achieve this, Schredl, Wittmann, Ciric, & Götz (2003) developed a structural equation model including several indicators identified by previous studies as being influential with regard to DRF. The analysis revealed that attitude toward dreams, sleep behaviour, (e.g. nocturnal awakenings) personality dimensions (openness to experience, thin boundaries, and absorption), as well as creativity correlated considerably with DRF, albeit with a relatively low rate of variance explained. Building on these findings, and more recently, Beaulieu-Prévost, & Zadra (2007) conducted a meta-analysis and found that it is especially 'absorption', thin boundaries, and attitude toward dreams that are strongly correlated with DRF.

Although not considered a trait factor in the same sense as the ones discussed above, it is important to mention that there are also considerable sex differences in relation to DRF. Numerous studies have found that females recall significantly more dreams than their male counterparts (Shredl, 2008; Schredl, Lahl, & Göritz, 2010; Schredl & Reinhard, 2008).

In summary, over the last couple of decades, studies have sought to, in a sense, 'profile' HFR individuals in terms of specific trait factors that are thought to lead to enhanced dream recall ability. By mostly relying on retrospective questionnaire data, multiple, albeit sometimes divergent, factors have been identified across studies. However, there seems to be a general consensus in the literature that HFR individuals display distinct differences in terms of certain personality traits. Furthermore, generally, a directionality has been implied by these studies in the sense that enhanced dream recall is regarded as an expression of possessing certain personality characteristics.

In recent years, however, there has been a shift away from investigating factors related to DRF via retrospective and questionnaire data, towards adopting an experimental neurobiological approach. Furthermore, and again, deviating from previous research, recent studies have also assumed an experimental design where HFR individuals and LFR individuals are directly compared to one another.

A Neurobiological Approach to Studying Dream Recall Frequency. In the preceding sections trait differences in terms of personality and cognitive dimensions were discussed in relation to variation in DRF. However, two recent studies have provided convincing evidence that the possibility exists that there are also distinct functional neurophysiological differences between HFR and LFR individuals.

The first study (Eichenlaub et al., 2014b) set out to investigate the cerebral underpinnings of dreaming via neuroimaging. This was done by conducting a positron emission tomography (PET) study measuring regional cerebral blood flow (rCBF) in healthy HFR and LFR individuals during both wakefulness and sleep. There were two regions of interest in this study – the temporoparietal junction (TPJ) and the medial prefrontal cortex (mPFC). These regions were chosen due to neuropsychological and lesion studies demonstrating a complete or near-complete cessation of dreaming when lesions occur in or around these regions (Solms 1997; Bischof & Bassetti, 2004). Therefore, one can surmise with a certain degree of confidence, that these regions (amongst others) are involved in dream production. The study found that, compared to LFR individuals, HFR individuals showed significantly increased rates of rCBF in the TPJ during stage 3 sleep (NREM3), during REM sleep, as well as during wakefulness. Furthermore, they also found significantly increased rates of rCBF in the mPFC in HFR individuals during both REM sleep and wakefulness.

The authors point out two important things in light of interpreting the results: firstly, it is important to note that participants were matched on emotional and cognitive domains, and secondly, that the differences were detected during both wakefulness and sleep. They conclude that the results are most likely ascribable to functional neurophysiological trait differences in relation to the HFR group. They propose that this functional neurophysiological trait associated with HFR individuals might facilitate increased dream production and/or better memory for dreams.

The second study (Eichenlaub et al., 2014a) compared the sleep architecture and brain activity of 18 HRF individuals compared to 18 LFR individuals by utilising polysomnography (PSG) and an event-related potentials (ERP)[6] protocol. With regard to investigating sleep architecture, the researchers found a significant difference in relation to intra-sleep wakefulness, in other words, HFR individuals spent significantly more time awake after sleep onset. The authors argue that this finding provides support for the arousal-retrieval model of dream recall in the sense that there is more opportunity for dream traces to be encoded into long-term storage due to prolonged periods of wakefulness.

The ERP experimental procedure entailed adopting a novelty oddball paradigm by presenting complex sounds (the participant’s first name, as well as an unfamiliar first name), randomly and rarely in combination with other repeated pure tones while they were awake, as well as during sleep. This procedure enabled researchers to assess various steps of auditory information processing across vigilance states. The aim was to determine to what extent participants orientate themselves to stimuli from the external environment, or put differently, measuring their brain ‘reactivity’ to such stimuli. It is important to note that during sleep, this reactivity does not equate to an awakening – the specific ERPs are detectable without participants being directly conscious of the stimuli.

The researchers found that during both wakefulness and sleep, HFR individuals orientated their attention more strongly to unexpected stimuli compared to LFR individuals. In other words, there is a significant difference between these two groups with regard to brain reactivity to stimuli across vigilance states. In addition, the authors believe that it is this

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[6] An event-related potential is measured in the brain via electroencephalography as a stereotyped electrophysiological response to a sensory, motor, or cognitive stimulus/event.

heightened brain reactivity that leads to longer intra-sleep wakefulness in HFR individuals. The authors attempted to explain how dreaming fits in with the above findings in relation to Freud's (1900) theory of dreams being 'the guardians of sleep'[7]. The authors propose that increased brain reactivity potentially leads to longer periods of intra-sleep wakefulness, and in an attempt to preserve and maintain sleep, dream *production* is triggered. The mechanism of preserving and maintaining sleep is thought to be achieved through producing dream content related to wish-fulfilment.

In summary, when both studies are taken together, the authors make a strong case that the functional cerebral organisation of HFR individuals is intrinsically different from LFR individuals. Furthermore, they propose that neurophysiological trait differences exist between these two groups across vigilance states. These findings cast doubt on earlier research propagating the notion that increased DRF is an expression of possessing certain personality traits. One could argue, for example, that certain personality traits, *as well as* increased DRF (better memory for and/or increased production of dreams), are an expression of a specific functional neurophysiological arrangement innate to HFR individuals. This assertion can be contextualised in the above findings in the following way: HFR individuals present, in a trait-like fashion, with increased activity in the TPJ. This increased activity leads to heightened brain reactivity and subsequent longer periods of intra-sleep wakefulness. Wakefulness in turn facilitates the encoding of dream traces into long-term storage leading to better recall at a later stage. In addition, in an attempt to circumvent wakefulness, dream production is triggered in order to preserve sleep.

Measuring Dream Production Across the Night. The abovementioned studies provide a firm evidence-based footing for the validity of the arousal-retrieval model of dream

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[7] "A dream is invariably an attempt to get rid of a disturbance of sleep by means of wish-fulfillment, so that the dream is a guardian of sleep" – Sigmund Freud (1940/1953).

recall, essentially indicating that these individuals have better memory for dreams. However, the authors of these studies also touched on the theoretical possibility that HFR individuals not only have better memory for dreams, but that they potentially also produce more dreams.

Adopting an empirical approach when investigating this hypothesis leaves one with a slight methodological dilemma. Rates of dream recall are typically derived from retrospective accounts, mostly from questionnaires, and less frequently, dream diaries (Schredl, 1999). Essentially, you would be obtaining an account of a person's *memory* for dreams. An alternative would be to perform laboratory awakenings, but this in itself is problematic in certain ways. It is unclear how many dream reports would need to be obtained in order to get a representative sample of rates of dream production across the night. Even if this was not an impediment, reporting dreams directly from an experimental awakening is not without difficulty. For example, reports might be affected by sleep inertia and memory decay (Schredl, 2003), a salience bias (Parke & Horton, 2009), and self-censoring (Köhler & Prinzleve, 2007). Therefore, it is questionable to what extent one can reliably and objectively measure rates of dream production across the night via currently available methods.

Alternatively, there is the possibility of looking at other physiological parameters during sleep that could potentially be used to index the occurrence of dreaming across the night. For example, the neurophysiological mechanism that subserves the relationship between rapid eye movements and the occurrence of dreaming, called ponto-geniculo-occipital (PGO) waves, has been proposed as one mechanism of interest in this regard (Nelson, McCarley, & Hobson, 1983; Leclair-Visonneau et al., 2010).

The Relationship between Dreaming, REM Sleep Features, and PGO waves. PGO waves consist of phasic field potentials that are typically recorded from the pons, the lateral geniculate body and the occipital cortex from which they originate. Since the early stages of sleep research, there have been many studies investigating the relationship between rapid eye movements (REMs), REM sleep and PGO activity. Numerous studies have found significant correlations between REMs and PGO activity in animals (for an extensive review on this topic, see Rechtschaffen (1973). One example of a hallmark study investigating this premise was by Orem & Dement (1974). The authors studied the relationship between REMs, REM sleep and PGO waves in sleeping cats. The authors found that 89% of eye twitches are related to the activity of PGO waves during REM sleep. This study, along with the numerous studies reviewed by Rechtschaffen (1973), provides convincing evidence for a strong association between REMs, REM sleep and PGO waves. A review of recent studies supports the findings of early studies regarding the relationship between REMs, REM sleep and PGO waves (Desseilles, Dang-Vu, Sterpenich, & Schwartz, 2011).

Although PGO waves have been extensively studied in animals, direct proof of their existence in humans has been problematic due to the necessity of utilising intracerebral recordings in order to detect PGO activity (Peigneux et al., 2001). Keeping the association between REMs and PGO waves in animals in mind, Peigneux et al. (2001) propose that because the evolution of species is parsimonious, it would be plausible to hypothesise that REMs during REM sleep in humans are generated by mechanisms similar or identical to the generation of PGO waves in animals. The authors conducted a positron emission tomography (PET) and cerebral blood flow (CBF) study hypothesising that the brain regions where the PGO waves are most easily recorded in animals, would be differentially more active during REM sleep in relation to REM density (frequency of eye movements during REM sleep) in humans. This PET and CBF study demonstrated a significant interaction effect between REM density and the brain regions known to be implicated in the generation of PGO waves in animals.

Although the above study provides strong inferential evidence for the presence of PGO waves in humans, direct evidence via intracerebral recordings have been very hard to obtain. However, there is one study that managed to collect intracerebral data in relation to PGO-related activity. Lim et al. (2007) set out to measure the pontine component of PGO waves via intrapontine and scalp EEG recordings in an individual with Parkinson's disease (PD). The participant was enrolled in a deep brain stimulation study as treatment for PD-related symptoms and gave consent for additional measures to be implemented. Results revealed the presence of phasic pontine potentials before and during REM sleep. Furthermore, the morphology, localization, and temporal distribution resembled the PGO waves observed in other mammals. The authors conclude that this serves as adequate evidence that PGO waves are a feature of human REM sleep. Intracerebral recording of epileptic patients also provides some evidence of the presence of PGO waves in humans (Desseilles, Dang-Vu, Sterpenich, & Schwartz, 2011).

The literature provides evidence for a relationship between REMs, REM sleep and PGO activity in humans. However, it is important to note that there is another feature strongly associated with all of the above, namely dreaming. The association between dreaming and the abovementioned variables has led many authors to hypothesise that PGO activity is also related to the generation of dream images and other hallucinatory aspects of dreams (Pace-Schott, 2005). This assertion is supported by neurobiological data as the projection pathways of PGO waves include visual, parietal, and temporal sensory brain regions (Leclair-Visonneau et al., 2010; Desseilles, Dang-Vu, Sterpenich, & Schwartz, 2011).

A hallmark study by Miyuchi et al. (2009) utilised simultaneous functional magnetic resonance imaging (fMRI) and polysomnographic recordings. Researchers found that the primary visual cortex, pontine tegmentum, ventroposterior thalamus and limbic areas were all activated in association with the occurrence of REMs. In order to disentangle the finding of the activation of the primary visual cortex further, researchers also conducted a control experiment. In this experiment participants were asked to perform self-paced saccades in total darkness. This experiment revealed no activation of the primary visual cortex. The authors conclude that the activation of the primary visual cortex without any input from the retina during REM sleep not only serves as neural evidence for the existence of PGO waves in humans, but that it also subserves the occurrence of dream imagery[8] (Leclair-Visonneau et al., 2010; Miyuchi et al., 2009).

Taking this one step further, many authors have postulated that one function of REMs in the context of REM sleep, dreaming, and PGO activity, relates to the scanning of visual imagery. To this day, the proposition that REMs are related to the scanning of visual imagery remains a contentious issue due to methodological constraints associated with investigating this hypothesis.

In the dream literature, the topic of the scanning of visual imagery is referred to as the 'scanning hypothesis' (Rechtschaffen, 1973). Rechtschaffen explicates this hypothesis in terms of two dimensions. The first dimension relates to the content-specific hypothesis. This hypothesis states that the eyes in REM sleep move as the dreamer scans the dream scene, while the amount of eye activity will be related to the amount of visual scanning in the dream. The second dimension of the scanning hypothesis is often referred to as the non-specific hypothesis. This hypothesis suggests that although scanning activity may form part of the determination of the relationship between REMs and the scanning of dream imagery, it is not crucial to them. In other words, one function of REMs might be the scanning of visual dream imagery, but a proportion of them may also be present in the absence of dream imagery. This is because they may present as a peripheral expression of other centrally activated neural mechanisms. These

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[8] It is important to mention that although this particular experiment highlights the significance of primary visual cortex activation in relation to dream imagery and PGO waves, Solms (1997) in a clinico-anatomical study reported intact dream imagery following lesions to the primary visual cortex. The author argues that it is especially the visual association cortex that plays an important part in generation of dream imagery. Therefore, these findings should be interpreted with caution.

other centrally activated neural mechanisms may overlap with the generation of dream imagery, but they may also simultaneously fulfil a functional role independent of dream imagery generation.

An early study set out to investigate the proposition that REMs during REM sleep is related to scanning visual imagery by studying individuals who are blind. Berger, Olley, & Oswald (1962) recruited individuals with lifelong blindness who reported no visual dream imagery (but did experience non-visual elements of dreams), and found that these individuals exhibited no REMs during REM sleep. The authors postulate that this could mean one of two things. Firstly, it could provide evidence for the premise that eye movements are indeed related to the scanning of dream imagery, or that owing to non-use, the neural pathways associated with the execution of conjugate eye movements are poorly developed in individuals who are blind, or once they are established, they deteriorate because of non-use during prolonged blindness (Berger, Olley, & Oswald, 1962).

Similar results were obtained by Offenkrantz and Wolpert (1963), while other studies have failed to support these findings (Gross, Byrne, & Fisher, 1965; Amadeo & Gomez, 1966). The findings of some of these studies have been criticized on methodological grounds, and the issue of eye movements in the blind remains controversial. As an extension of this, Rechtschaffen (1973) proposed that novel methodological designs need to be devised in order to deal with some of the contentious issues:

> *"To show how inconclusive… the arguments are, consider that they would all fall by the wayside if there was strong, replicable evidence that the direction of recorded eye movements correspond to the direction expected from the reported imagery. This would be the most direct test of the scanning hypothesis because this is what is meant by scanning – moving the eyes in the direction required to inspect the visual environment".*

This is exactly what a more recent study set out to investigate. A study by Leclair-Visonneau et al. (2010) tested the hypothesis that REMs during REM sleep are associated with the visual scanning of dream images in the sense that there is a relationship between the direction of eye movements and goal directed behaviour in dreams. In their study they recruited 56 patients with REM sleep behaviour disorder (RBD) (a condition where patients enact their dreams by persistence of muscle tone during REM sleep[9]). They investigated directly whether their eyes move in the same direction as their head and limbs when patients exhibit goal directed behaviour (as determined by video monitoring). An example the authors used in their article is that of a smoker exhibiting behaviour during REM sleep that mimics the different aspects of smoking in waking life. The authors found a concordance of up to 90% between the direction of REMs and goal directed motor movement across participants. This evidence provides support for the premise, in terms of the criteria initially stipulated by Rechtschaffen (1973), that REMs during REM sleep are related to the scanning of dream imagery. However, this does not exclude the possibility that not *all* REM eye movements are related to the scanning of dream imagery (as a perfect correlation was not demonstrated in this study).

In summary, the above studies provide convincing evidence for, firstly, the presence of PGO waves in animals and humans, secondly, that REMs function as a physiological correlate of PGO activity, and thirdly, that PGO activity subserves the occurrence of dream imagery. This relationship can lead one to extrapolate that the incidence of REMs is also associated with the occurrence of dream imagery during REM sleep. As mentioned in previous sections, studies have been unable to reliably and objectively study the theoretical possibility of increased dream production across the night in HFR individuals. However, by using REMs as a physiological

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[9] REM sleep is characterized by, with the exception of ocular muscles, a complete loss of muscle tone. However, short, phasic bursts of motor activity are evident on the EMG channel during REM sleep.

correlate of PGO activity to index the occurrence of dream imagery, it is possible to investigate if HFR individuals not only remember more dreams, but also possibly produce more dreams.

If this is indeed the case, one could contextualise increased dream production during REM sleep as another expression of a specific functional neurophysiological arrangement innate to HFR individuals. Interestingly, the neural underpinnings of REM sleep and REM dreaming overlap with other neurobiologically-related processes (LaBar & Cabeza, 2006). Two of these processes include overnight emotional memory consolidation and emotion regulation (Walker, 2009). Therefore, if HFR individuals do in fact produce more dreams during REM sleep, it can lead one to surmise that they potentially also exhibit enhanced overnight emotional memory consolidation and emotion regulation.

Delineation of Memory Processes. Like sleep, the term 'memory' is not a single entity. Memory can be broadly divided into two categories: declarative memory and non-declarative memory. Declarative memory can be regarded as memories that are consciously accessible and that are fact-based information (i.e. knowing 'what') (Squire, 1992). Declarative memory can be divided into different subcategories. These subcategories include episodic memory (autobiographical memory related to one's past), as well as semantic memory (memory related to general knowledge that is not associated with specific events) (Tulving, 1985). Furthermore, there is a subtype of declarative memory, namely emotional declarative memory. Emotional declarative memory relates to a situation where episodic events are associated with specific and salient emotions (LaBar & Cabeza, 2006).

The declarative memory system serves the function of acquiring and consolidating information in the context of long-term storage, thereby promoting the retrieval of episodic events and knowledge (Squire, 2004). Currently, the neural underpinnings of declarative memory formation are believed to involve the structures of the medial temporal lobe (MTL) and supported by the neocortex. The structures of the MTL that form a functional unit include the hippocampal, perirhinal and entorhinal regions, for example (Eichenbaum, 2000). The MTL is essential to the formation of permanent and long-term declarative memory, where the neocortex serves as the permanent repository of memory (Squire, 1996; Lavenex & Amaral, 2000).

The process of consolidating new information into long-term storage involves different aspects. This is thought to include the MTL orchestrating a process whereby consolidation is directed in the neocortex by gradually binding together the various geographically separate cortical regions that are implicated in storing the memory for a whole event (Squire, 1996). Furthermore, the hippocampus coordinates the process by which associations between newly acquired information and existing knowledge contextual networks are formed, thereby promoting encoding and consolidation of the new information into long-term storage (Eichenbaum, 2004). The hippocampus is also thought to provide a temporally ordered retrieval mechanism for information stored in this way (Squire, 1996). The prefrontal cortex also plays an imperative part in the different processes implicated in the declarative memory system. Although the prefrontal cortex is not essential for the encoding process to take place, it does support the formation of rich contextual details and networks in which declarative memory is embedded (Ofen et al., 2007).

With regard to emotional declarative memory on the behavioural level, emotion influences memory in an intricate and robust manner. The process of memory enhancement can either be propagated by the intensity of the valence of the stimulus, or by the elicited emotional arousal by the stimulus (for a review, see Kensinger, 2004). Valence in this context refers to how positive or negative the memory source is, and arousal refers to how exciting or calming the memory source is perceived to be (Kensinger & Corkin, 2004). There is evidence to support the premise that it is especially the amygdaloid complex that plays an important role in the arousal dimension of emotional memory. For example, pharmacological interventions resulting in increased arousal (e.g. noradrenergic agonists) enhances emotional memory performance in animals and humans, while the converse is true when β-noradrenergic antagonists are administered

However, the amygdaloid complex does not function in isolation in terms of emotional memory processes. The hypothalamic-pituitary-adrenal (HPA)-axis has also been identified as exerting a prominent influence on the neural pathways involved in the consolidation process discussed in the previous paragraph (Cahill & McGaugh, 1998; LaBar & Cabeza, 2006). More specifically, it fulfills a modulatory role in terms of these pathways. The memory modulation hypothesis states that long term memory is enhanced for emotional events (Cahill & McGaugh, 1998). It is proposed that memory consolidation mechanisms benefit from attentional influences mediated by emotional arousal and that this promotes subsequent recall (LaBar & Cabeza, 2006). More specifically, attentional focusing ensures that emotionally salient material associated with complex events are preferentially preserved in memory. The mechanism underlying long-term enhancement reflects the neuromodulatory influence of the amygdala on the consolidation processes. These processes are orchestrated by the MTL regions in part through the engagement of the stress hormones adrenaline and cortisol (released by the HPA-axis).

Specifically related to the role that the amygdaloid complex plays, studies have supported its influential role by demonstrating that long-term emotional memory is impaired in patients with selective damage to the amygdaloid complex, while memory for relatively unemotional material appears intact in these individuals (Adolphs et al., 1997; Cahill, Babinsky, Markowitsch, & McCaugh, 1995). Furthermore, neuroimaging studies have elaborated on these findings demonstrating a link between the extent of amygdalar activation at the moment of encoding, and the probability of successful retrieval of emotionally salient items (Cahill et al., 1996; Canli et al., 1999; Hamman, Ely, Grafton, & Kilts, 1999).

In terms of the role of adrenaline, pharmacological manipulations in humans have showed β-adrenergic receptor antagonists (for example propranolol) before encoding diminishes the long-term retention advantage typically associated with emotionally arousing stimuli relative to neutral stimuli (Cahill, Prins, Weber, & McCaugh, 1994; van Stegeren, Everaerd, Cahill, McCaugh, & Gooren, 1998). When β-adrenergic receptor agonists are administered, the converse is true.

Furthermore, cortisol is known to influence emotional and more neutral memory. Although acute secretion of cortisol enhances emotional learning and memory relative to neutral stimuli, chronic heightened levels of cortisol seem to impair various memory functions across categories (LaBar & Cabeza, 2006). It is believed that adrenaline and cortisol fulfill a complimentary role in the processes involved in emotional memory consolidation.

Sleep Stages & Declarative Memory Processes. Early research attempted to ascribe a specific function to the different sleep stages not only in terms of memory consolidation, but also memory consolidation for either declarative versus non-declarative memories. Earlier views postulated that SWS is especially important in terms of declarative memory consolidation, while REM sleep seemed to play a more important part in non-declarative memory consolidation (Plihal & Born, 1997). However, it is now believed that this distinction is less clear cut and that SWS and REM sleep appear to be complimentary in the overall consolidation process, but contributes differently by providing distinct states of optimal brain region activation implicated in memory consolidation processes. This will be discussed in more detail below.

Early research investigating the effects of sleep deprivation on declarative memory recall as well as declarative sleep-dependent learning and memory consolidation, is marked by inconsistencies in terms of whether or not sleep exerts any influence, or is influenced by these processes (Walker & Stickgold, 2006). Furthermore, these early studies often focused primarily on the relationship between REM sleep and memory performance. For example, Chernik (1972) found no significant relationship between selective REM sleep deprivation and memory impairment (using a paired-associate learning task), while Tilley and Empson (1978) did detect deterioration in memory recall as part of a story retention task following REM sleep deprivation.

With regard to changes in sleep architecture following learning, De Koninck et al. (1989) found a significant correlation between language learning efficiency and an increase in REM sleep percentage with regard to pre-course and post-course periods, indicating that REM sleep possibly plays an important role in learning and information processing. However, another early study failed to detect significant changes in REM sleep parameters following long-term language acquisition (Meienberg, 1977).

A more recent study looking at the relationship between sleep and memory performance using different memory tasks (e.g. word paired associates), and looking at sleep architecture as a whole (NREM sleep as well as REM sleep), found both of these sleep stages to significantly enhance performance on a recall task (Plihal & Born, 1997).

Although discrepant findings regarding the relationship between sleep and memory are prevalent in the early literature, more recent studies provide convincing evidence that following encoding, sleep plays an important role in the stabilization and enhancement of declarative memory traces during the consolidation process (Fischer et al., 2002; Gais & Born, 2004; Stickgold & Walker, 2005).

The synaptic homeostasis hypothesis (SHY) is possibly one explanatory mechanism underlying the memory stabilisation and enhancement process (Tononi & Cirelli, 2014). More specifically, during waking interaction with the environment, there is increased neuronal firing and bursting in the context of learning. During sleep, however, renormalisation takes place by means of a collective down-selection of synapses. The outcome of this process leads to a situation where relatively weakly activated (during both wakefulness and sleep) synapses become increasingly less effective compared to strongly activated synapses that are preserved and enhanced.

In summary, as reviewed above, there is evidence for the proposition that both SWS and REM sleep uniquely contribute to the consolidation of complex material in an interdependent manner in the following way: the integration of recently acquired information with past knowledge and experiences, the anatomical reorganization of memory representations (memory translocation from the hippocampus to the neocortex), and the reconsolidation of memory representations following recall (for a review, see Walker & Stickgold, 2004).

Sleep and Emotional Declarative Memory. There is a substantial body of evidence supporting the premise that memory processing can be modulated by the emotional valence of the material being learned (for a review, see McGaugh, 2004). This modulation influences memory processes in terms of enhanced memory retention and recall, for example. Furthermore, it is believed that sleep exerts a prominent influence on the relationship between encoding, consolidating and recalling emotionally salient material, as it promotes the overnight enhancement of these processes. (Hu, Stylos-Allan, & Walker, 2006).

With regard to the mechanism of the enhancement process, REM sleep appears to be a major contributing factor. The neurobiological association between REM sleep and emotional declarative memory has been made due to the neurochemical changes that take place in the brain (e.g. increased acetylcholine release), as well as the activation of certain brain regions (e,g. increased activity in the amygdala and cingulate cortex) that make the brain amenable to affect-related memory consolidation (Stickgold, Hobson, & Fosse, 2001; Hu, Stylos-Allan, & Walker, 2006; Nishida, Pearsall, Buckner, & Walker, 2009). This neurobiological association is also supported in the literature. For example, a study by Wagner, Gais & Born (2001) found that memory for emotional material was significantly enhanced after a period of late sleep in which REM sleep was predominant. The same was not true for memory related to emotionally neutral stimuli, while early sleep (predominated by NREM sleep) did not produce significant results either. Similar results have been obtained by Nishida, Pearsall, Buckner, & Walker (2009) who found a correlation between offline emotional memory enhancement and the amount of REM sleep, while no correlation was found with regard to emotionally neutral material.

Although a neurobiological association between REM sleep and emotional declarative memory has been established, there is still some uncertainty regarding the mechanism that binds these two processes together during consolidation. Dreaming has been proposed as one such mechanism of memory consolidation during REM sleep. Dreaming in this context could fulfill the function of forming part of a multilevel system of sleep-dependent learning and memory reprocessing, where dreams can be regarded as the conscious manifestation of these processes (Stickgold, Hobson, & Fosse, 2001).

Dreaming and Emotional Declarative Memory Consolidation. Although there are several theories that speculate about the role of dreaming as a possible mechanism underlying emotional declarative memory consolidation, a causal link remains to be demonstrated (Stickgold, Hobson, Fosse, & Fosse, 2001; Nielsen & Stenstrom, 2005). There are several hypotheses regarding the role of dreaming in memory consolidation. For example, Stickgold, Hobson, Fosse, & Fosse (2001) propose that during REM sleep limbic forebrain structures along with the amygdala are activated, while there is also an inhibition of hippocampal outflow that presumably prevents the reactivation of episodic memories. Consequently, dreams would be constructed mainly from weak neocortical associations that are available during REM sleep and dreams are thus typically unpredictable, bizarre and laden with emotion. The authors hypothesise that these features reflect the brain's attempt to recognise and assess novel cortical associations in the context of emotions mediated by limbic structures. They propose that one functional consequence of REM dreaming is the strengthening or weakening of specific activated associations.

There are several other hypotheses regarding the function of dreaming in relation to memory processes. One such hypothesis states that the appearance of memory traces in dreams promotes learning by reactivating those elements in their original (perception-like) state, a second one states that the binding of various elements (especially around emotionally relevant themes) strengthens and consolidates those elements, while a third one states that dreaming about newly learned material enhances subsequent recall of that material (Payne & Nadel, 2004; Nielsen & Stenstrom, 2005).

Considering the discussion above regarding the convincing link between dreaming, emotional declarative memory consolidation, and the neural substrates subserving both, one could surmise that HFR individuals possibly have enhanced consolidation abilities with regard to emotional declarative memory compared to neutral declarative memory. In addition, another function that could possibly be enhanced in HFR individuals that is intimately related to REM sleep, dreaming, and emotional memory processes, relates to overnight emotion regulation.

Sleep, Dreaming, & Emotion Regulation. Over the last couple of decades, many studies have attempted to elucidate the long-standing belief that there is a reciprocal relationship between sleep and waking mood (e.g. Gerner, Post, Gillin, & Bunney, 1979; Rosen, Gimotty, Shea, & Bellini, 2006; Scott, McNaughton, & Polman, 2006). Since the early years of sleep research, a relationship between sleep deprivation and subsequent irritability, affective volatility, and general emotional difficulties have been documented (Horne, 1985; Dinges et al., 1997). A more recent study demonstrated that sleep loss amplifies negative emotional consequences of disruptive daytime events, while there is a blunting of positive benefits associated with reward or goal-enhancing related activities (Zohar, 2005). However, euphemistically stated, sleep is a multidimensional phenomenon, and it is important to identify and explicate the processes that are specifically implicated in the relationship between mood/emotion regulation and sleep.

Neuroimaging studies throughout the years have provided convincing evidence for the proposition that REM sleep might fulfil a particularly prominent role in the regulation of emotions during sleep. This is due, for example, to the distinct regions of neural activation associated with emotion processing during REM sleep, e.g. limbic and paralimbic structures like the amygdala (for a review, see Desseiles, Dang-Vu, Sterpenich, & Schwartz, 2011)[10].

Although these studies provide substantial support for an association between emotion regulation and REM sleep, a recent functional magnetic resonance imaging (fMRI) study attempted to elucidate the functional pathways implicated in emotion dysregulation with regard to sleep deprivation (Yoo et al., 2007). In this study, participants (sleep-deprived and controls) were exposed to picture slides ranging in a gradient from material that is emotionally neutral to increased negative valence to pictures of an aversive nature. The sleep-deprived group exhibited a noteworthy +60% greater magnitude of amygdala[11] reactivity to emotionally negative stimuli relative to controls. Furthermore, this amplified hyperlimbic reaction by the amygdala is also associated with a loss of functional connectivity with the medial prefrontal cortex (mPFC) in the sleep-deprived group. This finding implies a failure of top-down inhibition of amygdala reactivity by the prefrontal lobe, and, keeping the intimate relationship between the amygdala and REM sleep in mind, that the function of sleep in this context might be to 'reset' the correct tone of affective reactivity in preparation for emotional challenges the following day (Walker, 2009).

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[10] The delineation of the relationship between REM sleep and emotion processing can be found in an earlier section, 'Sleep and Emotional Declarative Memory'.

[11] The amygdala forms part of the limbic system and is known to play an imperative part in the processing of emotionally salient material, as well as contributing to the orchestration of a physiological response to such material.

Therefore, there is ample evidence for a functional relationship between REM sleep, emotion regulation and the brain structures and regions implicated in both. But there is a third variable, namely dreaming, that is also possibly involved in this relationship due to its high co-occurrence with REM sleep (and the associated patterns of neural activation), as well as the increased emotional valence and vividness of dreams during this sleep stage (Payne & Nadel, 2004). This inter-relationship between emotion regulation, REM sleep and REM dreaming have led to the assertion that dreaming might be one mechanism through which emotion regulation is achieved during REM sleep (Cartwright et al., 1998; Levin & Nielsen, 2009). Emotion regulation in this context generally refers to the regulation of negative emotions like fear or anxiety, for example. Therefore, various theories concerning the relationship between REM sleep, dreaming and emotion regulation have been formulated in the context of this.

A neurobiological model of dreaming postulates that dreaming during REM sleep fulfils a desomatisation function (Levin & Nielsen, 2009). More specifically, the resulting atonia (lack of muscle tone) from entering REM sleep could serve as a desensitisation mechanism by repeatedly blocking kinesthetic feedback during fearful or anxiety-provoking imagery in dreams, in an attempt to eliminate the arousal that is associated with this imagery. In other words, there is a separation of fearful dream imagery from its expected psychophysiological concomitants (Perlis & Nielsen, 1993; Nielsen & Levin, 2007; Walker, 2009).

A different, but not necessarily incompatible theory, relating to emotion regulation and REM dreaming, states that REM sleep is characterized by a surge of affective arousal (i.e. limbic activation, eye movements, and heart and respiratory activity) across the REM sleep period (Kramer, 1991). The purpose of dream content is to adaptively regulate or contain these surges by lowering the intensity and variability of the allied emotion associated with this surge of affective arousal (Kramer, 1993; Nielsen & Levin, 2007). This containment is achieved via the patterning of dream content in a longitudinal fashion over successive REM periods and that this forms part of an emotional problem-solving mechanism that ameliorates mood difficulties over time.

In support of the premise that dreams fulfil an adaptive emotion regulatory function over time, Cartwright et al. (1998a & 1998b) have conducted studies addressing this topic directly. For example, in one of their hallmark studies investigating the relationship between mood, dreaming and life stressors, the authors studied participants undergoing marital separation. Each participant was assessed for depression at baseline as well as 1 year later as a follow-up. Participants spent three nights in the sleep laboratory, undergoing multiple REM sleep awakenings. One year later 71.9% of the 39 participants who were classified as suffering from depression could be classified correctly as remitted or not remitted on the basis of the presence of negative/unpleasant dreams during REM sleep awakenings at baseline. Participants who were not depressed at baseline had few negative dreams throughout the night. More specifically, the direction of the relationship indicates that an increase in expression of negative affect in dream reports arising from REM awakenings in the first half of the night, results in a person being less likely to present with depression one year later.

Walker (2009) proposes that the mechanism subserving this time-dependent regulatory process is related to a reduction of affective tone associated with memory recall over time. More specifically, at initial encoding, the emotional event elicits a range of autonomic and neurochemical reactions. However, over time, the later recall of the same material is not associated with anywhere near the same magnitude of autonomic (re)activation that was elicited at the moment of learning.

This is thought to be due to the overnight regulation of affective neural systems that is involved in the (re)processing of recent salient experiences through appropriating limbic and autonomic reactivity the following day (Walker & van der Helm, 2009). This is supported by neuroimaging studies that have demonstrated that initial exposure to and learning of emotional stimuli relative to neutral stimuli results in greater activation of the amygdala (Kilpatrick & Cahill, 2003; Dolcos et al., 2005). Authors of the latter study found that when participants were exposed to the same stimuli during recognition testing several months later, they found that the initial difference in amygdala reactivity in relation to emotional stimuli compared to neutral stimuli dissipated over time. It is important to note that the amygdala plays an imperative part in orchestrating autonomic arousal in response to emotionally salient events. Walker (2009) postulates that the neuroanatomical, neurophysiological and neurochemical conditions of REM sleep offer a unique biological context in which the autonomic arousal or charge originally elicited in response to an emotional memory, can be depotentiated and ultimately ameliorated. He proposes that an integral part of this mechanism is REM dreaming.

In previous sections it was discussed that the possibility exists that rapid eye movements (also known as REM density), as a physiological correlate of PGO activity can be used to index the occurrence of dream imagery during REM sleep. Therefore, one could surmise that if HFR individuals produce more dreams compared to LFR individuals, there would be a significant difference with regard to REM density between these two groups, i.e. HFR individuals will exhibit an increased frequency of rapid eye movements compared to LFR individuals. Furthermore, if REM dreaming is considered an integral part of overnight emotion regulation, and REMs are used to index its occurrence, a significant relationship between REMs and affective variables used to measure overnight emotion regulation is a strong possibility. There is evidence in the literature supporting this proposition.

REM Density & Emotion Regulation. The majority of literature on REM density and emotion regulation is rooted in clinical research looking at mood disorders, especially major depressive disorder (MDD). Specific changes in individuals with depression have been noted, for example, REM density was found to be positively correlated with depression severity

(Buysse et al., 1997; Buysse et al., 2001; Cartwright, 1983; Nofzinger et al., 1994). In addition, increased REM density in remitted individuals proved to be indicative of a recurring depressive episode in the future. Cartwright et al. (1998a; 1998b) propose that REM density values at specific times of the night have specific functional consequences. For example, the authors found that low REM density values during the first REM sleep period is suggestive of a failure in initiating the overnight working-through process, and, that this failure potentiates depressive symptoms the following day.

Rationale & Significance Relating Personality Characteristics, Sleep Architecture, Emotional Memory Performance, & Emotion Regulation in HFR Individuals

Sleep and dreaming have been prolific research topics over the years, but definitive knowledge regarding the role of these phenomena have been elusive to a large extent. Several theories have been formulated over the years in an attempt to understand why we dream, the meaning of our dreams, as well as the process of recalling our dreams. More recent research has focused on, in a sense, to 'profile' individuals with regard to specific personality traits that possibly contribute to enhanced dream recall ability. Personality traits like 'openness to experience', 'extroversion', 'neuroticism' and having 'thin' boundaries are often associated with increased dream recall frequency in certain individuals (Hartmann, Elkin, & Garg, 1991; Schredl, Kleinfercher, & Gell, 1996; Schredl, Ciric, Götz, & Wittmann, 2003).

The general consensus is that these traits lend itself, for example, to individuals being more focused on internal emotions, thoughts, and perceptions, having a more fluid sense of self in relation to the outside world, and a decreased ability to sometimes distinguish between fantasy and reality (generally in a non-pathological sense). All of these things are believed to underlie an increased focus on, and interest in dreaming mentation, and that this contributes to better memory for dreams.

Although there is agreement in the literature that HFR individuals often possess certain personality traits, results over the last couple of decades have been divergent in many instances. There could be several factors accounting for this discrepancy. For example, failing to control for psychiatric and cognitive confounds could be one explanation – depression, anxiety, obsessive-compulsive disorder, and substance abuse disorders all have strong associations with specific personality dimensions (Bienvenu et al., 2004; Kotov, Gamez, Shmidt, & Watson, 2010; Samuels et al., 2000). Another confound in the existing literature could be rooted in the experimental design of the studies, e.g. studies directly comparing healthy HFR and LFR individuals utilising operationalised criteria relating to DRF, are rare. Therefore, in order to disentangle the factors and dimensions associated with HFR individuals, samples should be (a) homogenous, (b) devoid of psychiatric and cognitive confounds, (c) contain a control group, e.g. LFR individuals, and (d) utilise operationalised criteria for determining dream recall frequency. To my knowledge, empirical studies employing all of the above whilst investigating personality traits in HFR, have not been brought into fruition.

Although unrelated to investigating personality traits, it is interesting to note that there are two studies that have adopted an experimental design where HFR and LFR individuals are directly compared to one another. The first study (Eichenlaub et al., 2014a) investigated the sleep architecture of HFR and LFR individuals and found that HFR individuals spent significantly more time awake after sleep onset. This provides strong objective support for the arousal-retrieval model of dream recall in a healthy population. However, it is imperative for these results to be replicated using the same stringent sampling and experimental protocol. In addition, the above study only recruited males, it is yet unknown whether these findings will be upheld when both males and females are included.

Apart from demonstrating differences with regard to sleep architecture between HFR and LFR individuals, the abovementioned study also provided evidence in support of the proposition that there is a specific functional neurophysiological arrangement innate to HFR individuals. More specifically, results revealed that HFR individuals exhibit increased brain reactivity to novel stimuli across vigilance states. In addition, a neuroimaging study (Eichenlaub et al., 2014b), also supports the notion of functional neurophysiological trait differences. This study detected increased rCBF in the TPJ and mPFC in HFR when compared to LFR individuals across vigilance states.

When the findings of these two studies are considered together, it can be contextualised in the following way: (a) HFR individuals have increased rCBF in areas associated with dream production (mPFC) and attention orientation (TPJ), (b) that increased activity in the TPJ can account for the increased brain reactivity to novel stimuli in HFR individuals, (c) that this heightened brain reactivity potentially leads to longer periods of intra-sleep wakefulness, (d) increased wakefulness leads to encoding dream traces into long-term storage, and/or in an attempt to circumvent awakenings, dream production is triggered in order to preserve and maintain sleep.

Although increased dream production in HFR individuals is a compelling proposition, it remains a challenge to reliably measure rates of dream production across the night with currently available methods. Available methods include retrospective questionnaires, dream diaries, and laboratory awakenings. The confounds associated with each of these were discussed in previous sections. Alternatively, one can utilise the occurrence of rapid eye movements to index the occurrence of dreaming during REM sleep. This assertion is based on neurophysiological data demonstrating that both rapid eye movements and the occurrence of dream imagery share a commonality – both of them are subserved by the occurrence of PGO activity (Miyuchi et al., 2009). At the time of conceptualisation (2014), to my knowledge, utilising REM density to objectively measure dream production across the night has not been done in an experimental design where healthy HFR individuals are compared to LFR individuals[12].

If one succeeds in demonstrating increased rates of dream production during REM sleep, it is important to investigate the possible effects that increased dream production might have on other neurobiologically-related processes. For example, the neurobiological underpinnings of REM dreaming also overlap with other processes during sleep, which include overnight emotional memory consolidation and emotion regulation (Walker, 2009). To my knowledge, no other studies have investigated overnight emotional memory consolidation and emotion regulation in an experimental protocol where healthy HFR and LFR are directly compared to one another.

Hypotheses

Based on the rationale above, I formulated four avenues of investigation rooted in an experimental design where HFR individuals are directly compared to LFR individuals. It is important to note that studies adopting this design are exceptionally rare. These four avenues of investigation include (a) studying trait characteristics of HFR individuals, (b) studying the sleep architecture of HFR individuals, (c) objectively measuring whether HFR individuals produce more dreams during REM sleep, and (d) studying the effects that increased dream production during REM sleep in HFR individuals might have in terms of enhanced overnight emotional memory consolidation and emotion regulation.

Investigation 1: Trait Characteristics of HFR Individuals. There have been numerous studies in the literature investigating trait characteristics in relation to HFR individuals. For example, studies have found personality dimensions like ‘openness’,

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[12] However, a recent study by Vallet et al. (2017) analysed sleep microstructure parameters in the Eichenlaub et al. (2014a) data, which included REM density.

‘extroversion’, ‘emotional stability’, and having ‘thin’ boundaries to be associated with increased DRF. However, there are several methodological confounds evident in the literature. Firstly, samples are not always homogenous, secondly, cognitive and psychiatric confounds are not always controlled for, thirdly, many studies lack a control group (e.g. LFR individuals), and fourthly, DRF is not always unambiguously operationalised.

In light of this, I (a) utilised operationalised definitions of DRF, (b) recruited healthy individuals, and (c) included a control group, i.e. the LFR group. Based on this, and the strong support in the literature for a relationship between DRF and three personality dimensions in particular, I tested the following hypotheses:

Hypothesis 1: HFR individuals will score significantly higher on the following personality dimensions compared to LFR individuals:

a. Openness
b. Extroversion
c. Emotional Stability

Hypothesis 2: HFR individuals will score significantly higher on the Boundary Questionnaire, indicating ‘thinner’ boundaries compared to LFR individuals.

Investigation 2: The Sleep Architecture of HFR individuals. There is, to my knowledge, only one other study (Eichenlaub et al., 2014a) that has investigated sleep architecture in healthy individuals via polysomnography in relation to DRF. This study recruited both HFR and LFR males. The authors found that HFR individuals spent significantly more time awake after sleep onset when compared to LFR individuals. This result provided convincing support for the arousal-retrieval model of dream recall. It is clear from the gap in the literature that these results need to be replicated, but also be built on.

In light of this, by recruiting both males and females and investigating additional sleep parameters, the following hypotheses were tested:

Hypothesis 1: HFR individuals will spend significantly more time awake after sleep onset compared to LFR individuals.

Hypothesis 2: HFR individuals will experience significantly increased number of awakenings across the night compared to LFR individuals, and, in addition,

- HFR individuals will experience significantly more awakenings from REM sleep compared to LFR individuals.

Investigation 3: Objective Measure of Increased Dream Production in HFR Individuals. Several studies have hypothesised that HFR individuals not only remember more dreams, but possibly also produce more dreams. Current methods used to measure dream recall include retrospective questionnaires, dream diaries, and laboratory awakenings, for example. However, there are methodological constraints associated with all of these. For instance, using questionnaires will effectively measure an individual's *memory* for dreams, while dream diaries have been found to increase DRF due to participants being more focused on dream recall (Schredl, 2004). Laboratory awakenings is another option; however, salience bias, sleep inertia, memory contamination, and self-censoring are all confounding factors. In addition, it is unclear how many dreams would be needed to provide an accurate reflection of dream production rates *across* the night.

In an attempt to circumvent these methodological confounds, one can opt to use other physiological parameters during sleep. For example, the occurrence of rapid eye movements (REM density) can be used to index the occurrence of dreaming. Using REM density in this way is feasible, because both REM density and dream imagery are subserved by PGO activity (Miyuchi et al., 2009) In light of this, the following hypotheses were formulated:

Hypothesis 1: HFR individuals will exhibit significantly higher rates of REM density across the night compared to LFR individuals.

In addition, the following exploratory hypothesis was included:

Hypothesis 2: There will be a significant difference between the HFR and LFR groups with regard to the following:

a) 1st REM period density value.
b) Split-Night 1 REM density value (value for the first half of the night).
c) Split-Night 2 REM density value (value for the second half of the night).

Investigation 4: Increased Dream Production in relation to Overnight Emotional Memory Consolidation & Emotion Regulation. There are many possible, and yet unknown, functions of dreaming. One way to uncover possible functions is to look at the neurobiological underpinnings of dreaming, and the systems and processes it overlaps with. Although dreaming can occur in any sleep stage, awakenings from REM sleep yield the highest rates of dream recall (Nielsen, 2004; Schredl, Barret, & McNamara, 2007; Stickgold, Pace-Schott, & Hobson, 1994). The neural underpinnings of two processes that overlap with REM dreaming include overnight emotional memory consolidation and emotion regulation (Walker, 2009). Furthermore, REM density has been proposed as one marker for emotion regulatory processes during sleep (Cartwright et al., 1998). To my knowledge, no other studies have looked at overnight emotional memory consolidation and emotion regulation in a design where healthy HFR and LFR individuals are directly compared to one another.

The first set of hypotheses relates to the possibility that, in the context of increased dream production during REM sleep, HFR individuals will exhibit enhanced emotional memory consolidation. Before testing this, and in order to demonstrate that this enhancement relates specifically to *emotional* declarative memory, the following control hypothesis was included:

Hypothesis 1: HFR and LFR individuals will perform comparably on neutral declarative memory tasks.

Following this, and in relation to an emotional declarative memory (EDM) task, the following hypothesis was tested:

Hypothesis 2: HFR individuals when compared to LFR individuals will perform significantly better with regard to recognition accuracy for emotionally salient items (negative and positive pictures).

The second set of hypotheses relate to overnight emotion regulation in the context of increased dream production during REM sleep:

Hypothesis 3: HFR individuals will be more successful in up-regulating positive emotion and/or down-regulating negative emotion compared to LFR individuals. This will be evidenced by significant between-group differences with regard to morning values of positive and negative emotion (based on comparable night-time values).

The final hypothesis is based on the premise that REM dreaming aids in overnight emotion regulation, while rapid eye movements can be used to index the occurrence of REM dreams. Based on this, the following hypothesis was formulated:

Hypothesis 4: Increased levels of REM density is significantly associated with one or both of the following:

a) An overnight increase in GPE scores
b) An overnight decrease in GNE scores

CHAPTER THREE: GENERAL METHODS

In this section I will begin by describing the methods common to all four investigations. The four investigations include investigating the following: *trait characteristics of HFR individuals, the sleep architecture of HFR individuals, objectively measuring increased rates of dream production during REM sleep in HFR individuals, and, the effects of increased dream production on overnight emotional memory consolidation and emotion regulation.* All four investigations entailed studying the same participants during the same study sessions. Following a discussion of the methods common to all four investigations, I will describe the methods of each investigation separately and in detail.

Design and Setting

This study consisted of a quasi-experimental design and was conducted over a number of phases. The first phase entailed completing an online survey, while the screening interview and the data collection phase took place at the UCT Sleep Sciences Sleep Laboratory at the University of Cape Town, South Africa.

Participants

This study recruited both males and females from a university population. The method of recruitment entailed sending out an email (see Appendix A) describing the study and the eligibility requirements. The email was sent out to the whole student body at the University of Cape Town (approximately 26500 students), four times, over the course of a year. Furthermore, the survey was also specifically sent out on additional occasions to Psychology undergraduate students who earn course points for participating in research conducted by the Department of Psychology. One drawback of sampling from Psychology undergraduates was that they could earn a different number of points depending on how many phases of the study they complete. Many potential participants opted to only complete the survey and were not interested in participating in the experimental nights, leading to relatively high rates of attrition in this regard. The online survey collected demographic, medical, psychiatric, substance use, sleep, and dreaming data (see Appendix B). Consent had to be provided before potential participants could proceed to the survey (see Appendix C)

Participants, being unaware that dream recall frequency is the primary criterion of inclusion, were asked the following question that was based in the online survey:

"If a dream is defined as a long and bizarre story, an image that vanishes rapidly, or a feeling of having dreamt, on average, how many mornings per week over the last couple of months did you wake up with a dream in mind?"[13]

This definition of a dream was chosen in order for the recruitment protocol to be identical to the Eichenlaub et al. (2014a; 2014b) studies. This is important when attempting to replicate previous results.

Based on participant responses[14], two groups were formed: 1) individuals recalling more than three dreams per week were classified as high frequency recallers (HFRs), and 2) individuals recalling less than two dreams per month were classified as low frequency recallers (LFRs). Individuals falling in one of these two categories were considered for participation in the study.

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[13] For the sake of brevity and style, any mention of dream recall frequency (DRF) or "remembering/recalling dreams", is in reference to the above operationalised definition.

[14] Potential responses include: a) Never, b) Less than once a month, c) about once a month, d) two or three times a month, e) about once a week, f) about two or three times a week, g) more than three times per week, h) almost every morning. Responses were quantified to reflect the number of dreams per week.

A total of 2041 individuals followed the link to the online survey, of which 1591 individuals successfully completed the survey in its entirety. Of the remaining individuals, 370 potential participants indicated that they remember more than three dreams per week, and 170 potential participants indicated that they remember less than two dreams per month. This brings the number of eligible potential participants to 540. Following all the different phases of the study (to be discussed below), the final sample (*N* = 36) consisted of 19 HFR individuals and 17 LFR individuals. With regard to sex, the HFR group contained 11 females and 8 males, while the LFR group contained 9 males and 8 females.

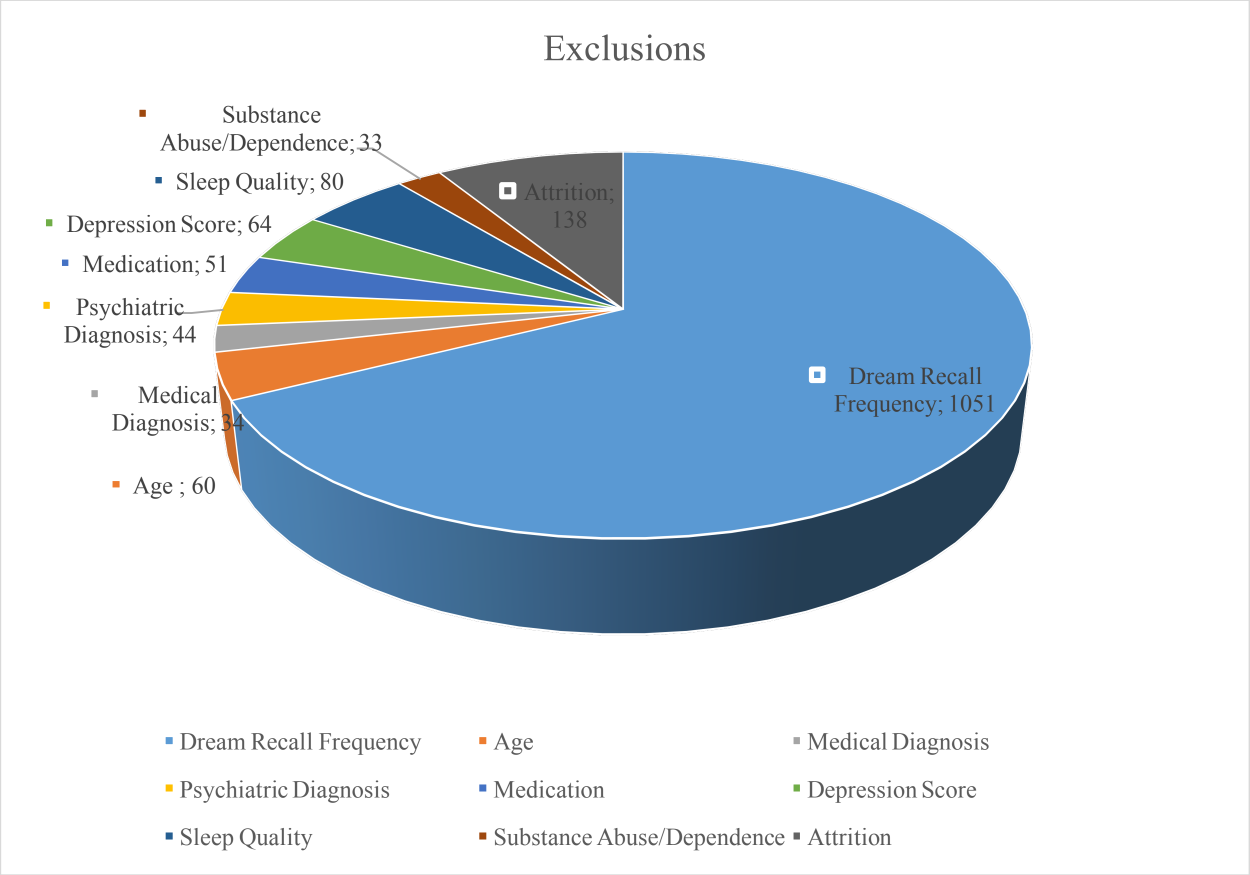
The general exclusion criteria are listed below, which also applies to excluding the remaining 504 potential participants who did fall into one of the two DRF inclusion categories:

Exclusion Criteria. All individuals who met any of the following criteria were excluded from participation in the study:

1) All potential participants who report between two and 12 dreams per month.
2) Potential participants below the age of 20 or over the age of 40. Sleep architecture changes in characteristic ways in late adulthood and display different properties when compared to younger adults and adolescents (Blackman, 2000).
3) Past and current history of alcohol or substance abuse/dependence. Alcohol and substance abuse need to be controlled for because studies have found significant differences in the sleep architecture of participants with excessive alcohol consumption. The findings include prolonged sleep latency, decreased slow-wave sleep, and shorter REM latency (Irwin, Miller, Gillan, Demodena, & Ehlers, 2000).
4) Current and past history of a sleep disorder.
5) Current and past history of a psychiatric disorder.

6) Evidence of the use of sleeping pills, sedative medication or any other psychoactive medication to treat sleep or psychiatric disorders. These different agents alter natural sleep cycles in different ways. Any participant who is using medication that might affect dreaming was also excluded.
7) *Any* medical condition that is known to affect cognitive functioning, sleeping patterns, emotional processes, and dreaming.
8) Pregnancy, as sleep architecture of pregnant women differs from non-pregnant women (Lee, 1998).

The figure below presents the reasons for excluding 1555 individuals who completed the online survey in its entirety:



Note. Dream Recall Frequency Exclusion: Between 2 and 12 dreams per month (range of sample: 0.125-0.25 for LFR and 14-28 for HFR); Age Exclusion: younger than 20 years, and older than 40 years; Medical Diagnosis Exclusion: Holding a diagnosis of any condition known to affect sleep, cognition, mood, and dreaming; Psychiatric Diagnosis Exclusion: Past and current history of holding a psychiatric diagnosis known to influence sleep, cognition, mood and dreaming; Medication Exclusion: Currently taking any medication known to influence sleep, cognition, mood, and dreaming; Depression Score Exclusion: Scoring ≥ 14 on the Beck Depression Inventory – 2nd Edition; Sleep Quality Exclusion: Scoring > 5 on the Pittsburgh Sleep Quality Index (a higher score = worse sleep quality).

Figure 1. Exclusions based on Screening Outcomes

The figure above clearly demonstrates that the vast majority of exclusions were based on reported DRF (*N* = 1051, 68%). This study essentially attempted to sample participants from opposite ends of the bell curve, which, understandably, would lead to a diminished sample size than if less rigorous criteria were implemented. Although it was a fleeting consideration to adopt less stringent DRF inclusion criteria in order to include more participants in the study, the reasons for not going ahead with this strategy were twofold. Firstly, the DRF criteria were based on the only other two studies studying this particular population (Eichenlaub et al., 2014a; Eichenlaub et al., 2014b), and, if one is to attempt to replicate previous findings, there cannot be a significant deviation in the basic sampling protocol. Furthermore, the final sample size ($N = 36$) is identical to the final sample size of both of the abovementioned studies.

In addition, an a priori power analysis was run prior to recruitment, where power ($1-\beta$) was set at 0.8 with $\alpha = 0,05$, one-tailed, and with d as high as 3.89. Results from the analysis revealed that a minimum sample size of 4 individuals per group would suffice. Given this information, the decision to retain the stringent DRF inclusion criteria was made, and an ideal sample size was set to be at least the equivalent of the other two studies in the literature: $N = 36$.

Another contributing factor to the current sample size is the fact that complete homogeneity between groups was pursued as part of the sampling strategy, i.e. not only were the criteria strict in terms of DRF, but also in terms of depression and sleep quality scores, medication and substance use, medical and psychiatric diagnoses, as well as cognitive functioning. Therefore, although the sample size is lower than if less stringent exclusion criteria were employed, the sample is essentially ‘clean’ and completely homogenous, and, according to previous studies and a priori power analysis, sufficient:

Table 1

Sociodemographic and Screening Outcomes of the Current Sample (N=36)

	Group				
Variable	HFR ($n = 19$)	LFR ($n = 17$)	t / χ^2 / U	p	ESE
Age (years)	21.37 (1.64)	24.18 (5.68)	104.00	.07	.30
Sex			.423	.516	.11
Male	8	9			
Female	11	8			
HLOE (years)	12.63 (1.38)	13.35 (1.94)	134.50	.40	.14
Shipley 2 IQ Score	107.53 (13.16)	104.3 (12.5)	.75	.46	.25
BDI-II	4.32 (2.57)	4.12 (3.73)	.19	.85	.10
PSQI	3.47 (1.31)	3.59 (1.12)	-.28	.78	-0.12
MAST	.63 (.68)	.82 (1.24)	-.59	.56	-0.19
Dream Recall Frequency	4.68 (1.19)	.24 (.03)	.000	<.001***	.85
Recall Upon Awakening			7.59	.006**	.36
Yes	19	8			
No	11	21			
Dream Interest	3.37 (.68)	2.88 (.93)	1.80	.08	.59

Note. For all variables except *Sex* and *Recall Upon Awakening* means are presented with standard deviations in parentheses. Chi-square statistic was computed for *Sex* and *Recall Upon Awakening, &* Mann-Whitney *U* for *Age, HLOE, & Dream Recall Frequency.* HFR = High Frequency Recall Individuals; LFR = Low Frequency Recall Individuals; ESE = effect size estimate (for *t,* Cohen's *d;* for χ^2, Cramer's *V;* for *U, r*); HLOE = Highest Level of Education Completed in Years; BDI-II = Beck Depression Inventory-2nd Edition; PSQI = Pittsburgh Sleep Quality Index; MAST = Michigan Alcoholism Screening Test. *Dream Recall Frequency* relates to self-report of number of dream traces recalled per week; *Recall Upon Awakening* refers to whether a dream trace was recalled upon awakening in the sleep laboratory; *Dream Interest* was rated on a scale from 1 (not interested), 2 (somewhat interested), 3 (moderately interested), 4 (very interested).
$^{**}p < .01$. $^{***}p < .001$.

Table 1 shows the sociodemographic and screening outcomes of 36 individuals who participated in the study. As mentioned above, participants were assigned to one of two groups: HFR ($n = 19$), and LFR ($n = 17$) based on subjective dream recall frequency. Both groups were matched equally in terms of age, sex, highest level of education (HLOE), Shipley 2 IQ score, depressive symptomatology scores, subjective sleep quality, as well as alcohol abuse and dependence. More specifically, none of the participants met the criterion for a depressive episode (a score of ≥14 on the BDI-II), subjective sleep disturbance, or alcohol and drug abuse and/or dependence. In addition to the measures reported above, the MINI Neuropsychiatric Interview was also administered at the second screening phase – none of the participants met the criteria for any of the axis I psychiatric diagnoses, while the measure also served to cross-validate the results of the Beck Depression Inventory – 2nd Edition, and the Michigan Alcoholism Screening Test.

The only significant differences detected in the above analyses relate to subjective DRF, as well as dream recall upon awakening. Dream recall upon awakening served as an objective measure of dream recall, while the absence or presence of dream traces upon awakening were determined by administering the Most Recent Dream Form (Domhoff & Schneider, 1998) in the morning following the conclusion of the sleep study – both on the adaptation as well as the testing nights. In order to determine whether the sleep stage participants awakened from [there are varying rates of dream recall for the different sleep stages (Nielsen, 2000)], exerted an influence on recall upon awakening, chi-square analysis was conducted. Results from the analysis can be seen below:

Table 2

Chi-Square Analysis of Dream Recall & Sleep Stage upon Awakening/Wakefulness (N = 58)

		Group				
Variable		HFR (*n* = 30)	LFR (*n* = 28)	χ^2	*p*	ESE
Stage 1 Awakenings				.752	.464	.114
	Yes	3	5			
	No	27	23			
Stage 2 Awakenings				3.52	.071	.246
	Yes	17	9			
	No	13	19			
Stage 3 Awakenings				1.93	.492	.183
	Yes	2	0			
	No	28	28			
Stage REM Awakenings				.208	.757	.060
	Yes	6	7			
	No	24	21			
WAKE				1.71	.246	.172
	Yes	2	5			
	No	28	23			

Note. HFR = High Frequency Recall Individuals; LFR = Low Frequency Recall individuals; *Sleep Stage upon Awakening* was determined by noting the sleep stage present on the electroencephalogram at the moment of awakening (conclusion of the sleep study) on both the adaptation and experimental nights; "yes" refers to the number of awakenings that occurred from a specific sleep stage; WAKE = Individuals who were in a state of wakefulness upon conclusion of the sleep study; missing data include 7 (adaptation night) for the HFR group and 5 (adaptation night) and 1 (experimental night) for the LFR group; ESE = Effect Size Estimate, in this case *Cramer's V.*

Results from the chi-square analysis reveal that there was no significant difference between groups with regard to the sleep stage upon awakening or whether participants were awake upon conclusion of the sleep study. In other words, individuals in both groups had a similar number of awakenings from the different sleep stages or presented with wakefulness a similar amount of times upon conclusion of the sleep study. Furthermore, the results from the objective measure of dream recall supports the premise that group allocation was statistically successful in adequately discerning between HFR and LFR individuals based on self-report.

In summary, groups were equally matched on all sociodemographic and screening outcomes, with the only difference pertaining to subjective and objective dream recall frequency. Therefore, any differences that are detected cannot be ascribed to inter-group variability, apart from the independent variable: dream recall frequency.

Materials and Apparatus

Screening Measures. A research recruitment email was sent to the entire student body at the University of Cape Town containing a link to an online screening survey. The online screening survey collected demographic information, medical history (past and current), psychiatric history (past and current), details about dream recall frequency and other dream-related information. The screening survey also required potential participants to fill out the Michigan Alcoholism Screening Test, the Pittsburgh Sleep Quality Index, and The Beck Depression Inventory – 2nd Edition. If potential participants passed the online screening phase, they were invited to come into the laboratory for a screening interview. At the screening interview the MINI Neuropsychiatric Interview and the Shipley-2 IQ test were administered.

The Michigan Alcoholism Screening Test (MAST; Selzer, 1971) is a quantifiable structured interview used to detect alcoholism and alcohol dependence/abuse, and demonstrates good consistency and validity. The screening test consists of 25 questions that are quick to administer and explores different aspects related to alcoholism and alcohol dependence/abuse, e.g. legal, medical, social, and occupational problems. One of the strengths of this questionnaire is that it not only focuses on current alcohol use patterns, but also takes past behaviours associated with alcohol use into consideration. It is essential to control for alcohol dependence/abuse as it is known to affect sleep in terms of both continuity and quantity (Roehrs & Roth, 2001). Any participant scoring ≥ 5 on the MAST was excluded. The MAST has proven to be a useful screening instrument with regard to South African populations (Bekker and van Velden, 2003).

The Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) is a self-rated questionnaire used to evaluate an individual's sleep quality and sleep disturbances over the past month. Seven 'component' scores are generated that assess subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. The PSQI has both psychometric and clinical properties which make it well suited for use in clinical practice and research activities. This study aimed to recruit individuals who present with no subjective sleep disruptions, therefore, any potential participant who scored >5 on the measure was excluded from participation. The PSQI has been successfully administered to South African populations (Rockwood, Mintzer, Truyen, Wessel, & Wilkinson, 2001).

The Beck Depression Inventory – Second Edition (BDI-II; Beck, Steer, & Brown, 1996) consists of 21 standardised self-report questionnaire items that evaluate the severity of depressive symptomatology in adults. In this study, the BDI-II was used as a screening measure as depression is known to affect both sleep stage distribution and duration. In general, a score of 14 -19 indicates mild depression; 20-28 indicates moderate depression; while 29-63 indicates severe depression (Beck, Steer, & Brown, 1996). An eligibility requirement of this study is that potential participants must not meet the criteria for a depressive episode.

Therefore, any individual scoring ≥14 on the measure was excluded from participation. The instrument is reported as valid and reliable by the developers and can be implemented in a clinical setting and as a research tool. The instrument has been successfully used with research conducted in South Africa (Seedat, Nyamai, Njenga, Vythilingum, & Stein, 2004).

The Mini International Neuropsychiatric Interview, (English version 5.0.0; MINI; Sheehan et al., 1998), is a structured diagnostic interview that was used to screen for the presence of major DSM-IV psychiatric disorders. According to the MINI's developer's, the tool has good psychometric properties and can be administered within approximately 15 minutes by a clinician or by a lay person who has undergone appropriate training. This instrument was used to screen for the presence of psychiatric pathology in potential participants. This includes, for example, Depression, Bipolar disorder, Anxiety disorders, Posttraumatic stress disorder, Substance use/dependence, and Obsessive-compulsive disorder. Potential participants meeting the criteria for any of the disorders contained in the MINI were excluded from participation. In terms of using the MINI in a South African sample, studies have shown that the MINI has high reliability and validity scores when used with South African populations (Olley et al., 2005).

The Shipley-2 IQ Test (Shipley et al., 2009) is a revised and re-standardised test that provides a robust measure of both crystallised and fluid intelligence. It is short and easy to administer and has been proven to be useful in educational, clinical, forensic and research contexts (Kaya et al., 2012). The strength of the test in a research context is that it is very brief both in terms of administration and scoring, allowing for swift decision-making when determining eligibility for participation. In this study, the test was used as a screening measure of cognitive functioning as memory tests formed part of the experimental protocol. In other words, groups were matched in terms of Shipley-2 IQ Score so that any differences with regard to performance on memory tests cannot be ascribed to differing levels of cognitive ability between groups.

Experimental Measures. Experimental measures will be discussed in subsequent sections in relation to the relevant study.

General Study Procedure

The study consisted of four phases. In the first phase, *the online screening phase,* a recruitment email containing a link to the online screening survey was sent out to the whole student body at the University of Cape Town. Ethical clearance from the Faculty of Humanities was obtained prior to distributing the email. The survey collected demographic data, past and current medical and psychiatric history, information about dream recall frequency, the Michigan Alcoholism Screening Test (MAST), the Pittsburgh Sleep Quality Index (PSQI), and the Beck Depression Inventory II (BDI-II). Participants who indicated that they recall less than two dreams per month, or more than three dreams a week, and who did not meet any of the exclusion criteria stipulated in the previous section, were invited to advance to the next phase of the study.

The second phase, the *screening interview,* took place at the UCT Sleep Sciences sleep laboratory. Upon arrival the potential participant was provided with an information sheet that described the study procedure in detail (See Appendix D). Potential participants were given the opportunity to ask questions, and if they indicated that they wanted to continue with the study, they were asked to sign a consent form (See Appendix E). Following this, the Shipley-2 IQ test was administered in order to ensure groups were adequately matched on cognitive ability as memory tests formed part of the experimental protocol of the study. In addition to this, the MINI Neuropsychiatric Interview was administered in order to exclude the presence of major

Axis I diagnoses. If the potential participant was eligible following this procedure, they were invited to come in for an adaptation night between two and 10 days later. If participants were not able to complete the adaptation night within 10 days, they were required to complete the online survey for a second time in order to ensure that, with the passing of time, they do not meet any of the exclusion criteria.

The third phase, the *adaptation night,* involved participants spending a night in the sleep laboratory in order to familiarise themselves with the equipment and the sleeping environment. This is imperative when conducting sleep studies as sleep is often disrupted when sleeping in a novel environment in what is known as the 'first night effect' (Lorenzo & Barbanoj, 2002). Upon arrival at the sleep laboratory, the full procedure that were to follow was explained to the participants and any questions they had were answered. Following this, the participant was prepared for a night's sleep. Participants were attached continuously throughout the night to the sleep-adapted EEG monitor that, in addition to brain activity, also measures muscle and eye movements, as well as heart rate. Participants were allowed to sleep uninterruptedly for 7-8 hours following lights off, while a Most Recent Dream Form was completed upon awakening.

Following the adaptation night, participants were invited to come in for their *sleep testing night* two to ten days following the adaptation night, this constituted the fourth and final phase of the study. It is important to schedule the sleep nights non-consecutively as to avoid the potential consequences of the 'first night effect'. One consequence of the first-night effect relates to the possibility that an individual might experience recovery sleep the night following an adaptation night (Borbély, Achermann, Trachsel, & Tobler, 1989). This is based on the assumption that sleep will be disrupted the first night in a new environment, and that the subsequent night will not be a true reflection of a person's sleep architecture.

Upon arrival, participants were fully briefed with regard to the study procedure what will follow, and any questions they had were answered. Following this, three different questionnaires were administered. This includes the Positive and Negative Affect Schedule – Expanded Version (PANAS-X) (see Appendix F), the Boundary Questionnaire-Shortform (BQ-Sh) (see Appendix G), and the Ten Item Personality Inventory (TIPI) (see Appendix H). These measures will be discussed in detail in subsequent sections.

After completing the questionnaires, participants underwent memory testing. This included the Logical Memory Test (LMT), the Rey Auditory Verbal Learning Test (RAVLT)[15], and the Emotional Declarative Memory Task (EDM Task). As mentioned above, these measures will be discussed in detail in subsequent sections.

Finally, participants were prepared for a night's sleep in the exact same way that was indicated above for the adaptation night. Participants were awakened 7-8 hours after lights-out where they were asked to complete the Most Recent Dream Form immediately following awakening. A debriefing of study procedures followed after participants were paid R300 for their participation.

Ethical Considerations

This study consisted of four phases, where consent was obtained preceding both of the screening phases. In terms of the first phase, when potential participants followed the link to the online survey, they were provided with all the necessary information, e.g. study objectives and the eligibility requirements before digital consent was requested. It was explained that all information will be kept strictly confidential and that potential participants can withdraw from the study at any point and without penalty. If a potential participant provided consent, they were redirected to the survey page. As mentioned before, the online survey amongst other

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[15] These measures will not appear in the Appendix due to copyright

things, collected demographic, medical, and psychiatric data. If it came to light that any potential participant exhibited symptoms of psychiatric illness, substance abuse/dependence, or a medical condition that were not being treated under the supervision of a healthcare professional, contact details of local counsellours/general practitioners were provided.

The second instance of obtaining consent took place at the *screening interview* phase of the study. Only participants who met one of the dream recall frequency criterion, and not any of the listed exclusion criteria, were invited to advance to the next phase. Upon arrival an information sheet describing the study, the procedures and the risks and benefits in detail were provided to the potential participant. They were given the opportunity to read through the information sheet and any questions they had were answered. Again they were reminded that all information is kept strictly confidential, and that they can withdraw from the study at any point and without penalty. Written consent was obtained before the researcher proceeded with administering the Shipley-2 IQ Test, as well as the MINI Neuropsychiatric Interview. If potential participants met any of the diagnoses contained in the MINI, the contact details of local counsellours were provided.

CHAPTER FOUR: INVESTIGATION 1 – TRAIT CHARACTERISTICS OF HFR INDIVIDUALS

Introduction

Traditionally, increased dream recall frequency in the literature has often been attributed to being a consequence of different personality traits, for example scoring high on the trait ‘neuroticism’, ‘openness to experience’, and/or having ‘thin’ boundaries (Hartmann, Elkin, & Garg, 1991; Schredl, Kleinfercher, & Gell, 1996; Schredl, Ciric, Götz, & Wittmann, 2003). This study, however, aimed to test an alternative hypothesis, challenging the popular notion that dream recall frequency is a product of certain innate traits. However, recent neuroimaging and ERP studies have demonstrated that there are functional neurophysiological differences between HFR and LFR individuals (Eichenlaub et al., 2014a; 2014b). In light of this, I propose that DRF is not necessarily a product of certain personality characteristics, but that both increased DRF and certain personality characteristics are potentially an expression of a functional neurophysiological arrangement innate to HFR individuals.

Methods

Participants. Participants recruited for this study include 19 HFR individuals, and 17 LFR individuals ($N = 36$)

Exclusion Criteria. The exclusion criteria described in the General Methods chapter were also implemented in this investigation.

Screening Measures. See the equivalent section in General Methods.

Experimental Measures. The first experimental measure, the *Ten-Item Personality Inventory* (TIPI; Gosling, Rentfrow, & Swann, 2003), is a short measure of personality based on the ‘Big-Five’ personality dimensions. These dimensions include ‘extroversion’, ‘agreeableness’, ‘openness to experience’, ‘conscientiousness’, and ‘neuroticism’ (its converse being ‘emotional stability’). Participants were asked to rate a number of different statements related to personality traits (corresponding to the personality dimensions mentioned above) in terms of the extent to which it applies to them. The scale ranged from 1=Disagree strongly, to 7=Agree strongly.

According to the developers, the instrument displays adequate levels of convergence with widely used Big-Five measures in terms of self, observer, and peer reports. Furthermore, it also demonstrated adequate levels of test-re-test reliability, patterns of predicted external correlates, as well as convergence between self and observer ratings (Gosling et al., 2003). This short measure was chosen in order to limit the testing burden on participants - in addition to completing two other questionnaires, three memory tests, as well as enduring a 90-minute set-up of the PSG equipment, the decision was made to include a shortform personality measure over a full length measure.

The second experimental measure the *Boundary Questionnaire – Shortform* (BQ-Sh) (Rawlings, 2001) is based on the original Boundary Questionnaire developed by Hartmann (1989). By means of factor analysis, the BQ-Sh is an empirically derived short version (46 items) from the full length (145 items) version. The factor analysis produced six subscales that are labelled ‘Unusual Experiences’, ‘Need for Order’, ‘Trust’, ‘Perceived Competence’, ‘Childlikeness’, and ‘Sensitivity’. The measure demonstrates good reliability and has a strong correlation with the original Boundary Questionnaire ($r = .88$).

Participants were asked to rate various statements corresponding to the different sub-scales on a five-point scale ranging from 0 (not at all true of me) to 4 (very true of me). Examples of questions include: “In my daydreams, people kind of merge into one another, or one person into another”; “I am a very sensitive person, or easily hurt”; “There is a place for everything, and everything should be in its place"; and "I have a clear and distinct sense of time". A higher score is indicative of 'thinner' boundaries.

The items in the questionnaire relate to how 'permeable' a person's boundary is to external influences. In other words, people with thin boundaries often demonstrate a fluid sense of self, they are tend to be sensitive, vulnerable, and sometimes fail to distinguish between fantasy and reality. Conversely, individuals with 'thick' boundaries have a distinct sense of self separate from others, can clearly distinguish between fantasy and reality, and are often guarded, and meticulously careful in their actions (Hartmann, 1989; Rawlings, 2001). The shortform was chosen in order to minimise the testing burden on participants in light of the measure demonstrating good reliability and validity.

General Study Procedure. See the equivalent section in General Methods for description of the different phases of the study.

Ethical Considerations. See the equivalent section in General Methods. In addition to this, participants were specifically reminded that they can stop at any point without penalty if they find any of the questionnaires distressing in any way.

Statistical Analyses. All collected data were analysed using SPSS software (Howell, 2004). The independent variable was *group condition:* HFR (*n* = 19) and LFR (*n* = 17). The dependent variables for the different measures include, firstly, for the TIPI, the total scores of the following categories: 'extroversion', 'agreeableness', 'openness', 'conscientiousness', and 'emotional stability' (also conversely known as 'neuroticism'). The dependent variable for the second measure, the BQ-Sh includes the Total BQ-Sh Score. Independent T-tests were run on all dependent variables. In addition to measuring between-group differences, correlational analyses were run in relation to the different experimental measures and the number of dreams recalled per week (DRFQ). It is important to note that there is a difference between DRF and DRFQ. DRF was used as a categorical variable (HFR and LFR) for the purpose of group allocation. DRFQ is a continuous variable that denotes the actual number of dreams recalled per week. The range for the HFR was 3.5-7 dreams per week, and 0.125-0.25 dreams per week for the LFR group.

Results

Trait Characteristics of HFR Individuals. As mentioned above, the measures used to investigate the trait characteristics of the sample include the Ten-Item Personality Inventory (TIPI) and The Boundary Questionnaire Shortform (BQ-Sh). The personality dimensions assessed by the TIPI include ‘extroversion’, ‘agreeableness’, conscientiousness’, ‘emotional stability’ (its converse being ‘neuroticism’), and finally, ‘openness’. With regard to the BQ-Sh, a higher score indicates ‘thinner’ boundaries.

All measures were implemented with the following hypotheses in mind:

Hypothesis 1:

HFR individuals when compared to LFR individuals will score significantly higher on the personality measure in relation to ‘openness’, ‘extroversion’ and emotional stability.

Hypothesis 2:

HFR individuals will score significantly higher on the BQ-Sh, indicating the presence of ‘thinner’ boundaries when compared to LFR individuals.

Table 3

Trait Characteristics of the Current Sample (N = 36)

	Group				
Variable	HFR (n = 19)	LFR (n = 17)	t / U	p	ESE
TIPI Extroversion	4.737 (1.456)	4.353 (1.308)	.828	.413	.28
TIPI Agreeableness	5.61 (.900)	4.53 (.927)	3.503	.001**	1.18
TIPI Conscientiousness	5.632 (1.177)	5.781 (.948)	150.00	.961	.006
TIPI Emotional Stability	5.684 (1.07)	5.559 (1.249)	.325	.748	.10
TIPI Openness	5.605 (1.185)	5.794 (.902)	-.533	.592	.17
Boundary Questionnaire-Sh	70.789 (12.977)	60.176 (9.812)	2.742	.010*	.91

Note. For all variables means are presented with standard deviations in parentheses; HFR = High Frequency Recall Individuals; LFR = Low Frequency Recall Individuals; TIPI = Ten-Item Personality Inventory; Boundary Questionnaire Sh*: * = Shortform;; *t* –statistic computed for all variables, with the exception of TIPI Conscientiousness where Mann-Whitney U was computed as part of non-parametric analysis. ESE = Effect Size Estimate, for *t, d;* for *U, r;* * = <.05; ** = <.01; ***=<.0001

Testing Hypothesis 1. The first hypothesis of this study was not confirmed: HFR and LFR individuals did not differ significantly on the ‘openness’, ‘extroversion’ and ‘emotional stability’ dimensions of the TIPI questionnaire. However, the analysis did reveal a significant difference between the HFR group (M = 5.61, SD = .90) and the LFR group (M = 4.53, SD = .93) with regard to the ‘agreeableness’ personality dimension $t(34)$, $p = .001$, with a very large effect size, $d = 1.18$.

Testing Hypothesis 2. The second main hypothesis of this study was confirmed, in line with previous research, I found that HFR individuals (M = 70.79, SD = 12.98) scored significantly higher t(34) = 2.74, $p = .010$, than the LFR individuals (M = 60.18, SD = 9.81) on the BQ-Sh, with a large effect size, $d = .91$. In other words, HFR individuals tend to have significantly “thinner” boundaries compared to their LFR counterparts.

Summary of Results. The first main hypothesis of this study was not confirmed: there were no significant differences between the HFR and LFR individuals on the ‘openness’, ‘extroversion’ and ‘emotional stability’ personality dimensions. However, there was a significant difference between groups with regard to the ‘agreeableness’ personality dimension. The second main hypothesis of this study was confirmed: Individuals in the HFR group score significantly higher on the BQ-Sh, which is indicative of having ‘thinner’ boundaries.

CHAPTER 5: INVESTIGATION 2 – THE SLEEP ARCHITECTURE OF HFR INDIVIDUALS

Introduction

Even though there are various studies investigating dream recall frequency in general, to my knowledge, there has only been one other study[16] systematically investigating the sleep architecture of HFR compared to LFR individuals via polysomnography (Eichenlaub et al., 2014). This is an important investigation as it lends itself to testing somewhat contentious hypotheses related to dream recall frequency, for instance the arousal-retrieval hypothesis, in an objective manner. The literature is littered with subjective accounts and retrospective data, making it increasingly difficult to draw empirically sound conclusions from the available data. Utilising polysomnography in conjunction with other measures in testing hypotheses related to both dream recall and sleep, is imperative in providing a starting point in formulating novel and objective ways to approach contentious issues evident in the dream literature.

The objective of the current sleep study was not only to replicate the findings of the Eichenlaub et al. (2014a) study, but also to build on these findings by including additional sleep parameters. Furthermore, as an additional contribution, the current study recruited both males and females in order to investigate sleep architecture in the context of dream recall frequency.

Methods

Participants. Participants recruited for this study include 19 HFR individuals, and 17 LFR individuals (*N* = 36)

Exclusion Criteria. The exclusion criteria described in the General Methods

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[16] A recently published study, Vallet et al. (2017), ran additional analyses on the Eichenlaub et al. (2014a) study data

Chapter are also applicable to the DRF and Sleep Architecture Study.

Screening Measures. See the equivalent section in General Methods

Experimental Measure: Objective Measure of Sleep Quality. *Polysomnography.* The sleep studies were conducted at the UCT Sleep Sciences sleep laboratory, Department of Psychology, University of Cape Town. This laboratory is equipped with two 16-channel Nihon Kohden Neurofax EEG900 electroencephalographs that were adapted for sleep research and contains all the necessary facilities to conduct sleep research. The equipment measures brain activity during sleep, electrooculograph (EOG) electrodes that monitor eye movement, chin electromyograph (EMG) electrodes that monitor muscle tone, and an electrocardiogram (ECG) to measure heart rate.

All the equipment meet the requirements stipulated for digital system regulations (e.g. filters on each channel), the guidelines for display and display manipulation (e.g. the option of viewing the sleep data in different time frames, from 5 seconds to 2 minutes), as well as specifications with regard to digital analysis (e.g. the option of scoring the data either electronically or manually).

A bipolar montage was used with the following bipolar derivations: F3-C3, C3-P3, P3-O1, and F4-C4, C4-P4, P4-O2. This was combined with a referential montage utilising F3-A2, C3-A2, O1-A2, and F4-A1, C4-A1, O2-A1 derivations. A combination approach was chosen in order to ensure the integrity of the records. Standard filters for sleep recordings were used for the EEG and EOG (0.5-35Hz), EMG (10-70Hz), and ECG (1-70Hz) in order to ensure the integrity of the signal. The ground electrode was placed in the middle of the forehead.

All electrodes used in our laboratory are gold-plated as to minimise artefact and interference. With regard to the placement of electrodes, I adopted the 10/20 system which is an internationally recognised method that's used to describe the placement of scalp electrodes. The relationship between the electrode and the underlying area of the cerebral cortex is the principle upon which this system is based. There are four anatomical landmarks that are used to position the electrodes. The first two includes the nasion (point between the forehead and the nose), and the inion (lowest point of the skull from the back of the head). The other two include pre-auricular points anterior to both ears. The numbers ‘10’ and ‘20’ indicate that the distances between electrodes adjacent to each other are either 10% or 20% of the total front (nasion) to back (inion) measurement of the skull, or the right (pre-auricular point) to left (pre-auricular point) measurement of the skull.

General Study Procedure. See the equivalent section in General Methods for description of the different phases of the study.

In terms of the experimental sleep testing night, participants arrived at the sleep laboratory two hours before their usual bedtime and completed the experimental measures (questionnaires and memory tests). Following this, participants were prepared for a night’s sleep in the exact way described above. Once the sleep equipment was set up, all the channels were tested in order to ascertain whether they were working correctly. This was done by asking the participant to perform simple actions, which included biting and blinking. The impedance (or amount of signal interference), was recorded in order to ensure the measurement of a clear reading.

Before lights off, participants were informed that they can contact the researcher in the adjacent room at any point during the night via intercom should they need assistance. They were instructed to switch off all electronic devices and were allowed to sleep uninterruptedly for 7-8 hours following lights off. Participants were asked to complete a Most Recent Dream Form upon awakening (conclusion of the sleep study). Following this the equipment was removed and participants completed an additional questionnaire, as well as the delayed recall and recognition components of the memory tests. Finally, participants were debriefed on all study procedures and payed R300 for their participation in the study.

Ethical Considerations

See the equivalent section in General Methods.

Statistical Analyses

All collected data were analysed using SPSS software (Howell, 2004). The independent variable was *group condition:* HFR (*n* = 19) and LFR (*n* = 17). The dependent variables relate to the *objective characteristics of sleep*. They were analysed in terms of the following subcategories: sleep onset latency (time spent falling asleep); total awakenings from sleep, as well as awakenings from (a) stage 2 sleep, (b) stage 3 sleep, and REM sleep; WASO (wake after sleep onset); sleep efficiency (SE); REM%; REM sleep latency; stage 1%; stage 2%; and stage 3%. All scoring and analyses were based on criteria delineated by the American Academy of Sleep Medicine (2015). Independent T-tests were run on all variables.

It is important to note that the sleep variables that were included in analyses are standard for most sleep studies; however, there were specific variables of interest based on the existing literature and the hypotheses of the current study. The only other study (Eichenlaub et al., 2014) investigating sleep architecture in this population, found significant differences in terms of intrasleep wakefulness (WASO) which provided strong support for the arousal-retrieval model of dream recall. Based on this, I made a priori predictions in relation to two hypotheses: 1) HFR individuals will spend significantly more time awake after sleep onset (WASO), and 2) HFR individuals will experience significantly more awakenings across the night. Furthermore, I also postulated that HFR individuals will experience significantly more awakenings from REM sleep.

Results

Objective Measure of Sleep Quality. As mentioned above, there are two overarching aims of this study, the first is to replicate the results of the only other study (Eichenlaub et al., 2014a) investigating the sleep architecture of HFR individuals compared to LFR individuals. The second aim is to build on the existing findings by including additional sleep parameters in the analyses, as well as recruiting both males and females.

The following hypotheses were tested:

Hypothesis 1: HFR individuals will spend significantly more time awake after sleep onset compared to LFR individuals.

Hypothesis 2: HFR individuals will experience significantly more awakenings across the night when compared to LFR individuals.

- In addition, HFR individuals will hexperience significantly more awakenings from REM sleep compared to LFR individuals.

Results can be seen below:

Table 4

Sleep Architecture and Sleep Characteristics of the Current Sample (N=36)

	Group				
	HFR	LFR			
Variable	(*n* = 19)	(*n* = 17)	*t* / *U*	*p*	ESE
Sleep Onset Latency	32.84 (20.65)	22.10 (14.85)	1.78	.084	.58
Sleep Efficiency	85.21 (11.45)	90.07 (5.45)	-1.60	.120	.52
WASO%	14.45 (10.95)	7.04 (3.74)	75.00	.003**	.46 ^{a}
Stage 1%	11.06 (4.87)	12.87 (7.51)	-.87	.393	.28
Stage 2%	57.50 (15.42)	58.76 (7.73)	-.306	.762	.10
Stage 3%	15.05 (7.57)	13.50 (4.95)	.737	.466	.23
REM sleep %	13.31 (6.81)	14.99 (5.06)	-.831	.412	.27
REM Onset Latency	143.50 (69.94)	174.64 (33.68)	-.167	.104	.54
Total Awakenings	25.26 (10.79)	18.59 (6.41)	2.222	.017*	.72
Stage 2 Awakenings	17.47 (9.95)	10.29 (4.82)	2.704	.011*	.88
Stage 3 Awakenings	2.47 (.91)	2.65 (1.77)	159.00	.933	.01
REM Awakenings	5.21 (3.43)	5.77 (4.12)	-.441	.662	.15

Note. For all variables means are presented with standard deviations in parentheses. HFR = High Frequency Recall individuals; LFR = Low Frequency Recall individuals; WASO% = Wake After Sleep Onset percentage; *t* Statistic computed for all variables, except for WASO% and Stage 3 Awakenings where Mann-Whitney *U* was computed as part of non-parametric analyses. ESE = Effect size estimate; ^{a} *Cohen's d* computed for all variables, with the exception of WASO% & Stage 3 Awakenings where *r* was computed; two-tailed analyses implemented for all variables, except for WASO% and Total Awakenings where a priori predictions were made. * = *p* <.05; ** = *p* <.001

Testing Hypothesis 1. Results from the above table confirm one of the main hypotheses of this investigation: individuals in the HFR group (M = 14.45, SD = 10.95) when compared to the LFR group (M = 7.04, SD = 3.74), spent significant more time awake after sleep onset; U(34) = 75, *p* = .003, with the results revealing a medium to large effect size (*r* = .46). These findings are in line with the Eichenlaub et al. (2014a) study who also reported increased WASO%, or what they termed 'intra-sleep wakefulness'. This is an exciting finding in two ways. Firstly, not only are the results from the abovementioned study replicable, but the findings are upheld even when both males and females are included in the analysis. Furthermore, this finding also provides strong support for the arousal-retrieval model of dream recall (Koulack & Goodenough, 1976). Wake after sleep onset is not the only variable of interest with regard to supporting the arousal-retrieval model – the number of awakenings could be an additional variable exerting an influence on how often and/or how many dreams are recalled. This brings us to Hypothesis 2.

Testing Hypothesis 2. The second main hypothesis of this study was also confirmed: The HFR group (M = 25.26, SD = 10.79) experienced significantly more total awakenings throughout the night t (34) = 2.22, *p* = .017, when compared to the LFR group (M = 18.59, SD = 6.41), with a medium to large effect size (*d* = .72).

The second dimension to this hypothesis was not confirmed, i.e. there was no significant difference with regard to the number of awakenings from REM sleep between the two groups. However, upon further analysis, it was uncovered that, surprisingly, the majority of awakenings for the HFR group (M = 17.47, SD = 9.95) tend to occur from stage 2 NREM sleep, with the LFR group (M = 10.29, SD = 4.82) experiencing significantly less awakenings in comparison, t (34) = 2.704, *p* = .011, with a very large effect size (*d* = .88). Therefore, it is important to note that the finding of increased total awakenings across the night is inflated by stage 2 awakenings, as awakenings from the other sleep stages are comparable when the two groups are considered together. Consequently, the main finding of interest with regard to awakenings, is the number of awakenings that HFR individuals experience from stage 2 NREM sleep as opposed to the total number of awakenings across the night.

In addition to between-group analyses, I also ran Pearson *r* correlation analysis in order to investigate whether the actual number of dreams recalled per week (DRFQ) are associated with the sleep variables that yielded significant results. Results revealed that DRFQ was significantly and positively correlated with WASO%, *r*(34) = .290, *p* = .043, Awakenings, *r*(34) = .291, *p* = .043, as well as Wake S2, *r*(34) = .340, *p* = .021. It is important to emphasize that the variable DRF and DRFQ represent two different constructs: DRF in terms of group allocation is used as a categorical variable, while DRFQ is a continuous variable denoting the actual number of dream traces recalled per week. Therefore, using DRFQ in this instance further builds on the significant group differences that were discussed above, i.e., the actual number of dreams are positively and significantly correlated with the sleep variables of interest. In other words, recalling an increased number of dreams is related to spending more time awake after sleep onset, experiencing an increased number of awakenings, and especially, awakenings from stage 2 sleep.

Summary of Findings. The findings can be summarised as follow: Firstly, to my knowledge, this is the first study to replicate the results of Eichenlaub et al. (2014a), indicating that HFR individuals spend significantly more time awake after sleep onset when compared to LFR individuals. In addition to this, I demonstrated that this finding is upheld even when both males and females are included in analyses.

Secondly, this study also revealed that HFR individuals compared to LFR individuals experience an increased number of awakenings. Moreover, I determined that it is especially awakenings from stage 2 NREM sleep that is significant in this regard.

Thirdly, and lastly, although not one of the main aims of this study, I did find a significant positive relationship between the actual number of dreams recalled per week and increased WASO%, Awakenings, and especially Awakenings from Stage 2 sleep.

CHAPTER SIX: INVESTIGATION 3 – OBJECTIVE MEASURE OF INCREASED DREAM PRODUCTION IN HFR INDIVIDUALS

Introduction

From discussions in the previous sections, it is evident that there is a gap in the literature with regard to studying different aspects related to HFR individuals compared to LFR individuals. There are, to my knowledge, only two other studies that have utilised the abovementioned protocol. As mentioned earlier, the one study (Eichenlaub et al., 2014a) is an ERP/sleep study, and the other one (Eichenlaub et al., 2014b), a neuroimaging study. These two studies have provided novel and important insights with regard to possible underlying functional neurophysiological mechanisms that seem to be associated with certain characteristic features of HFR individuals. An important point that both these studies make, relates to the proposition that it is difficult to disentangle, at this stage, whether recalling more dreams is (1) a consequence of better memory for dreams (in support of the arousal-retrieval model of dream recall), (2) increased rates of dream production across the night, or (3) a combination of the two. Studying the frequency of eye movements during REM sleep is one possible way to objectively and reliably measure rates of dream production during REM sleep.

Methods

Participants. Participants recruited for this study include 19 HFR individuals, and 17 LFR individuals ($N = 36$)

Exclusion Criteria. The exclusion criteria described in the General Methods chapter were also implemented in this study.

Screening Measures. See the equivalent section in General Methods.

Experimental Measures. The first experimental measure relates to the *Electrooculograph (EOG) Measurement of Rapid Eye Movements.* I decided to base the montage on the Rechtschaffen & Kales (1969) method as it is generally regarded as a very common, simple, and robust measure of horizontal eye movements. This montage includes placing one EOG positive electrode (EOG R) just below the midline of the right eye, and another EOG positive electrode (EOG L) just above the midline of the left eye. Both these positive electrodes have a common reference electrode at the left mastoid (M1), and the ground electrode (GROUND) was placed on the forehead. This montage results in two EOG channels i.e. EOG R – M1 and EOG L – M1. See illustration below:

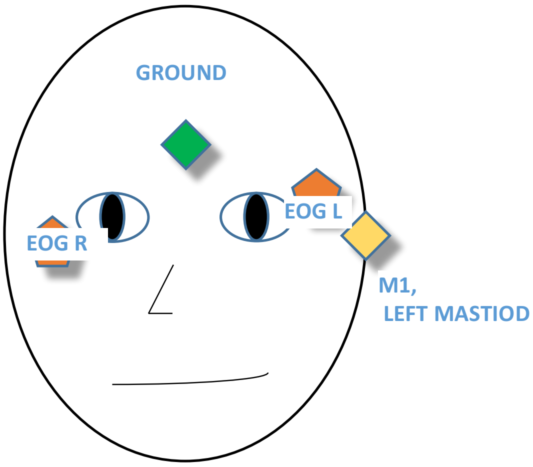


Illustration 1. Visual Representation of Montage including Reference Electrodes

The second experimental measure relates to the *Quantitative REM Density Analysis.* Due to digital computers, EEG and EOG activity data can be analysed 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). As discussed above, rapid eye movements were measured through application of EOG electrodes on two points surrounding the eyes (Rechtschaffen & Kales, 1969).

Within each REM stage, REM density was calculated through a process, which was based on a method employed by Stanford's Centre for Sleep Sciences (Moore, Mignot, Shenoy, Widrow, & Woodward, 2013). Each EOG channel was 50Hz notch filtered; bandpass filtered from 0.3-30Hz and then down-sampled to 100Hz. A double-threshold eye movement detection method was employed to mark rapid eye movement events: the high threshold was set at 30uV and the low threshold at 10uV; multiple eye movements within 0.05s were merged into one movement and the minimum duration of an eye movement was set at 0.1s. Each REM stage was then divided into 30 second epochs, and each of those epochs was then further sub-divided into 2 second mini-epochs. Each of these 2 second mini-epochs was inspected for the presence of 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. A REM density value was then calculated for each 30s epoch as the percentage of 2s mini-epochs that contained at least one rapid eye movement. Following this, each EOG epoch was further also qualitatively inspected for artefact, and where artefact was identified, the corresponding REM density values were disregarded. REM density was thus calculated for every 30s epoch of each REM stage, for each of the two EOG channels.

During preliminary analysis, it was further noted that in certain instances one EOG channel would detect the presence of a rapid eye movement in a mini epoch, where the other EOG channel would not. In order to overcome this incongruence, it was decided to apply the *OR Logical Disjunction Method* to each 2 second mini-epoch of the data. The objective of this method is to flag a movement if it is present in either EOG channel. For each mini-epoch, movement is represented by a logical 1 and no movement by a logical 0, and a logical OR is then applied between the two EOG channels resulting in a combined EOG channel. The table below illustrates the application of the *OR Logical Disjunction Method:*

Inputs **(2 EOG channels)**		**Output** **(1 combined EOG channel)**
EOG R	EOG L	EOG R **OR** EOG L
0	0	0
0	1	1
1	0	1
1	1	1

The Input column refers to whether a rapid eye movement did occur in either of the EOG channels, while the Output column refers to whether a rapid eye movement did occur, by considering both EOG channels simultaneously. In summary, if *either one* or both of the EOG channels detected a rapid eye movement, the presence of a rapid eye movement would be confirmed for that mini epoch; however, if, and only if *both* channels failed to detect an eye movement, that specific mini epoch would be regarded as being devoid of a rapid eye movement.

Once the occurrence or absence of a rapid eye movement has been confirmed for each mini-epoch, the REM density value was re-calculated for each 30 second epoch in that specific REM cycle. As for the initial method, the REM density for each 30s epoch was the percentage value of the 2 second mini-epochs within that 30 second epoch containing rapid eye movements. There can be one to many 30 second epochs forming part of one REM sleep cycle, and the calculation process is repeated for every 30 second epoch in that cycle. Thus, longer REM sleep cycles produced several REM density values that corresponds to each 30 second epoch constituting that cycle.

The total REM density value for each participant was calculated as part of a two-step process. Firstly, the mean REM density percentage was calculated for each REM cycle. This was achieved by considering each REM cycle separately and averaging all the values within that specific REM sleep cycle in order to obtain a single value for each REM cycle. Secondly, the total REM density value per participant was derived from averaging the final values of all the REM sleep cycles.

As before, in addition to this quantitative analysis, the entire dataset was also manually inspected. This was achieved by isolating the two original EOG channels and combining them into one file and proceeding to qualitatively visually detect artefact in either channel. Where artefact was detected then the data for the corresponding epoch of that channel was disregarded and only the corresponding epoch of the artefact free channel was used for REM density calculations.

General Study Procedure. See the equivalent section in General Methods for description of the different phases of the study.

Ethical Considerations. See the equivalent section in General Methods.

Statistical Analyses. In addition to calculating the total REM density value per participant, additional analyses were conducted on the data. This includes doing a split-night analysis, as well as looking specifically at the first REM cycle of the night. Conducting split-night analysis is common practice in sleep studies, while there is evidence in the literature indicating that REM density values change depending on the time of night. The split-night parameters were determined by calculating the half way mark between lights off and lights on in the sleep record. All collected data were analysed using SPSS software (Howell, 2004). The independent variable was *group condition:* HFR (*n* = 19) and LFR (*n* = 17), and the dependent variables include *Total REM density %, Split-night 1 REM density % (*first half of the night), and *split-night 2 REM density%* (second half of the night), as well as *REM density during the 1st REM sleep Period.* Independent T-tests were run on all dependent variables.

Results

The main objective of this investigation relates to developing and employing a method to obtain objective rates of dream production during REM sleep. This objective was chosen in order to determine whether HFR individuals not only have better memory for dreams (due to increased periods of intra-sleep wakefulness), but potentially also produce more dreams compared to LFR individuals. In this investigation I used the frequency of the occurrence of rapid eye movements (REM density), to index the occurrence of REM dreaming, and in turn, use REM density values as an indicator of dream production across the night.

At the time of analysis (2016), no other studies have published results pertaining to REM density as a marker for dream production across the night in an experimental design where HFR and LFR individuals are directly compared to one another. Therefore, apart from looking at total REM density values, I also included subcategories of REM density in an attempt to delineate any changes/fluctuations in REM density that might occur at different times of the night.

Consequently, in addition to Total REM density value, three subcategories were included in analysis: (a) 1st REM period density value, (b) Split-Night 1 REM density value (value for the first half of the night), and (c) Split-Night 2 REM density value (value for the second half of the night).

The following hypotheses were tested:

Hypothesis 1: HFR individuals will exhibit significantly higher rates of REM density across the night compared to LFR individuals.

In addition, the following exploratory hypothesis was included:

Hypothesis 2: There will be a significant difference between the HFR and LFR groups with regard to the following:

a) 1st REM period density value.

b) Split-Night 1 REM density value (value for the first half of the night).

c) Split-Night 2 REM density value (value for the second half of the night).

Results can be see below:

Table 5

Between-group Analyses: REM Density Parameters

	Group				
	HFR	LFR			
Variable	(*n* = 19)	(*n* = 17)	*U*	*p*	ESE
Total REM Density	44.80 (27.40)	36.58 (15.47)	132.00	.175	.18
Split-Night 1*	45.12 (32.24)	33.49 (17.20)	108.00	.314	.22
Split-Night 2*	46.10 (27.71)	35.60 (15.11)	108.00	.314	.23
1st REM Period	43.62 (31.53)	36.40 (19.81)	139.5	.486	.13

Note. For all variables means are presented with standard deviations in parentheses. HFR = High Frequency Recall individuals; LFR = Low Frequency Recall individuals; *U* statistic computed for all variables as part of non-parametric analyses; ESE = Effect size estimate, in this case *r*; one-tailed analyses adopted for Total REM Density due to a priori predictions, two-tailed analyses for all remaining variables; * = Two individuals in the HFR group, and one individual in the LFR group only had one REM cycle, therefore there are no split-night 1 and 2 data for these three individuals, leaving the final *n* for HFR at 17, and LFR at 16 for these two parameters.

Testing Hypothesis 1: The first hypothesis of this study was not confirmed: HFR individuals did not exhibit significantly higher Total REM density values across the night compared to LFR individuals.

Testing Hypothesis 2: The second set of hypotheses were not confirmed: There were no significant between-group differences with regard to a) Split-Night 1, (b) Split-Night 2, and (c) the 1st REM period.

Although the hypotheses of this investigation were not confirmed, the mean trends are in line with the direction of the hypotheses:

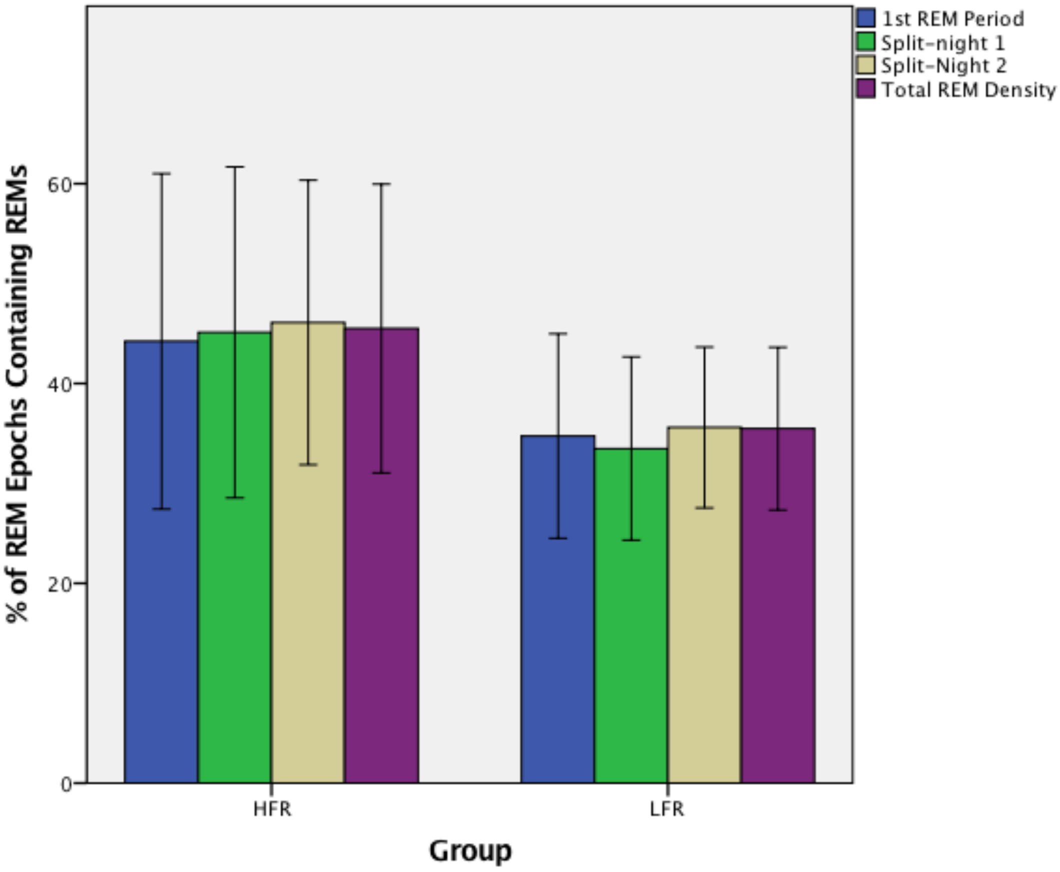


Figure 2: Between-group differences: REM density parameters. HFR = High frequency recall individuals; LFR = Low frequency recall individuals. Error bars represent 95% confidence intervals.

As can be seen above, the HFR group had higher mean values for all of the four REM density variables. The four variables include the 1st REM period, Split-Night 1, Split-Night 2, and Total REM density.

Summary of findings. There were no between-group differences detected with regard to any of the REM density parameters.

CHAPTER SEVEN: INVESTIGATION 4 – INCREASED DREAM PRODUCTION IN RELATION TO OVERNIGHT EMOTIONAL MEMORY CONSOLIDATION AND EMOTION REGULATION

Introduction

The main premise of this investigation rests on the possibility that HFR individuals not only have better memory for dreams, but that these individuals possibly also produce more dreams during REM sleep. In light of this, a central consideration of this investigation relates to how increased dream production during REM sleep affects other neurobiologically-related processes. The two processes that were chosen for this investigation include overnight emotional memory consolidation and emotion regulation.

Methods

Participants. Participants recruited for this study include 19 HFR individuals, and 17 LFR individuals ($N = 36$)

Exclusion Criteria. The exclusion criteria described in the General Methods chapter were also implemented in the memory Study.

Screening Measures. See the equivalents section in General Methods.

Experimental Measures. The first declarative memory task that was administered is the WMS-III *Logical Memory Subtest – LM* – (WMS-IV; The Psychological Corporation, 1998). The subtest was administered in the conventional fashion in order to test neutral episodic memory. With regard to the subtest as a whole, different aspects of memory were tested. This included the ability to learn and retain new material, how quickly new information is learned, how well new information is stored following a delayed interval, and finally whether individuals benefit from cues when remembering new material.

The LM subtest is divided into two parts: Logical Memory I (LM-I) and Logical Memory II (LM-II). The administration procedure for administering LM-I entails, during the night condition, reading two stories. The first story, ‘story A’, is read once followed by immediate recall from the participant. Subsequent to this, ‘story B’ is read once, again, followed by immediate recall from the participant. Finally, ‘story B’ is read for a second and final time before recording the immediate recall from the participant.

The following procedure was followed for LM-II: Upon conclusion of the sleep study the following morning, participants complete the delayed component of the measure. They were asked to recall all the words they can remember from story A and story B respectively. Following this the recognition component is administered. The recognition component entailed reading a list of statements relating to story A and story B, and asking participant whether it is true or false.

The second neutral declarative memory task that was administered is the *Rey Auditory Verbal Learning Test* (RAVLT) (Rey, 1964). This measure tests a variety of functions, which include short-term auditory verbal memory, rate of learning, interference, retention of information, and retrieval of information. The test makes use of two lists. The first list, list A, consists of 15 unrelated words that are repeated over 5 different trials. After each trial, participants are asked to repeat all the words they can remember, in no specific order. On the 6th trial, a second list, list B, consisting of 15 unrelated words are read to the participant, and they are instructed to repeat as many words they can remember from *that list only*. On the 7th trial participants are asked to recall items *only* from list A, the list that was read to them five times.

The following morning, the delayed component of the test was administered where participants were asked to recall al the words they can remember from list A. In addition to this, the recognition component of the test was administered. This entailed reading a list of 50 words to the participant where they are instructed to indicate whether the words were in list A or not. The full list consists of 15 words from list A, 15 words from list b, and 20 novel words that are in some instances semantically related to the words in list A.

The final measure is a computerised *Emotional Declarative Memory (EDM) Task.* The experiment was developed by a senior researcher in our laboratory using E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). It has been used successfully in two other studies in our laboratory (Lipinska & Thomas, 2017; Nestadt & Kantoor, 2015). The experiment entailed assessing recognition accuracy for emotional stimuli. The visual stimuli consisted of a series of pictures selected from the International Affective Picture System (IAPS). All pictures that were selected contain normative ratings and fall into standardised categories which include ‘negative’, ‘neutral’, or ‘positive’. In terms of picture selection, a pilot study was run on a local sample before a final decision was reached in terms of which pictures to include in the experiment.

The task consists of a night and morning condition. In the night condition, participants are first provided with the opportunity to read through the instructions before the task commences. The instructions entail looking at and remembering the different pictures that appear on the screen. In addition to this, it is explained that at times a number will appear on the screen. Participants are required to press the corresponding number on the keyboard of the computer. This serves the purpose of assessing attention to the visual stimuli throughout the experiment. Participants are also informed that some individuals might find some of the pictures offensive, and that they can opt out of the experiment at any point without penalty.

Following this, participants complete a practice trial where the different pictures are presented. All pictures were presented in a pseudo-random order in order to ensure that no more than three pictures of the same category (negative, neutral, positive) were presented consecutively. Pictures were presented on a standard 19-inch computer monitor at full size.

Before the picture is presented, a fixation cross appears (2000 ms). Following this, the target picture was presented (6000 ms), and followed by a blank screen (5000 ms). The total inter-stimulus interval amounts to 7000 ms. After the practice trial, participants are reminded that the objective is to remember the pictures that are presented, following this, the experimental procedure commences. This constitutes the night condition of the EDM task.

During the morning condition (recognition trial), participants were presented with 135 pictures in a pseudo-random order. The recognition trial consisted of pictures from the night before, as well as novel pictures. Participants then had to provide a forced-choice recognition response for every picture ('yes' indicating that they have seen the picture before, and 'no' indicating that they have not seen it before). Following this, they were also asked to assign a valence rating to each picture ranging from 1 (extremely positive) to 9 (extremely negative). Therefore, data regarding picture recognition accuracy, as well as valence ratings to positive, neutral, and negative pictures were collected.

The final measure of Investigation 4 relates to the *Positive and Negative Affect Schedule – Expanded Version* (PANAS-X) (Watson, & Clark, 1994). This questionnaire consists of 60 items measuring 11 specific affects: Fear, sadness, Guilt, Hostility, Shyness, Fatigue, Surprise, Joviality, Self-assurance, Attentiveness, and Serenity in the broad context of positive and negative affect.

The scale consists of a number of words and phrases describing different feelings and emotions. Participants were asked to read each item and to indicate to what extent they feel that way *at that very moment.* The scale ranged from 1 = very slightly or not at all, to 5 = extremely. Examples include words like "cheerful", "afraid', delighted", and "disgusted". The final scores are classified in a 'General Positive Emotion' score, and a 'General Negative Emotion' score. Participants completed the questionnaire in the evening, as well as the following morning. This questionnaire is simple and easy to administer and according to the developers, demonstrates good validity, reliability and internal consistency.

General Study Procedure. See the equivalent section in General Methods for description of the different phases of the study.

Ethical Considerations. See the equivalent section in General Methods. In addition, when written consent was obtained at the screening interview, it was specifically pointed out that some of the pictures in the *Emotional Declarative Memory Task* may be offensive to sensitive viewers. The nature of some of the pictures were discussed with potential participants and they were informed that they do not have to make a decision regarding their participation at that very moment. Participants were given the option of notifying the researcher at a later stage whether they want to continue with their participation in the study. It was also explained that they will have the option of opting out of the experiment without penalty at any point should they wish to do so. If participants decided that they want to participate in the study, verbal consent was obtained prior to starting the EDM task.

Statistical Analyses

All collected data were analysed using SPSS software (Howell, 2004). The independent variable was *group condition:* HFR (n = 19) and LFR (n = 17), and the dependent variables include the different *Memory Test Parameters.* For the Logical Memory Test, the parameters include: *First Total Recall Score, Learning Slope Score, Memory Retention %,* and finally the *Recognition Score.*

For the RAVLT, the Memory Test Parameters include *Immediate Memory Score, Best Learning Score, Total Learning Score, Delayed Score,* and *Recognition Score.*

With regard to the *Emotional Declarative Memory Task,* the Memory Test Parameters include the *Recognition Accuracy,* as well as *Positive Picture Valence Rating, Neutral Picture*

Valence Rating, and *Negative Picture Valence Rating.* Independent T-tests were run on all dependent variables.

The PANAS-X was used to generate two affective variables across two conditions: *Night* and *Morning General Positive Emotion (GPE),* and, *Night* and *Morning General Negative Emotion (GNE).*

Results

The first set of hypotheses relates to the possibility that HFR individuals will exhibit enhanced emotional memory consolidation. Before testing this, and in order to demonstrate that this enhancement relates specifically to *emotional* declarative memory, the following control hypothesis was included:

> **Hypothesis 1:** HFR and LFR individuals will perform comparably on neutral declarative memory tasks.

Following this, and in relation to the emotional declarative memory (EDM) task, the following hypothesis was tested:

> **Hypothesis 2:** HFR individuals when compared to LFR individuals will perform significantly better with regard to recognition accuracy for emotionally salient items (negative and positive pictures) on the EDM task.

The second set of hypotheses relates to overnight emotion regulation in the context of increased dream production. The Positive and Negative Affective Schedule – Expanded form (PANAS-X) was used to assess General Positive Emotion (GPE), as well as General Negative Emotion (GNE). Participants were required to fill out the PANAS-X before they went to bed on the experimental night, as well as the following morning upon conclusion of the experimental night.

Hypothesis 3: HFR individuals will be more successful in up-regulating positive emotion and/or down-regulating negative emotion compared to LFR individuals evidenced by significant between-group differences in morning values of positive and negative emotion (based on comparable night-time values).

The final hypothesis is based on the premise that REM dreaming aids in overnight emotion regulation, while rapid eye movements can be used to index the occurrence of REM dreams. Based on this, the following hypothesis was tested:

Hypothesis 4: Increased levels of REM density is significantly associated with one or both of the following:

d) An overnight increase in GPE scores

e) An overnight decrease in GNE scores

Testing Hypothesis 1: Between-Group Differences on Neutral Declarative Memory Tasks. Results can be seen below:

Table 6

Between-Group Analysis: Neutral Declarative Memory Tasks (N=36)

	Group				
	HFR	LFR			
Variable	(*n* = 19)	(*n* = 17)	*t*/*U*	*p*	ESE
LM1st Recall	27.89 (7.96)	25.41 (7.93)	.936	.356	.31
LM Learning Slope	5.11 (3.16)	5.18 (2.04)	-.079	.937	.03
LM % Retention	78.72 (11.31)	76.18 (24.75)	145.00	.600	.07
LM Recognition	26.32 (3.60)	25.12 (4.10)	.936	.356	.31
RAVLT Immediate Memory	8.16 (2.83)	8.59 (2.76)	-.460	.648	.15
RAVLT Best Learning	14.11 (1.33)	13.65 (1.46)	.988	.330	.32
RAVLT Total Learning	60.47 (8.53)	59.06 (9.09)	.482	.633	.16
RAVLT Delayed Recall	13.37 (1.89)	11.94 (3.03)	1.715	.096	.56
RAVLT Recognition	14.74 (.45)	13.69 (2.09)	115.00	.150	.34

Note. For all variables, means are presented with standard deviations in parentheses. HFR = High Frequency Recall individuals; LFR = Low Frequency Recall individuals; LM = Logical Memory Task = Wechsler Memory Scale – Third Edition; RAVLT = Rey Auditory Verbal Learning Test; *t* statistic computed for all variables, except for LM % Retention and RAVLT Recognition where Mann-Whitney *U* was computed as part of non-parametric analyses. ESE = Effect size estimate, *Cohen's d* for all variables with the exception of LM % Retention and RAVLT Recognition where *r* was computed.

The first hypothesis of this investigation was confirmed: HFR and LFR individuals performed comparably on two neutral declarative memory tasks, i.e. no significant differences were found on any of the neutral declarative memory parameters.

Testing Hypothesis 2: Between-Group Differences on the Emotional Declarative Memory Task. Results can be seen below:

Table 7

Emotional Declarative Memory Picture Recognition Accuracy (N=36)

Variable		Group HFR (*n* = 19)	 LFR (*n* = 17)	*t*	*p*	ESE
Recognition						
	Negative	2.91 (.80)	2.84 (1.02)	.241	.406	.08
	Neutral	2.98 (.90)	2.60 (.97)	1.22	.230	.41
	Positive	2.75 (1.05)	2.57 (.91)	.547	.294	.18
	Total	3.03 (1.03)	2.78 (1.05)	.730	.470	.24

Note. For all variables means are presented with standard deviations in parentheses; HFR = High Frequency Recall individuals; LFR = Low Frequency Recall individuals; Negative = Negative picture item; Neutral = Neutral picture item; Positive = Positive picture item; *t* statistic computed for all variables; ESE = Effect size estimate, *Cohen's d* for all variables. 2-tailed analysis for all variables, with the exception of Recognition Negative and Positive where 1-tailed analyses were implemented based on a priori predictions.

The second hypothesis of this study was not confirmed – HFR and LFR individuals performed comparably on the EDM task, i.e. HFR individuals did not demonstrate enhanced emotional declarative memory consolidation compared to LFR Individuals.

Testing Hypothesis 3: Between-Group differences on Overnight Emotion Regulation. Results can be seen below:

Table 8

Between-group Differences: Overnight Positive and Negative Emotion Regulation (N = 34)

	Group				
	HFR	LFR			
Variable	(*n* = 18)	(*n* = 16)	*t*	*p*	ESE
GPE Night	28.56 (8.63)	27.94 (9.01)	.204	.840	.07
GPE Morning	24.56 (9.01)	26.50 (8.56)	-.643	.525	.22
GNE Night	11.50 (1.95)	12.88 (5.06)	-1.069	.293	.36
GNE Morning	12.61 (5.98)	11.88 (3.03)	.444	.660	.15

Note. For all variables means are presented with standard deviations in parentheses; HFR = High Frequency Recall individuals; LFR = Low Frequency Recall individuals; GPE Night = General Positive Emotion – Night Condition; GPE Morning = General Positive Emotion – Morning Condition; GNE Night = General Negative Emotion – Night Condition; GNE Morning = General Negative Emotion – Morning Condition; *t* statistic computed for all variables; ESE = Effect size estimate, *Cohen's d* for all variables. Missing data for one participant from each group due to experimental error.

Hypothesis 3 of this investigation was not confirmed: There were no significant between-group differences with regard to night-time nor morning GPE and GNE scores. Therefore, HFR individuals were not more efficient at up-regulating positive emotion nor down-regulating negative emotion throughout the course of the night. Mean trends can be seen below:

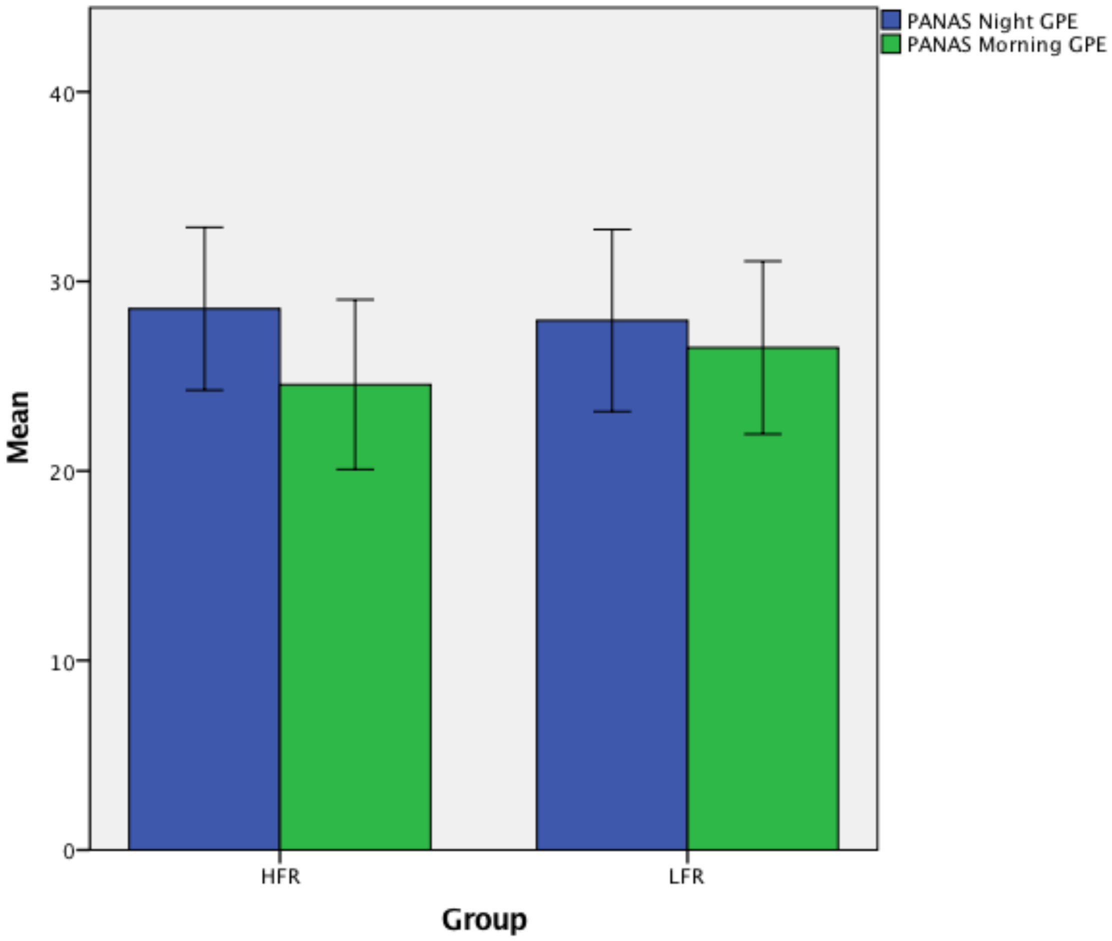


Figure 3: Between-group differences: Night to Morning GPE Scores. Error bars represent 95% confidence interval.

Results for night to morning GNE scores can be seen below:

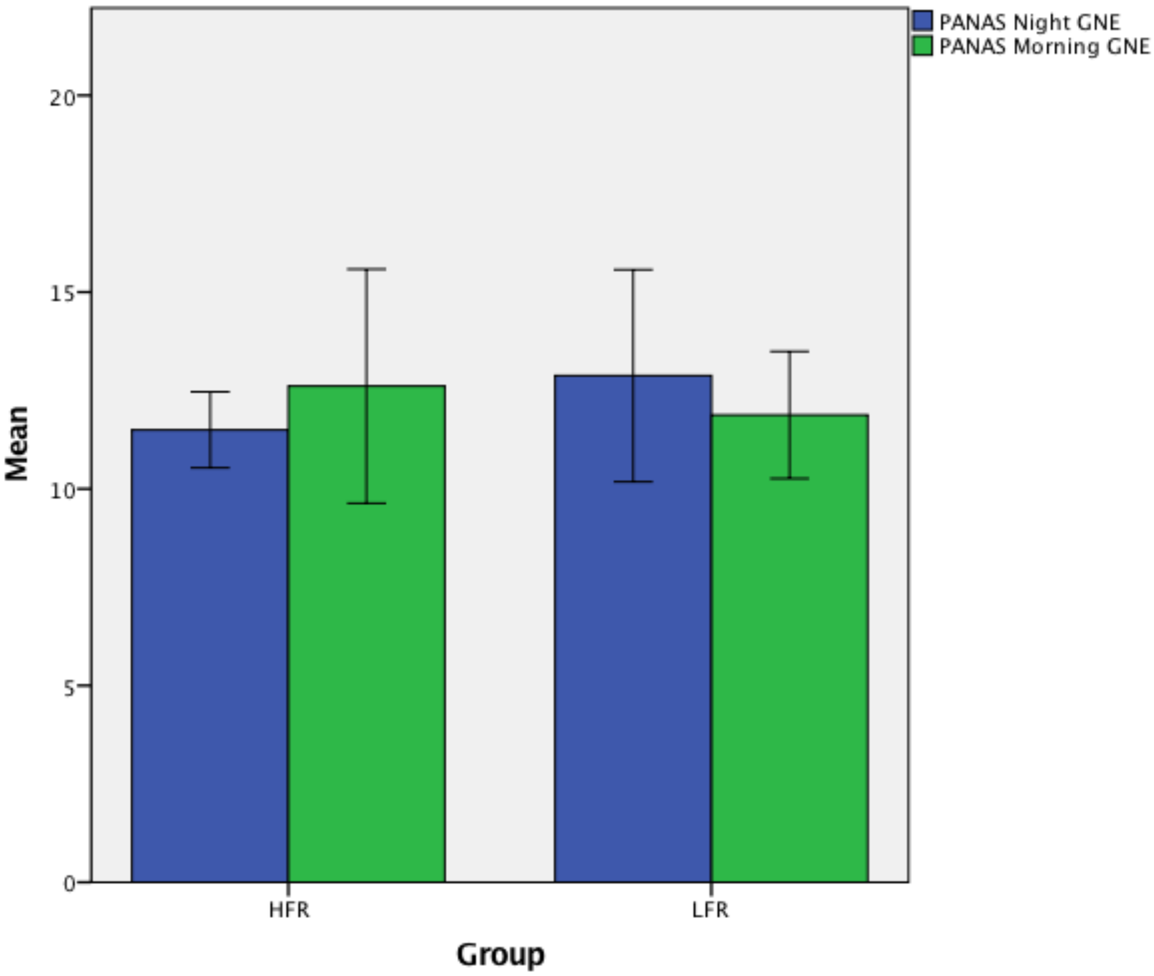


Figure 4: Between-group differences: Night to Morning GNE Scores. Error bars represent 95% confidence interval.

The graph above reveals that there was an overnight increase in GNE scores in the HFR group while there was a decrease in overnight GNE scores in the LFR group. Although there were no between-group differences in the initial analysis, based on the mean trends outlined in the graphs above, within-group analyses with regard to night to morning GPE and GNE scores were conducted. Results can be seen below:

Table 9

Within-Group Differences: Night to Morning GPE and GNE Scores

Group	Analysis	M (SD)	*t*	*p*	ESE
HFR	GPE: N-M	4 (7.59)	2.237	.039*	.53
	GNE: N-M	1.111 (5.77)	-.817	.446	.23
LFR	GPE: N-M	1.44 (7.35)	.783	.425	.20
	GNE: N-M	1.00 (4.02)	.996	.335	.28

Note. For all variables means are presented with standard deviations in parentheses; HFR = High Frequency Recall individuals (*n* = 18); LFR = Low Frequency Recall individuals (*n* = 16); GPE N-M = General Positive Emotion – Night Condition to Morning Condition. GNE N-M = General Negative Emotion – Night to Morning Condition; *t* statistic computed for all variables; ESE = Effect size estimate, *Cohen's d* for all variables; * = < .05

Within-group analyses revealed a significant difference between night and morning GPE scores (M = 28.56, SD = 8.63 and M = 24.56, SD = 9.01) in the HFR group, *t* (17) = 2.237, *p* = .039, with a medium effect size, *d* = .53. In other words, HFR individuals experienced significantly lower levels of positive emotion following a night's sleep. No other significant within-group differences were detected, with regard to GPE scores in the LFR group, or GNE scores in both groups.

Testing Hypothesis 4: Relationship between Affective Variables and REM Density. This hypothesis relates to the relationship between REM density and affective variables in the context of overnight emotion regulation. REM density was divided into four subcategories: Total REM density value, 1st REM period density value, Split-Night 1 REM density value (value for the first half of the night), and Split-Night 2 REM density value (value for the second half of the night). It is important to note that, due to the chronology of the experimental procedure (PANAS-X Night Condition → REM density generation during sleep → PANAS-X Morning Condition), one can make tentative inferences about causality with regard to any significant relationships that might be detected. Results can be seen below:

Table 10

Correlations for REM Density and Affective Variables

Variable		1	2	3	4	5	6	7	8
1. Total REM Density									
	r	-	.922	.933	.990	-.422	-.025	-.422	-.034
	p		.0001***	.0001***	.0001***	.013*	.890	.013*	.849
2. 1st REM Period									
	r	.922	-	.973	.872	-.282	-.100	-.401	.012
	p	.0001***		.0001***	.0001***	.106	.575	.019*	.947
3. Split-Night 1 RD									
	r	.933	.973	-	.880	-.388	-.155	-.453	-.004
	p	.0001***	.0001***		.0001***	.028*	.396	.009**	.981
4. Split-Night 2 RD									
	r	.990	.872	.880	-	-.478	.043	-.381	-.007
	p	.0001***	.0001***	.0001***		.006**	.815	.031*	.970
5. Night GPE									
	r	-.422	-.282	-.388	-.478	-	-.122	.631	.246
	p	.013*	.106	.028*	.006**		.491	.0001***	.162
6. Night GNE									
	r	-.025	-.100	-.155	.043	-.122	-	.344	.313
	p	.890	.575	.396	.815	.491		.046*	.072
7. Morning GPE									
	r	-.422	-.401	-.453	-.381	.631	.344	-	.186
	p	.013*	.019*	.009**	.031*	.0001***	.046*		.293
8. Morning GNE									
	r	-.034	.012	-.004	-.007	.246	.313	.186	-
	p	.849	.947	.981	.970	.162	.072	.293	

Note. Total REM Density = Average REM Density % value across the experimental night; 1st REM Period = Average % value for the first REM sleep period of the experimental night; Split-Night 1 RD = Split-Night Analysis of REM density % value during the first half of the experimental night; Split-Night 2 RD = Split-Night Analysis of REM density % value during the second half of the experimental night; Night GPE = PANAS-X Night Condition: General Positive Emotion; Night GNE = PANAS-X Night Condition: General Negative Emotion; Morning GPE = PANAS-X Morning Condition: General Positive Emotion; Morning GNE = PANAS-X Morning Condition: General Negative Emotion. *p* = <.05*; *p* = <.01**; *p* = <.001***

It is important to mention that before reporting the results is that the REM density variables are all significantly correlated with each other. This is to be expected as the 1st REM period and split-night 1 and 2 all form part of the Total REM density value.

The first result of note relates to a significant negative relationship between Total REM density value and Night-time GPE *r*(34) = -.422, *p* = .013, as well as Morning GPE *r*(34) = -.422, *p* = .013. In other words, the lower participants scored on the GPE scale at night, the higher their REM density value was across the night, while, in turn, the higher REM density value was associated with lower scores on the GPE scale in the morning.

The second result relates to a significant relationship between REM density in the 1st REM period, and GPE in the morning *r*(34) = -.401, *p* = .019. In other words, the higher the REM density value during the first REM period of the night, the lower participants tend to score on the GPE scale the following morning.

Thirdly, a significant negative relationship was found between Split-night 1 and GPE scores in the evening, *r*(34) = -.388, *p* = .028, as well as Split-night 1 and GPE scores in the morning, *r*(34) = -.453, *p* = .009. It is interesting to note that REM density during the first half of the night was more strongly correlated with GPE scores in the morning, as opposed to GPE scores in the evening.

Fourthly, a significant relationship was found between Split-night 2 and GPE scores in the evening, *r*(34) = .-478, *p* = .006, as well as between Split-night 2 and GPE in the morning, *r*(34) = -.381, *p* = .031. Interestingly, REM density during the second half of the night is more strongly correlated with night-time GPE scores as opposed to morning GPE scores.

Summary of Results. Hypothesis 1 of this investigation was confirmed – HFR and LFR individuals performed comparably on the neutral declarative memory tasks. However, the second hypothesis of this study was not confirmed, there were no significant between-group differences with regard to picture recognition accuracy for emotionally salient items on the EDM task. Therefore, HFR individuals did not demonstrate enhanced overnight emotional memory consolidation compared to LFR individuals. The third hypothesis of this study was also not confirmed – HFR was not more efficient at up-regulating positive emotion and/or down-regulating negative emotion over the course of the night. Finally, the fourth hypothesis of this study was confirmed, there were significant positive correlations between all the REM density variables and night-time and morning positive emotion.

DISCUSSION

In this research project I set out to investigate four overarching themes: firstly, I looked at specific trait characteristics associated with HFR individuals, secondly, I studied the sleep architecture of HFR in relation to LFR individuals, thirdly, using objective measures, I investigated whether HFR individuals produce more dreams compared to LFR individuals, and fourthly, I studied overnight emotional declarative memory consolidation and emotion regulation in HFR individuals. In this concluding chapter I will discuss findings from the four investigations separately before I comment on how they relate to one another.

Before proceeding, it is worth mentioning the methodology employed in this study in an attempt to overcome many confounds evident in the literature across all four investigations. First of all, contrary to many studies in the literature, the current study included a comparison group by also recruiting LFR individuals. Secondly, and related to this, a very rigorous sampling strategy was employed in this study – out of 2041 individuals who completed the online questionnaire, I ended up including only 36 individuals in the final sample following the screening process in its entirety. Although relatively small, this sample is entirely free of psychiatric, medical, and cognitive confounds leading to the creation of two homogenous groups. Finally, the current study also utilised operationalised criteria for determining DRF. This was done via questionnaire, while laboratory awakenings confirmed that HFR individuals recall significantly more dreams compared to LFR individuals.

Investigation 1: Trait Characteristics Associated with HFR Individuals

This investigation had two main aims. Firstly, I aimed to elucidate the specific personality dimensions associated with HFR individuals. More specifically, I hypothesised that HFR individuals will score significantly higher on the ‘openness’, ‘extroversion’, and ‘emotional stability’ personality dimensions compared to LFR individuals. Personality dimensions were assessed using the Ten-Item Personality Inventory (TIPI). Furthermore, I also investigated the relationship between the different personality dimensions and the actual number of dreams recalled per week.

Secondly, I investigated whether HFR individuals will score significantly higher on the Boundary Questionnaire – Shortform (BQ-Sh), indicating the presence of ‘thinner’ boundaries. In addition to this, I also studied the relationship between scores on the BQ-Sh, and the actual number of dreams recalled per week.

Personality Dimensions & DRF. The first hypothesis of this investigation was not confirmed: HFR and LFR individuals did not differ significantly on the ‘openness’, ‘extroversion, and ‘emotional stability’ dimensions of the TIPI questionnaire. Apart from considering the possibility that these differences do not exist in the current sample, one could also argue that, alternatively, the shortform of the TIPI is not sensitive enough to be able to detect existing differences. The TIPI as a short measure of personality dimensions was chosen in order to lessen the testing burden on participants. Although slightly psychometrically inferior to longer measures of personality dimensions, the measure does reach adequate levels of convergent and discriminant validity, test-retest reliability, convergence between self- and observer- ratings, and patterns of external correlates, (Gosling, Rentfrow, Swann, 2003; Ehrhart et al., 2009).

In addition, and very importantly, it is essential to look at the results of the other personality dimensions measured by the TIPI. Evidence suggests that it is more likely that differences with regard to ‘openness’, ‘extroversion’, and ‘emotional stability’ do not exist in the current sample. This assertion is based on significant difference detected with regard to the ‘agreeableness’ personality dimension, with a very large effect size (*d* = 1.18). It is hard to believe that the questionnaire would be able to detect such a strong result in relation to one personality dimension, and not in any of the others. Therefore, one can conclude with reasonable confidence that between-group differences with regard to ‘openness’, ‘extroversion’, and ‘emotional stability” do not exist in the current sample.

In terms of explaining the incongruence between the results of this study and results from previous research, it is important to note that failing to detect differences between groups might be due to the sampling strategy that was employed. More specifically, there are various psychiatric disorders that show strong associations with different personality dimensions, especially ‘neuroticism’, or its converse, ‘emotional stability’, ‘extroversion’, and ‘openness to experience’, (Bienvenu et al., 2004; Kahn et al., 2005; for a meta-review, see Kotov, Gamez, Shmidt, & Watson, 2010; Samuels et al., 2000). This is especially true of depression, anxiety, obsessive compulsive disorder, and substance abuse disorders.

In order to elucidate the potential role of co-morbid psychopathology in relation to certain personality dimensions, the epidemiological study by Kahn et al. (2005) is worth mentioning. In this study, the authors assessed personality dimensions in relation to psychiatric illnesses in 7588 individuals. They focused specifically on ‘extroversion’, ‘neuroticism’, and ‘novelty seeking’ (a trait that is strongly correlated with ‘openness to experience’). Results suggest that ‘neuroticism’ serves as a potential underlying vulnerability for the development of psychopathology in general. Furthermore, ‘extroversion’ was significantly associated with several psychiatric disorders ranging from depression and anxiety to substance abuse disorders. Interestingly, ‘novelty seeking’ showed strong and significant associations with especially substance abuse and personality disorders like antisocial personality disorder and conduct disorder.

Therefore, there is convincing evidence in the literature indicative of strong and significant associations between several personality dimensions and the presence of psychopathology. Studies that do not rigorously control for potential psychiatric confounds in the sample are at risk of having their data skewed. The presence of co-morbid psychopathology could be one explanation for the divergent results in the literature with regard to which specific personality dimensions are associated with HFR individuals. In the current study, I screened for, and excluded, all participants who met the criteria for any of the disorders mentioned above, in addition to other major axis I disorders. In light of this, one could argue that because psychiatric confounds were rigorously controlled for, the probability of detecting significant differences between groups on personality dimensions known to be associated with various psychiatric illnesses, was significantly lower.

However, between-group analyses did detect a significant difference with regard to the 'agreeableness' personality dimension – HFR individuals scored significantly higher on this personality dimension compared to LFR individuals. Before contextualising this finding, it is important to discuss the construct of 'agreeableness' in a bit more detail.

According to Jensen-Campbell & Graziano (2001), 'agreeableness' as a personality dimension is the least well understood compared to the other four dimensions ('extroversion', 'openness to experience', 'neuroticism', and 'conscientiousness') that form part of the big-five personality model. It is important to note that both 'agreeableness' and 'extroversion' are related to social behaviour, but with an important difference: 'extroversion' relates to *social impact'*, while 'agreeableness' relates to *maintaining positive relations* with other people. In this context, maintaining positive relations with other people is expressed in behaviours linked to cooperation, empathy, altruism, friendliness, compliance, and promotion of social harmony, for example (Grazanio & Tobin, 2009; Meier, Robinson, Wilkowski, 2006). Conversely, the negative pole of the 'agreeableness' personality dimension relates to hostility, anger, aggression, manipulation, competitiveness, and a lack of empathy.

Another way of conceptualising the functional significance of high levels of 'agreeableness', relates to the regulation of behaviours associated with the negative pole of this dimension, i.e. successfully regulating anger, hostility, and aggression in a social situation (Campbell et al., 2002). Meier, Robinson, & Wilkowski (2006) propose that one mechanism of regulating aggression-related cues can be seen in the context of recruiting pro-social thoughts, e.g. a sense of helping and caring instead of adopting an opposing position during social interaction/confrontation.

This proposition is supported by empirical findings in the abovementioned study where aggression-related primes led to aggressive behaviour only in individuals who score low on the 'agreeableness' personality dimension – agreeable individuals were relatively unaffected by aggressive priming. Furthermore, aggression-related primes increased the accessibility of pro-social thoughts in high-scoring individuals. Essentially, agreeable individuals are able to override hostility-related primes rendering them less susceptible to reactivity effects related to aggression and anger (Robinson, 2007). Succeeding in this regulatory process potentially leads to the preservation of social harmony.

Therefore, a case can be made that the functional significance of high levels of agreeableness relates to modulating emotional reactivity in order to preserve social bonds. By extension, one can surmise that HFR individuals, having scored significantly higher on the 'agreeableness' dimension, are more successful at modulating emotional reactivity in social situations. Importantly, how can this be contextualised in terms of DRF?

To my knowledge, only one study (Schredl, 2009) found a significant, yet weak, relationship between the 'agreeableness' dimension and increased DRF. However, this finding was not paramount in the discussion and appeared to be of little significance in the context of that particular study. Nevertheless, the significant between-group difference with regard to the 'agreeableness' dimension in this study is paramount – not only due to its novelty in the context of the extant literature, but also because of the statistical strength of the finding. Therefore, in the context of the current study, one can say with reasonable confidence that high levels of the personality dimension 'agreeableness' is associated with increased DRF in certain individuals.

Traditionally, a directionality has been implied in the literature with regard to personality dimensions and DRF. For example, authors postulate that possessing certain personality traits lead to individuals being more absorbed in and understanding their inner emotions, thoughts, and perceptions (Schredl & Montasser (1996-97a, b Blagrove & Akehurst, 2000; Suzuki & Matsuda, 2012). Consequently, this leads to an increased focus on and interest in dreaming mentation, which in turn leads to a better memory for dream traces. Essentially, the consensus is that increased DRF is an expression of possessing certain personality traits.

However, my appraisal of the findings differs with regard to the directionality of the abovementioned relationship: I propose that possessing certain personality traits, as well as experiencing better memory for and/or increased production of dreams, are both an expression of a specific functional neurophysiological arrangement innate to HFR individuals. I base this assertion on the results from ERP and neuroimaging studies that have found functional differences across vigilance states in HFR individuals when compared to LFR individuals (Eichenlaub et al., 2014a; Eichenlaub et al., 2014b).

For example, findings from the ERP study (Eichenlaub et al., 2014) demonstrated increased 'brain reactivity' in the HFR group in response to novel auditory stimuli, both when individuals are awake and asleep. With regard to the neuroimaging study (Eichenlaub et al., 2014b), results revealed that there was increased regional cerebral blood flow (rCBF) in the medial prefrontal cortex (mPFC), as well as the temporoparietal junction (TPJ). Both of these regions are thought to be implicated in dream production, as lesion studies have demonstrated a cessation or near cessation of dreaming when lesions occur in or around these areas (Solms, 2000). Authors of both the ERP and neuroimaging studies propose that these findings, that are present during both wakefulness and sleep, can be regarded as trait-like functional neurophysiological differences that are intrinsic to HFR individuals.

In addition to finding between-group differences with regard to rCBF in the mPFC and TPJ, significant differences with regard to the HFR group in rCBF were also found in areas in the brain collectively known as the Default mode network (DMN). The DMN, in addition to the mPFC and the TPJ, also include the precuneus, and areas in the parietal and temporal cortex for example. The DMN is characterised by high metabolic activity when the brain is in a resting state, e.g. mind wandering, while it exhibits decreased metabolic activity during goal-directed actions (Sampaio et al., 2013). There is a very high degree of functional connectivity between several brain regions when this mode is activated, therefore, although the brain is in a 'resting state', it by no means imply that it is inactive. Eichenlaub et al (2014b) propose that increased activity in the DMN across vigilance states in the HFR group serves as another example of functional trait-like differences innate to HFR individuals.

Interestingly, there is evidence in the literature indicative of a strong association between the DMN and the personality dimension 'agreeableness'. A study by Sampaio et al. (2014) explored the relationship between the big-five personality dimensions and DMN activity through functional magnetic resonance imaging (fMRI). Results showed a significant positive correlation between 'agreeableness' and activity in the midline core of the DMN, which included the mPFC and the anterior cingulate cortex (ACC). Both of these areas are associated with social awareness, as well as the ability to attribute a mental state to others (Gusnard et al., 2001). The authors propose that these different areas are related to a general pro-social orientation in individuals scoring high on the 'agreeableness' personality dimension. It is important to note, that the study discussed above is just one of several imaging studies demonstrating a significant association between 'agreeableness' and activation in the DMN regions (Adelstein et al., 2011; Hassabis et al., 2013; Ryan, Sheu, Gianaros, 2011).

Taken together, three themes emerge from the discussion above: (1) the current study demonstrated significantly higher levels of ‘agreeableness’ in the HFR group compared to the LFR group, (2) I surmised that certain personality traits, in this case ‘agreeableness’, might be an expression of a specific functional neurophysiological arrangement in the brains of HFR individuals, and (3) there is a neurobiological link between ‘agreeableness’ and increased DRF since both are significantly associated with increased activity in the DMN. In conclusion, there is a neurobiological-based explanation for why HFR individuals in the current study scored high on the ‘agreeableness’ personality dimension, and, furthermore, the neural underpinnings of ‘agreeableness’ form part of a functional neurophysiological arrangement believed to be innate to HFR individuals.

Boundary Thickness & Dream Recall Frequency. The second hypothesis of this investigation was confirmed: HFR individuals scored significantly higher on the BQ-Sh, indicating the presence of ‘thinner’ boundaries. In other words, HFR individuals tend to be more ‘permeable’ to external influences and have a more fluid sense of self, for example. This finding is in line with previous research, where studies have consistently found increased DRF to be associated with having ‘thinner’ boundaries (Beaulieu-Prévost, & Zadra, 2007; Hartmann, Elkin, & Garg, 1991; Schredl, Ciric, Götz, & Wittmann, 2003; Schredl, Kleinferchner, & Gell, 1996; Schredl, Schäfer, Hoffman, & Jacob, 1999).

Although the literature on DRF and boundary thickness have consistently demonstrated increased DRF to be associated with having thin boundaries, again, my appraisal of the directionality of the relationship differs from the convention. Traditionally, the consensus has been that certain personality factors, including having thin boundaries, lead to individuals reporting an increased number of dreams. Based on the studies above, this is purportedly due to these individuals being more focused on their internal thoughts, feelings, and perceptions, having a more fluid sense of self in relation to the outside world, exhibiting an increased tendency to engage in day-dreaming, as well as a decreased ability to discern between fantasy and reality at times. This is believed, as mentioned earlier, to lead to an increased focus on and better memory for dreams.

However, based on ERP and neuroimaging studies (Eichenlaub et al., 2014a; Eichenlaub et al., 2014b) discussed in previous sections, I propose that, along with certain personality dimensions, having thin boundaries and exhibiting the cognitions and behaviours associated with both, are expressions of the functional neurophysiological arrangement innate to HFR individuals. I conceptualise this assertion as a ‘constellation of functional neurophysiological sequelae’ innate to HFR individuals. Importantly, I by no means imply that the examples and evidence I have provided thus far are comprehensive or all-inclusive, I surmise that there are numerous, yet undiscovered, dimensions that potentially form part of this specific ‘constellation of sequelae’.

Personality Dimensions & Boundary Thickness in relation to Individually Reported DRF. The final discussion of Investigation 1 relates to the relationship between the actual number of dreams recalled per week, and the different dimensions of the TIPI, as well the BQ-Sh. It is important to note that there are two dimensions to ‘DRF’. In the first instance, DRF is used as a categorical variable for the purpose of group allocation, i.e. HFR or LFR group. In the second instance, which is applicable to this particular part of the discussion, DRF is used as a continuous variable, i.e. this refers to the actual number of dreams individuals recall per week (DRFQ). The number of dreams recalled per week ranges from 0.125-0.25 in the LFR group, and 3.5-7 in the HFR group.

The first analysis entailed investigating the relationship between DRFQ and the BQ-Sh. There was a significant positive relationship between DRFQ and BQ-Sh scores. In other words, the more dreams an individual report per week, the higher they tend to score on the BQ-

Sh. Therefore, the actual number of dreams is significantly and strongly correlated with scores on the BQ-Sh, or, in other words, having thinner boundaries.

The second analysis relates to DRFQ and the different personality dimensions measured by the TIPI. The only significant finding relates to a strong positive correlation between DRFQ and the ‘agreeableness’ dimension on the TIPI. In other words, the more dreams an individual report per week, the higher they tend to score on the ‘agreeableness’ dimension. Importantly, none of the other personality dimensions correlated significantly with DRFQ.

The two significant findings mentioned above, as well as the finding of no significant relationship between DRFQ and the other personality dimensions on the TIPI, both serve to validate the significant between-group differences that were detected in the initial analyses. More specifically, when DRF is used as a categorical variable, as well as a continuous variable, the results are upheld and effectively cross-validated.

Summary of Findings of Investigation 1. The overarching aims of this investigation relate to studying the relationship between certain personality dimensions and the ‘thickness’of boundaries in relation to DRF. Personality dimensions were assessed by the TIPI, and boundary thickness by the BQ-Sh. Both of these measures yielded significant between-group differences with HFR individuals scoring significantly higher on the ‘agreeableness’ personality dimension, as well as on the BQ-Sh. High scores on the BQ-Sh is indicative of having ‘thin’ boundaries.

The significant finding with regard to the ‘agreeableness’ personality dimension is not in line with previous research. However, there is a neurobiological explanation for why HFR individuals in this study scored significantly higher on this specific personality dimension. More specifically, the neural underpinnings of ‘agreeableness’ overlap with functionally connected areas in the brain known as the DMN. Eichenlaub et al. (2014b) demonstrated increased activity in the DMN in HFR individuals during both wakefulness and sleep. Therefore, though unexpected, this novel finding is rooted in neurobiological evidence suggesting that there is a strong possibility that it represents an important functional aspect of cognitions and behaviours associated with 'agreeableness' that are innate to HFR individuals.

Lastly, and in line with previous research, I found significant between-group differences with regard to boundary thickness, with HFR individuals exhibiting significantly 'thinner' boundaries compared to LFR individuals. Although this finding is consistent with previous research, my interpretation differs from viewpoints traditionally adopted in the literature. I regard the findings of 'thinner' boundaries, as well as higher scores on the 'agreeableness' personality dimension, not as causative factors leading to increased DRF. Instead, I regard thin boundaries, high levels of 'agreeableness', and the cognitions and behaviours associated with both, functioning as an expression of a specific functional neurophysiological arrangement characteristic of HFR individuals.

Investigation 2: The Sleep Architecture of HFR Individuals

The structure of the discussion for Investigation 2 will deviate slightly to the one adopted in Investigation 1. Firstly, an overview of the results will be provided and contextualised in existing literature in a preliminary fashion. Following this, a comprehensive discussion will ensue merging several theoretical backgrounds within which the findings of the current study will be situated in.

Differences in Sleep Architecture between HFR and LFR Individuals. This investigation consisted of two main aims. Both of these relate to replicating, and building on the results from, to my knowledge, the only other study investigating sleep architecture in HFR individuals compared to LFR individuals (Eichenlaub et al., 2014a). More specifically, the first aim relates to investigating whether HFR individuals spend significant more time awake after sleep onset (WASO), while the second aim entails examining whether HFR individuals experience significantly more awakenings across the night. In addition to examining the total number of awakenings across the night, I also investigated whether HFR individuals experience significantly more awakenings from REM sleep compared to LFR individuals.

With regard to the first aim, I successfully replicated the results from the Eichenlaub et al. (2014a) study showing that HFR individuals spent significant more time awake after sleep onset compared to LFR individuals. Apart from replicating existing results, I also built on them in the sense that I demonstrated that the findings are upheld even when both males and females are included in the study (the abovementioned study sample consisted solely of males). Results from the current study with regard to increased WASO in conjunction with the Eichenlaub et al. (2014a) study provide strong, replicable evidence for the validity of the arousal-retrieval model of dream recall.

The arousal-retrieval model (Koulack & Goodenough, 1976) is regarded as a comprehensive model of dream recall that is supported by strong empirical evidence (Eichenlaub et al., 2014; Shredl, Schafer, Weber, & Heuser,1998; Schredl, 1999; Shredl, 2009). In its essence, the arousal-retrieval model is embedded in two-stage memory theory in relation to DRF. The first stage involves processing dream traces while it is still in its short-term form as this enables encoding into long-term storage. This process can only take place if wakefulness occurs, and is sustained for a period long enough to facilitate the encoding process. The second stage of this model relates to the retrieval of the dream traces from long-term storage. The success of the retrieval stage relies on the efficiency of the encoding process. Longer periods of wakefulness enhance the efficiency of the encoding process leading to better retrieval at a later stage. As mentioned above, along with the Eichenlaub et al. (2014a) study, the current study provides replicable, empirical evidence in support of the validity of the arousal-retrieval model from an experimental protocol where HFR and LFR individuals are directly compared to one another.

In addition to replicating existing findings, the current study also found significant between-group differences with regard to another sleep parameter: HFR individuals experienced significantly more total awakenings across the night compared to LFR individuals. Therefore, taken together, increased WASO and total number of awakenings fit in well with the encoding and retrieval mechanisms delineated by the arousal-retrieval model. For example, an increased number of awakenings leads to the possibility of an increased number of opportunities for dream traces to be processed, while longer periods of wakefulness following awakenings enhances the encoding of dream traces from short- to long-term memory.

The second dimension of the second aim relates to investigating whether HFR individuals experience significantly more awakenings from REM sleep compared to LFR individuals. REM sleep was chosen due to yielding the highest dream recall rates upon awakening (up to 90%) compared to the other sleep stages (Nielsen, 2000). My prediction was not confirmed – there was no significant between-group difference with regard to awakenings from REM sleep. However, the analysis did detect a highly significant between-group difference in relation to awakenings from stage 2 NREM sleep, with a large effect size (d = .88). In order to elucidate this finding further, I examined the morning dream recall rates from stage 2 and REM sleep in both groups. I found that in the HFR group, 88.89% of awakenings from stage 2 sleep yield a dream report, compared to 33% from REM sleep awakenings. In the LFR group 22% of stage 2 awakenings yield a dream report, compared to 29% from REM sleep awakenings. An increased number of awakenings from stage 2 sleep is a very unexpected, yet very strong finding of this study. It appears that both the number of awakenings, as well as dream recall from awakenings, are very strongly associated with stage 2 sleep in the HFR group.

Considering all of the findings together, it is imperative to investigate the possible mechanisms that underlie, (a) increased wakefulness after sleep onset, (b) increased number of total awakenings, and (c) awakenings from stage 2 sleep specifically.

Mechanisms involved in Awakenings and Wakefulness in HFR Individuals: A Preliminary Discussion. Eichenlaub et al. (2014a) propose that one underlying mechanism in relation to increased wakefulness after sleep onset, as well as awakenings from sleep in general, relates to heightened brain reactivity in HFR individuals. This assertion is based on results from their ERP study that showed HFR individuals respond more strongly to novel stimuli during both wakefulness and sleep. The neurophysiological mechanism underlying this heightened brain reactivity in HFR individuals is thought to be a P3a-like component, or P3a-like wave detected on electroencephalogram (EEG). The P3a-like component is strongly associated with the orientation of attention to external stimuli (Friedman, 2001). The HFR group exhibited larger P3a-like waves in response to novel auditory stimuli across vigilance states compared to LFR individuals. It is accepted that the larger the P3a-like wave, the stronger the attention orientation response. (Dominguez-Borras et al., 2008; Lv et al., 2010). Eichenlaub et al. (2014a) postulate that a stronger attention orientation response to external stimuli in the HFR group, is possibly one of the neurophysiological mechanisms underlying awakenings and longer periods of wakefulness after sleep onset in these individuals.

The neurophysiological mechanism underlying awakenings and increased WASO in HFR individuals can also be used to explain the finding of increased awakenings from stage 2 sleep specifically. Detection of a larger P3a-like wave in response to novel and deviant auditory stimuli was not homogenous across sleep stages in the Eichenlaub et al. (2014a) study. For example, larger P3a-like waves in HFR individuals at earlier latencies in response to novel stimuli were detected most strongly during stage 2 sleep. During REM sleep larger P3a responses to deviant stimuli was detected most strongly. Consistent with this, Bastuji et al.

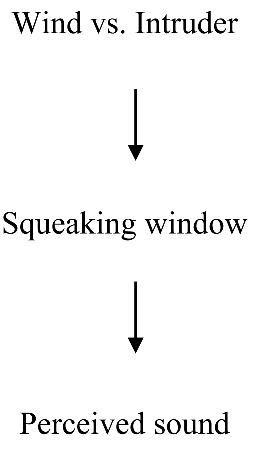
(2008) found large P3a-like waves in response to (non-awakening) painful stimuli to be strongly associated with subsequent arousal and awakening responses in both stage 2 and REM sleep. Therefore, there is a convincing neurophysiological explanation for why an increased number of awakenings from stage 2 sleep was detected in the current study.

In summary, findings from the current study are well-situated within existing neurophysiological evidence supporting the premise that increased brain reactivity in HFR individuals possibly accounts for increased awakenings and WASO. Furthermore, an increased number of awakenings and increased WASO in HFR individuals support the arousal-retrieval model of dream recall. Finally, this study contributes to existing literature by replicating results from the only other study examining sleep architecture in healthy HFR individuals compared to LFR individuals. Furthermore, the current study illuminated additional aspects of the sleep architecture of HFR individuals by demonstrating that stage 2 awakenings and dream recall rates from stage 2 sleep might be of particular importance in this specific population.

Following this preliminary discussion, I will now proceed to assimilate a variety of different fields of research in an attempt to provide a comprehensive framework within which the findings of the current study can be situated. It is important to note that, in certain instances this theoretical framework will be based on inferential evidence that must be regarded as speculative at this stage.

Theoretical Digression: Predictive Coding and Perceptual Inference in relation to Dreaming. Predictive coding (PC) theory is believed to form part of one of the fundamental functional and cognitive principles of the brain (Roa & Ballard, 1999; Spratling, 2008). It propagates the notion that the brain does not simply passively register environmental stimuli, but actively predicts the nature of the sensory input based on previous experience (Friston, 2002). According to PC theory, the perceptual system is a hierarchical generative model that executes a Bayesian[17] type of inference from available sensory data in order to generate probabilistic cause and effect relationships (Kersten, Mamassian, & Yuille, 2004).

Pezzulo (2014) uses an example of hearing a squeaking window at night in order to illustrate how these generative models operate. Once perceived, sensory data from the squeaking window is transformed to perceptual and cognitive hypotheses relating to the most likely cause of the sensory input. This leads, on a higher level, to two competing hypotheses that can be used as possible explanations for the perceived sensory input, e.g. the sound is caused either by the wind or by an intruder. Because these two competing hypotheses are mutually exclusive, the probability sums to 1 [e.g. if P(wind) = .75, then P(thief) = .25]. These hypotheses are competing on the basis of the degree to which they accurately explain the sensory input. This leads to the generation of a three-level predictive coding hierarchy seen below:



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[17] Essentially, Bayesian Networks consist of a probabilistic graphical model that depicts random variables and its conditional dependencies in order to signify probabilistic relationships between a number of variables.

Fundamentally, the predictive coding structure employs the notion that the inference regarding the causes of the stimulus is based on unconscious perception. In this context, the arrows are used to indicate causality, while the inference is executed in the reverse direction. It is done in this manner because its objective is to infer the most likely *cause* (wind vs. intruder) by utilising its perceived consequences (the squeaking window) as evidence. In a mechanistic way, the higher level hypotheses produce sensory predictions (e.g. one hypothesis predicts the sensory input to be caused by the wind, and the second hypothesis predicts the cause to be an intruder). These predictions are propagated in a top-down fashion and evaluated in terms of the sensory measurement (the sound of a squeaking window). Following this, a sensory prediction error[18] is generated in a bottom-up fashion with the purpose of revising the initial hypotheses. Ultimately, the hypothesis that generates the least prediction error is strengthened, and subsequently its probability of being accurate increases.

For argument's sake, let's assume that due to it being a windy night, and the absence of the dog barking, the explanation with the highest probability of being true, is that the wind is causing the window to squeak. This explanation is now integrated into the predictive framework relating to the perceived sensory stimulus. Consequently, the window squeaking throughout the night will not require the same level of cognitive processing as long as the prediction is upheld. The prediction is upheld if the conditions in which the stimulus occurs remain stable, i.e. there is no new information refuting the validity of the original prediction. However, if for example, you hear the squeaky window, while at the same time the dog starts barking and you see a shadow by the wall, the probability that an intruder is responsible for the noise, is dramatically increased. In this instance, a prediction error has occurred and the

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[18] Prediction error in this context relates to learning and decision-making. More specifically, predictions are based on prior experience and response patterns, and uses this information to predict an outcome in the context of a specific stimulus or situation.

predictive coding hierarchy needs to be revised and updated. In other words, the original prediction of what causes the squeaky window cannot be upheld in light of novel information.

It is important to note that once established, predictions are tested unconsciously, but constantly. Testing predictions remains an unconscious process as long as the prediction is upheld. However, when a prediction error occurs, immediate consciousness is required in order to update existing predictions. Put differently, consciousness is only required if there is a discrepancy between the prediction and the actual sensory input. In order to illustrate this, another example would be taking the same route to work every day. The prediction integrated into the predictive framework is that this specific route will always lead to arrival at the desired destination. If, however, the road is closed due to roadworks, a prediction error has occurred. Consequently, immediate consciousness is required in order to update the prediction by selecting an alternative route to reach the desired destination. Therefore, prediction errors facilitate learning and the formulation of new predictions (Schultz & Dickinson, 2000). Importantly, this process necessitates consciousness/awareness of the occurrence of a prediction error in order to instigate the cognitive and mental processing required to update predictions successfully.

Dreaming is a form of consciousness during sleep, while it is accepted that sleep is not a passive state. Cognitive/mental processes are ongoing throughout the night across sleep stages (Antrobus, 1990). Furthermore, sleep is not homogenous, nor is dreaming. Even though it is now widely accepted that dreaming takes place during both REM and NREM sleep, there appears to be a qualitative difference between REM and NREM dream mentation (Nielsen, 2000). For example, *on average,* NREM dreams appear to be more thought-like in nature, while REM dreams tend to be more vivid, bizarre, and laden with emotion (Nielsen, 2000; Stickgold, Pace-Schott, & Hobson, 1994; Solms, 2000). However, irrespective of the qualitative differences between NREM and REM dream mentation, dreaming manifests as consciousness during both sleep stages, and is associated with the occurrence of a degree of cognitive/mental processing.

This can best be illustrated by an example of memory processes taking place, to varying degrees, during both NREM and REM sleep. These processes include, for example, the reprocessing, consolidation and enhancement of memory traces. NREM and REM sleep appear to play a complimentary role in these memory processes, but contribute in different ways by providing specific neurochemical contexts and patterns of brain region activation (Stickgold, 2005).

For example, during NREM sleep, structures in the medial temporal lobe (MTL) are recruited in order to consolidate new information into long-term storage (Eichenbaum, 2004). This is achieved by the hippocampus coordinating a process by which associations are formed between newly acquired information and existing knowledge. Following this process, memory representations undergo reorganisation and are translocated from the hippocampus to the neocortex (Walker & Stickgold, 2004). It is especially the prefrontal cortex, or more specifically, the medial prefrontal cortex (mPFC), that supports the formation of rich contextual details and networks in which declarative memory traces are embedded (Preston & Eichenbaum, 2013). REM sleep also plays an important role in different memory processes, especially with regard to the consolidation and enhancement of *emotional* declarative memory traces (Nishida, Pearsall, Buckner, & Walker, 2008). The cholinergic context of REM sleep along with the activation of limbic and para-limbic structures make the brain amenable to affective memory consolidation in particular (Hu et al., 2006).

From the discussion above, it is clear that cognitive and mental processing are essential features of both NREM and REM sleep. However, on average, the nature of these processes during NREM and REM sleep have a qualitative difference. For example, in relation to memory processes, NREM sleep in comparison to REM sleep appears to be important especially, but not exclusively, for neutral memory processes, while REM sleep appears to be important especially, but not exclusively, for emotional memory processing (Plihal & Born, 1997; Walker, 2009).

The difference in the quality of cognitive and mental processes during NREM and REM sleep reflects the qualitative differences of NREM and REM sleep dream reports: NREM dreams are typically more thought-like, while REM dreams are typically vivid, bizarre and laden with emotion (Nielsen, 2000). Furthermore, dream content often reflect elements of episodic memory, while dreams are believed to aid in memory consolidation processes (Payne & Nadel, 2004; Nielsen & Stenstrom, 2005). Therefore, it is clear that there is a close affiliation between dreaming and memory processes, while the nature of memory processes during NREM and REM sleep often reflect the qualitative differences in dream reports obtained from these two sleep stages.

Consequently, if dreams are regarded as consciousness during sleep, the nature of sleep-dependent consciousness can be characterised in a way that reflects both the difference in nature of memory process, as well as the qualitative difference of dream reports from NREM and REM sleep. Therefore, during sleep, consciousness appears to be, on the one hand, of a thought-like/logical nature, and on the other hand, of an emotive/affective nature. These two facets of sleep-dependent consciousness correlate strongly, but not exclusively, to the occurrence of NREM and REM sleep respectively.

Importantly, what is the function of consciousness, or put differently, dreaming, during sleep, and what is the reason for/purpose of the qualitative differences regarding sleep-dependent consciousness? There are many proposed functions of dreaming, several of which have been reviewed here, which include memory consolidation and emotion regulation, for example (Walker, 2009). However, I propose, tentatively, that there is an additional function of consciousness/dreaming during sleep. More specifically, I surmise that *consciousness/dreaming during sleep fulfils the function of updating predictions in an off-line fashion.* Updating predictions in an off-line fashion manifests in two ways: firstly, recently occurring prediction errors are processed and integrated into memory networks during NREM sleep. Secondly, in a prospective fashion, novel prediction frameworks are generated and future prediction errors are rehearsed and resolved via REM dreaming (Llewellyn, 2015).

Furthermore, I propose that *the mechanism through which predictions are integrated and updated/generated during sleep is closely related to the workings of memory reprocessing, consolidation, and enhancement.* I base this assertion on the notion that updating predictions in the presence of predictive errors is conditional on learning and relies on memory function (Schultz, & Dickinson, 2000). Moreover, in line with memory processes, I surmise that NREM and REM sleep are complimentary in the prediction integration and updating/generating process, but contribute differently due to their distinct neurochemical properties and patterns of brain region activation.

NREM and REM Sleep Mechanisms of Predictive Coding through Dreaming. As mentioned above, I propose that integrating and updating/generating predictions via dreaming during sleep, follow a process similar (but not necessarily identical), to memory reprocessing, consolidation, and enhancement during NREM and REM sleep. For example, during NREM sleep, episodic memory traces acquired during the day are retrieved and reprocessed by the hippocampus (Preston, & Eichenbaum, 2009). This retrieval process is mediated in part by the mPFC via bidirectional pathways with the hippocampus that lead to context-dependent memory retrieval. The mPFC is not only influential with regard to the contextual retrieval of memories in the hippocampus, but it also provides the rich contextual details and memory frameworks in which declarative memory is embedded. The ‘transfer’ of memory traces from the hippocampus to the mPFC is known as memory translocation and forms the cornerstone of integrating newly acquired information into existing knowledge frameworks.

I propose that predictive models generated and/or updated during the day follow a process similar to the retrieval, reprocessing and integration of memory traces during NREM sleep. The process of generating and updating predictions is based on learning from previous experience and strongly relies on memory function (Schultz, & Dickinson, 2000). If new and/or updated predictions are congruent with existing knowledge and memory frameworks, the integration process will remain unconscious. However, if a discrepancy between existing and novel predictions occur, consciousness is required in order for the predictive framework to be revised and updated.

Dreaming is a form of consciousness during sleep and could serve as one mechanism through which new predictions that are incongruent with existing ones, are updated during NREM sleep. Payne & Nadel (2004) propose that dreams can be regarded as a "window" onto the inner workings of memory systems. Therefore, the thought-like quality *typically* associated with NREM dreams could be accounted for by the kind of memories predominantly processed during NREM sleep. The abovementioned authors (2004) propose that NREM dreams typically, although not exclusively, contain mostly recent episodic memory traces leading to narratives of a more logical nature relatable in many instances to waking life. This is in contrast to REM dreams that are *typically* more hallucinatory and bizarre in nature, while REM dreams seldom contain episodic memory traces relatable to waking events (Schwartz, 2003).

From the discussion above, it is clear that the memory systems that are operative during NREM sleep relate specifically to the retrieval, consolidation and integration of mostly *recent episodic events*. This is in support of the premise that NREM sleep provides an ideal context for newly generated and/or updated predictive models to be retrieved, consolidated and integrated into existing predictive networks. Finally, when a discrepancy between novel and existing predictions in the predictive framework is detected, consciousness is required in order to update existing predictions. I propose that NREM dreams are one mechanism of consciousness through which predictions are updated, while the thought-like nature of NREM dreams can be accounted for by the memory systems that are predominantly operative during this stage of sleep. The discussion thus far has delineated one facet of how predictive frameworks operate during sleep, namely the re-processing and the integration of new predictions into existing knowledge and memory frameworks during NREM sleep. The second facet relates to the workings of predictive frameworks during REM sleep

As discussed earlier, REM sleep as opposed to NREM sleep, is particularly, although not exclusively, important for emotional memory consolidation and enhancement. It is especially the neurochemical properties (e.g. increased levels of acetylcholine), as well as the activation of certain brain regions (e,g. the amygdala and the cingulate cortex) that make the brain amenable to affect-related memory consolidation (Stickgold, Hobson, & Fosse, 2001; Hu, Stylos-Allan, & Walker, 2006; Nishida, Pearsall, Buckner, & Walker, 2009). Emotionally salient memory traces are preferentially preserved in memory, and REM sleep appears to be of particular importance with regard to the enhancement of emotional memory traces (Hu, Stylos-Allan, & Walker, 2006). REM dreaming is thought to enhance memory traces by reactivating and strengthening those traces via a process of hyperassociation, while also assigning emotional salience to the newly integrated associations (Llewellyn, 2015; Stickgold, Hobson, Fosse, & Fosse, 2001).

REM sleep is also the stage in which the majority of dreams occur, with recall rates from awakenings of up to 90% (Nielsen, 2000). Furthermore, as previously stated, there is also a qualitative difference in dream reports obtained from REM sleep compared to REM sleep. REM dreams tend to be more, vivid, bizarre, and laden with emotion compared to the thought-like characteristics of NREM dreams (Nielsen, 2000). The strong emotional valence, motivationally-driven, and hallucinatory nature of REM dreams have been linked to specific patterns of brain region activation, which include, for example, the limbic and para-limbic regions (Stickgold, Hobson, & Fosse, 2001).

More specifically, patterns of activation innate to REM sleep also include increased neuronal bursting in regions that form part of the mesolimbic dopaminergic system underlying in part what is known as the SEEKING system (Dahan et al., 2007; Lena et al., 2005). The SEEKING system in mammals is evolutionary derived and relates to the appetitive pursuit of positive rewards to satisfy drives that are essential for survival (Panksepp, 2004; Panksepp, & Moskal, 2008). This pursuit manifests, for example, in exploration of the environment as well as behaviours related to foraging for food and sex. The SEEKING system is regarded as forming an integral part of the generation of dreams, as well as playing a role with regard to the motivational content of dreams directed at satisfying drives essential for survival (Perogamvros & Schwartz, 2012; Solms, 2000).

Related to ensuring survival, Llewellyn (2015) proposes that one function of REM dreaming might relate to generating prospective[19] predictions about the world in an off-line fashion. This is achieved by identifying probabilistic patterns rooted in past events in an attempt to craft an appropriate response to an anticipated event in the future. Furthermore, the author believes that this pattern is portrayed in "unconscious, associative, sensorimotor images which may support cognition in wake through being mobilised as a predictive code". Threats to survival require prompt processing and rapid action, while possessing a prospective predictive framework would increase the chances of recruiting a rapid and successful response in a challenging situation (Schütz-Bosbach & Prinz, 2007).

In light of this, Hobson, Hong, & Friston (2014) have conceptualised a model that outlines a specific role for REM sleep in relation to generative models. The authors describe a

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[19] 'Prospective predictive coding' in this context refers to generating predictive codes as part of anticipating a situation before it occurs. This process is thought to occur during REM sleep. (Llewellyn, 2015).

process of optimisation taking place during REM sleep. REM sleep serves as an ideal state wherein perceptual processing can take place where the brain is insulated from sensory interference (Hobson, Hong, & Friston, 2014). This gating of modulatory input is essential to the process of minimising the complexity associated with generative models. Complexity in this context is described as the difference between “prior beliefs” (in relation to a probability distribution), and “posterior beliefs” (following the updating process of prior beliefs based on observing sensory outcomes). This process is comparable to the ‘synaptic homeostasis hypothesis’ and can be likened to the pruning/elimination of redundant and unnecessary synaptic connections. This pruning process of reducing complexity results in a model that is both parsimonious and hierarchically simplistic, rendering it optimised in terms of efficiency in the face of perceptual inference during waking. Put simply, the brain can shift its focus from explaining sensory input to generating fictive predictions that result in prediction errors at each level of the hierarchy. This process leads to an “efficient model of the experienced world on waking” (Hobson, Hong, & Friston, 2014).

In relation to this, generating a prospective predictive framework via dreaming in an off-line fashion would enable an organism to select an appropriate response during wakefulness before the anticipated event comes to fruition (Llewellyn, 2015). This effectively increases, for example, successful threat avoidance through rehearsal, as well as formulating strategies for the fulfilment of appetitive needs (e.g. reproduction and foraging for food) through reward networks. (Schütz-Bosbach & Prinz, 2007). One can theorise, that both of the abovementioned examples would contribute to more effective strategies and behaviours during wakefulness. Finally, generating prospective predictive frameworks in the neurobiological and neurochemical context of REM sleep, could account for the typically vivid, motivationally-driven, and emotionally salient nature of REM dreams.

In summary, the processes underlying integrating and updating/generating predictions via dreaming in an off-line fashion closely resembles the memory mechanisms underlying NREM and REM sleep respectively. For example, NREM sleep is important for retrieving and consolidating recent episodic events, and finally integrating them into existing knowledge frameworks. When there is a discrepancy between incoming novel predictive frameworks and existing predictive frameworks, a prediction error has occurred and consciousness is required in order to revise and update the predictive frameworks. I propose that NREM dreaming is the vehicle of consciousness through which incongruent predictions are revised and updated during sleep before finally being integrated into existing knowledge frameworks.

With regard to REM sleep, the neurochemical properties and patterns of brain region activation innate to this sleep stage make the brain amenable to the consolidation of affective memories, while it could also account for the vivid and emotionally salient nature of REM dreams. I propose that REM dreams fulfil the function of anticipating future situations and producing prospective predictive frameworks in order to maximise efficiency when confronted with a similar situation during wakefulness. Furthermore, I surmise that REM dreams also provide the neurobiological context in which strategies for the fulfilment of appetitive drives are rehearsed and encoded. Both of the aforementioned processes would contribute to increased efficiency and optimise chances of survival during wakefulness.

Finally, the above proposed function of dreams in relation to predictive coding processes could account for the qualitative difference typically observed in reports obtained from NREM and REM sleep. Now that the tentative theoretical framework of the mechanisms and functions of NREM and REM dreaming have been delineated, the findings of the current study will be situated within this framework.

Brain Reactivity and Predictive Coding during Sleep. Eichenlaub et al., (2014a) propose that increased brain reactivity to external stimuli in HFR individuals is possibly one explanation for why they experience an increased number of awakenings and WASO. The mechanism underlying increased brain reactivity is believed to relate to a stronger attention orientation response to novel stimuli in HFR individuals. The finding of a stronger attention orientation response was based on the results from an ERP study that detected a larger P3a-like wave in response to novel external auditory stimuli during both wakefulness and sleep. The P3a wave, along with the P3b wave form part of the P300 wave, but the two components occur at different response latencies (P3a earlier, P3b later) and demonstrate a different topographical distribution on the EEG (Maidhof, Rieger, Prinz, & Koelsch, 2009). Typically, the P3a wave entails an attentional switch to novel or deviant stimuli, while the P3b wave is thought to involve memory updating operations in relation to this. Interestingly, there are other ERP components, namely error waves[20] that are morphologically and topographically so similar to the P300 wave, that some authors surmise that they might embody the same phenomenon (Davies, Segalowitz, Dywan, & Pailing, 2001; Falkenstein, Hohnsbein, & Hoorman, 1999; Miltner, Braun, & Coles, 1997).

One study has provided evidence demonstrating that it is especially the positive deflection of the error waveform (Pe) that correlates strongly with P300 wave components. Furthermore, the authors suggest that this supports the notion that the positive deflection of the error wave is a P300-type response to internal error-detection[21] (Davies, Segalowitz, Dywan, & Pailing, 2001). Furthermore, the authors propose that individuals are consistent in the type of P300 waves they produce, whether it is in response to an external stimulus [e.g. auditory stimuli in the Eichenlaub et al., 2014a)], or as a response to internal error-detection.

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[20] Error waves occur in response to, for example, an incorrect motor response on the Go/NoGo task. Error waves typically consist of two components: (1) a negative deflection that peaks approximately 50-80ms after error execution (error-related negativity), and (2) a positive deflection that peaks approximately 100-200ms after error execution (error-related positivity) (Maidhof, Rieger, Prinz, & Koelsch, 2009).

[21] Internal error-detection relates to the conscious or unconscious awareness of, for example an incorrect motor response on the Go/NoGo task.

Due to the strong relationship and shared temporal distribution of the Pe and P300 waves (Maidhof, Rieger, Prinz, & Koelsch, 2009), the authors propose that in the context of error-detection, the early P3a and late P3b components of the P300 wave reflect a process of attention switching in terms of the former, and memory updating processes in the latter. It is important to note that the Pe deflection is larger when individuals are consciously aware that an error has occurred, where the amplitude of the negative deflection is similar in relation to perceived and unperceived error detection (Orr, & Carrasco, 2011). Therefore, it is proposed that the Pe is most likely a P300 type response to internal error detection (Davies, Segalowitz, Dywan, & Pailing, 2001).

From the discussion above, a strong case can be made for the P300 wave to be associated with internal error-detection. However, testing this proposition in relation to dreaming in sleeping individuals, is problematic. Nevertheless, to my knowledge, there is one study (Eichenlaub et al., 2014a) that has implemented an ERP protocol as part of a sleep study where HFR and LFR individuals are compared to one another. The researchers found a larger P3a-like wave in HFR individuals in response to external auditory stimuli during both wakefulness and sleep. More specifically, novel sounds elicited a larger response at earlier latencies during stage 2 sleep, while deviant tones elicited larger responses during REM sleep. This is indicative of a stronger attention orientation response in HFR individuals. Importantly, as discussed earlier, components of the P300 wave are morphologically and topographically so similar to Pe waves that they are thought to represent the same phenomenon (Falkenstein, Hohnsbein, & Hoorman, 1999; Miltner, Braun, & Coles, 1997). Therefore, a case can be made that the occurrence of the P300 wave is comparable to the Pe wave in response to internal error detection (Davies, Segalowitz, Dywan, & Pailing, 2001).

Brain Reactivity, Prediction Errors, & Awakenings in HFR Individuals. Following the discussion above, I propose, albeit admittedly speculative at this stage, that the process of internal error detection is comparable to becoming conscious of a prediction error having occurred. Furthermore, the possibility exists that a stronger attention orientation response to error detection in HFR individuals is potentially one mechanism underlying increased number of awakenings across the night.

I base this tentative assertion on the following logic: (a) HFR individuals exhibit larger P3a components during both sleep and wakefulness, (b) larger P3a-like waves are indicative of heightened brain reactivity and a stronger attention orientation response to novel external auditory stimuli, (c) the P3a component forms part of the P300 wave and individuals are consistent in the P300 waves they produce, whether to novel external stimuli or in response to internal error-detection, (d) if one accepts that HFR individuals have a stronger attention orientation response to auditory stimuli during both wakefulness and sleep, one can extrapolate that they also have a stronger attention orientation response to detecting an internal error during both wakefulness and sleep, (e) internal error detection can be likened to becoming conscious of the occurrence of a prediction error, (f) heightened brain reactivity in HFR individuals and a stronger attention orientation response to the occurrence of a prediction error, lowers the arousal threshold, potentially leading to an increased number of awakenings.

Results from the current study indicate that it is especially awakenings from stage 2 sleep that is of importance in this specific population. I propose that one possible mechanism underlying stage 2 awakenings is related to the re-processing and integrating of new predictive frameworks in a way similar to the re-processing and integration of recent episodic memories during NREM sleep. For example, when there is an incongruence between new predictive frameworks and existing predictive frameworks during the integration phase, a prediction error occurs and consciousness is required to revise and update the predictive frameworks. I propose that dreaming is the mechanism of consciousness through which this is achieved. However, due to heightened brain reactivity in HFR individuals and a stronger attention orientation response to the prediction error, the arousal threshold of these individuals are lowered which, in turn, leads to an increased chance of the occurrence of an awakening.

However, importantly, why is there a significant difference with regard to increased awakenings from stage 2 NREM sleep specifically as opposed to stage 3 NREM sleep when both of these sleep stages form part of NREM sleep processes? One possible explanation relates to the nature of brain activity during, and the susceptibility to, arousal from the different sleep stages. The brain waves during stage 2 sleep is characterised by increased frequency and low amplitude compared to brain waves detected during stage 3 sleep, which consists of large and slow delta waves (Carskadon, & Dement, 2005). An increased arousal threshold is associated with large, slow waves, while the converse is true for the smaller and faster brain waves typically detected during stage 2 sleep. A decreased arousal threshold during stage 2 sleep coupled with increased brain reactivity in the HFR group, could account for the increased number of awakenings from stage 2 sleep in the current study. Furthermore, increased brain reactivity coupled with an increased number of awakenings could also explain why HFR individuals spent more time awake after sleep onset compared to LFR individuals.

Dream Recall Frequency in relation to Awakenings & WASO. Both an increased number of awakenings and increased WASO detected in HFR individuals provide support for the arousal-retrieval model of dream recall. According to this model, sufficient periods of wakefulness are required for dream traces to be encoded into long-term storage in order for successful retrieval at later stage. The increased number of awakenings provides an increased number of opportunities for dream traces to be encoded, while longer periods of wakefulness supports the transfer of memory traces from short- to long-term memory.

Furthermore, apart from a better memory for dreams, Eichenlaub et al. (2014a; 2014b) propose that HFR individuals also potentially produce more dreams. The theoretical framework within which findings from the current study is situated in, potentially provides support for this proposition; however, it must be emphasised that this is highly speculative at this stage. Consider the following explanation: Comparable to memory processes during NREM sleep, new predictive frameworks are reprocessed and integrated into existing predictive frameworks. However, if there is an incongruence between existing and novel predictive frameworks, a prediction error has occurred and a certain degree of consciousness is required in order to revise and update erroneous prediction frameworks.

I propose that dreaming is the form of consciousness through which this is achieved. Importantly, becoming conscious of a prediction error requires an attentional shift in order to resolve the problem/update predictions. Heightened brain reactivity/stronger attention orientation response in HFR individuals lead to a lower awakening threshold. With the purpose of protecting sleep, awakenings are circumvented by triggering increased dream production in an attempt solve the prediction error without requiring waking consciousness.

However, in the context of the current study, this process is not successful and awakenings do occur, especially from stage 2 sleep. Additional evidence, although to be interpreted with caution due to limited number of reports (58), relate to significantly higher dream recall rates from morning awakenings from stage 2 sleep (88.89%) compared to REM sleep (33%) in the HFR group in the current study. Therefore, there is both a higher number of awakenings, as well as a higher dream recall rate from stage 2 sleep. In other words, the stronger the susceptibility to awakenings in the HFR group (due to increased brain reactivity), the more dream production will be enhanced in order to preserve sleep. The failure of dreams to preserve sleep could account for the significantly higher number of awakenings, as well as dream recall rates from stage 2 sleep in the HFR group.

Summary of Investigation 2. The main findings of Investigation 2 relate to HFR individuals have significantly increased WASO, as well experiencing significantly more awakenings across the night, especially from stage 2 sleep. These findings are in line with the only other study investigating sleep architecture in healthy HFR and LFR individuals (Eichenlaub et al., 2014a). The neurophysiological mechanism underlying increased awakenings and WASO is thought to be a consequence of heightened brain reactivity in HFR individuals. Heightened brain reactivity leads to a stronger attention orientation response to novel stimuli in these individuals during both wakefulness and sleep. The electrophysiological response to novel stimuli is comparable to the electrophysiological response during the detection of an internal error (Davies, Segalowitz, Dywan, & Pailing, 2001). I proposed that detecting an internal error is a process similar to becoming aware of a prediction error and that, during sleep, dreaming is the mechanism through which prediction errors are resolved and updated.

Investigation 3: Objective Measure of Increased Dream Production in HFR Individuals

One of the main objectives of this investigation pertains to developing and employing an objective measure to determine rates of dream production during REM sleep. Before discussing the findings of this study, an overview of currently available methods for determining DRF is worth a mention in order to illustrate the reasoning for adopting the method employed in this study.

There are a number of measures typically used to obtain rates of dream recall frequency. One of the most popular methods entail using retrospective self-report questionnaires. One of the main problems with this approach is that, essentially, results from this method would reflect a person's *memory* for dreams. Another option would be to use dream diaries, but there is evidence in the literature that increased focus on dream content and frequency tend to lead to higher recall rates (Schredl, 2004).

An alternative approach would be to rely on laboratory awakenings; however, obtaining reliable rates of dream recall frequency in this manner is not without limitations. For example, it is unclear how many dream reports would have to be collected in order for it to accurately reflect dream production rates across the night. Furthermore, reporting dreams upon awakening in an experimental setting is not without difficulty – dream reports collected upon awakening are susceptible to memory decay, sleep inertia, a salience bias, self-censoring due to social desirability, as well as the recall process being affected by interference from competing stimuli. Ideally one would want to utilise a combination of the above, but even then it is debatable as to how accurately these measures reflect true dream production across the night.

In the current study two measures for determining dream recall frequency were employed. The first measure was used for the purpose of group allocation and includes an 8-point scale (Eichenlaub et al., 2014a; 2014b) enquiring about dream recall frequency over the last couple of months. In this scale, dream recall frequency was operationalised based on absolute categories as opposed to relative categories, e.g. 'about once a month' as opposed to 'occasionally'. The reason for this is that 'occasionally' might mean different things to different people as opposed to stipulating an unambiguous category (Schredl, 2004).

In addition, laboratory awakenings, as a more objective measure of DRF, were performed in order to ascertain whether the questionnaire data was statistically successful in adequately discerning between HFR and LFR individuals. Results revealed that 63.3% of awakenings in the HFR group yielded a dream report, with 27.6% in the LFR group. This difference was statistically significant ($p = .006$), while there was no difference between groups with regard to the sleep stages from which participants were awakened from (different sleep stages yield different rates of dream recall). Therefore, both subjective and objective measures confirm a significant difference with regard to dream recall frequency between groups. Although both these measures of DRF proved to be valuable and useful with regard to specific objectives of this study, they are not sufficient in terms of providing an objective and reliable measure of dream production across the night.

Therefore, it was decided to develop a reliable and quantifiable method of measuring rates of dream production. The first and most obvious sleep parameter to focus on is REM sleep, as up to 90% of awakenings from this sleep stage yield dream reports (Nielsen, 2000). Furthermore, based on the overview and explanations outlined in preceding sections, rapid eye movements (REMs) as a physiological correlate of PGO activity can be used to index the occurrence of dream imagery, enabling one way of investigating whether HFR individuals not only remember more dreams, but also possibly produce more dreams.

REM Density and Rates of Dream Production during REM sleep. To my knowledge, at the time of analysis (2016), no other studies have published results pertaining to REM density in relation to DRF where HFR and LFR individuals were directly compared to one another. Furthermore, apart from examining the total REM density value across the night, additional REM density variables were included in analysis, as there is reason to believe that REM density has different functional consequences at different times of the night (Cartwright et al., 1998a; 1998b). In light of this, and in addition to the Total REM density value across the night, the following REM density parameters were also included in analysis: (a) 1st REM period density value, (b) Split-Night 1 REM density value (value for the first half of the night), and (c) Split-Night 2 REM density value (value for the second half of the night).

Results revealed no significant between-group differences with regard to any of the REM density parameters. There are two explanations to be put forward with regard to the proposition that differences do exist, but they were undetected in this study. Firstly, one could argue that the methods and measures employed in the current study was not sensitive enough to detect between-group differences. However, I find this an unlikely explanation as there were strong and significant correlations between the REM density parameters and affective variables in Investigation 4. Therefore, it is unlikely that the measure would be sensitive enough to detect significant results in one investigation, but not in another. This assertion is in favour that between-group differences do not exist in this sample.

The second explanation relates to the observation that the mean trends in the data were congruent with the direction of the hypotheses, i.e. the HFR group had higher values across all the REM density parameters compared to the LFR group. Based on this, one could argue that there is a chance that with an increased sample size, significant between-group differences might emerge. However, I find this an unlikely explanation: Based on post-hoc power analyses with $\alpha = 0{,}05$, all other significant between-group differences thus far, e.g. higher Agreeableness scores, increased WASO, and increased number of stage 2 awakenings, yield power values of .93, .90, and .81 respectively. The significance of this relates to the unlikelihood of consistently detecting strong results in the sample in certain instances, but failing to do so in other instances. Therefore, I propose that it is more likely that these differences do not exist in the current sample.

In light of this, I argue that between-group differences with regard to REM density in the current study do not exist, because, perhaps, REM dreaming is not of prime relevance in the current sample. For example, there were no between-group differences with regard to REM sleep %, REM sleep latency, and the number of awakenings from REM sleep. Furthermore, at the time of writing (2017), new findings with regard to REM sleep and REM density based on the Eichenlaub et al. (2014a) data, were published (Vallat et al., 2017). Researchers found no significant difference with regard to REM density values, nor between the number and length of awakenings from REM sleep. They conclude that higher DRF in the HFR group "could not be explained by the REM sleep hypothesis of dreaming" (Vallat et al., 2017). Indeed, findings from the current study are in line with this assertion – it seems that NREM sleep, and more specifically, stage 2 NREM sleep, appear to be of particular importance in the current sample. Crucially, is there a theoretical footing to link increased DRF in HFR individuals with NREM sleep features? I propose that the Cyclic Alternating Pattern (CAP) during stage 2 NREM sleep might be of particular importance.

Cyclic Alternating Pattern and Increased DRF. A possible mechanism underlying an increased number of awakenings and increased WASO in HFR individuals, has been discussed in preceding sections of Investigation 2. The focus was specifically on the neurobiological and neurophysiological features subserving increased WASO and stage 2 awakenings in this group. However, the focus of this section of the discussion relates specifically to sleep stages and the associated neurophysiological factors that might be of importance in terms of leading to increased dream recall in the HFR group. As mentioned above, findings from the current study in conjunction with recently published results (Vallat et al., 2017), provide support for the premise that, contrary to what was expected, it appears that REM sleep features are not of particular importance in the context of increased DRF in HFR individuals. I propose that stage 2 NREM sleep is significant in this regard, and that cycling alternating patterns (CAP) might be one essential feature subserving increased DRF in HFR individuals.

CAP refers to periodic electrocortical events that manifest in recurring sequences at approximately one minute intervals during NREM sleep (Parrino, Grassi, Milioli, 2014). These transient electrocortical events stand out from the tonic background EEG and signify a state of sleep instability and fluctuations in the depth of sleep (Terzano et al., 2002). CAP encompasses a process of both sleep maintenance and fragmentation and occurs in sequences consisting of two different phases: Phase A ("activation") and Phase B ("background"). Phase A is thought to be triggered by endogenous and exogenous processes and is identifiable by transient events (e.g. K-complexes) that are associated with cerebral activation (Ferini-Strambi et al., 2000). Phase B is associated with a period of deactivation. CAP sequences are comprised of the consistent succession of Phases A and B.

Phase A of the CAP sequence can further be divided into three sub-types (A_1, A_2 and A_3), where all three are believed to play a distinct influential role in the dynamic organisation of sleep via different underlying mechanisms (Halász & Bódizs, 2013). Subtype A_1 consists of slower, synchronised rhythms, while subtype A_3 is comprised of faster desynchronised rhythms. Subtype A_2 is a compromise of the other two subtypes identifiable by synchronised A_1 activity transitioning to faster desynchronised activity associated with A_3. Therefore, it is clear that NREM sleep is not a passive nor a homogeneous state, but could rather be characterised as dynamic and consisting of a multitude of phasic phenomena related to variable levels of arousal (Halász, 1998). This has led to the proposition that the occurrence of NREM dreaming might be related to phasic phenomena occurring during NREM sleep.

There is, to my knowledge, no existing literature on the relationship between CAP features and dream recall in healthy individuals, apart from unpublished work in our laboratory (Wainstein & Solms, 2013). The main aim of this study was to explore whether there is any relationship between dreaming and phasic arousals forming part of Phase A of the CAP sequence during NREM sleep. 213 Dream reports were collected via laboratory awakenings from healthy individuals during both stage 2 and stage 3 NREM sleep containing CAP activity (unstable sleep) or no CAP activity (stable sleep). In addition, the different Phase A subtypes were evaluated in relation to dream recall.

Results showed that, on average, the highest rate of dream recall was obtained from stage 2 NREM sleep specifically in relation to the A_2 subtype in the CAP sequence. Compared to subtype A_1, subtype A_2 is associated with desynchronised faster waves and represents a phasic state where the brain is more connected to the external environment. The researchers conclude that, in light of their findings, “periods of sleep that are more vulnerable to connecting with the external environment are regularly related to dreaming in… NREM sleep” (Wainstein

& Solms, 2013). This assertion is consistent with the Eichenlaub et al. (2014a) study that showed that HFR individuals have heightened brain reactivity and a stronger orientation response to stimuli from the external environment. Furthermore, results from both of these studies are consistent with the findings of the current study in relation to increased number of awakenings, as well as dream recall rates, from stage 2 sleep. Therefore, taken together, the two abovementioned studies along with the current study support the premise recently outlined by Vallat et al. (2017), that increased DRF in HFR individuals cannot be explained by the REM hypothesis of dreaming. I propose that it is the electrophysiological features of especially stage 2 NREM sleep in conjunction with the functional neurophysiological traits (increased brain reactivity) innate to HFR individuals, that lead to a significantly increased number of awakenings and dream recall rates from stage 2 sleep.

Summary of Investigation 3. Investigation 3 entailed developing and applying a method to objectively and reliably measure rates of dream production during REM sleep. Analysis of the frequency of eye movements (REM density) was chosen as a method used to index the occurrence of dream imagery during REM sleep. One would expect that REM sleep is a reliable choice for studying dream production as up to 90% of REM sleep awakenings yield dream reports (Nielsen, 2000). However, results revealed no significant between-group differences with regard to REM density. Arguments for the possibility that the measure was not sensitive enough, or, that a bigger sample might lead to significant differences, have been refuted in preceding sections. The most likely explanation, rooted in empirical evidence from three different studies taken together, point to the possibility that it is the phasic electrophysiological features of stage 2 NREM sleep coupled with the functional neurophysiological traits innate to HFR individuals, that possibly lead to an increased number of awakenings and higher dream recall rates from stage 2 sleep. Essentially, it is NREM sleep and not REM sleep as one would intuitively surmise, that is of particular importance in relation to this specific population.

Investigation 4: Increased Dream Production in Relation to Overnight Emotional Memory Consolidation & Emotion Regulation

There are two overarching aims forming part of Investigation 4. Both of these aims are based on the premise that HFR individuals not only have better memory for dreams, but potentially also produce more dreams. Increased dream production was measured by examining the frequency of eye movements during REM sleep. Therefore, 'increased dream production' in this section refers to REM dreams specifically. In light of this assertion, one of the main objectives of this investigation relates to determining whether increased dream production during REM sleep has functional significance in its own right, i.e. does increased dream production affect other neuriobiologically-related processes? Overnight emotional memory consolidation and emotion regulation are two processes that have been identified as potentially being significant in this regard.

Increased Dream Production & Overnight Emotional Memory Consolidation. In the context of increased dream production during REM sleep, I postulated that HFR individuals will exhibit enhanced emotional memory consolidation compared to LFR individuals. More specifically, I surmised that there will be significant differences with regard to positive and negative pictures forming part of the emotional declarative memory (EDM) task. Importantly, the emphasis is on *emotional* memory consolidation, and therefore I decided to include two control tasks assessing neutral declarative memory. The first analysis revealed no significant between-group difference with regard to the neutral declarative memory tasks. This finding is in line with the predictions of this investigation; however, findings with regard to the emotional declarative memory task are not – no significant differences between groups were found.

There are two explanations to be put forward with regard to the possibility that differences do exist in the sample, but were not detected in this investigation. Firstly, the possibility exists that the task failed in eliciting a strong enough emotional response to the pictures containing high valence ratings. Eliciting a strong emotional response in relation to pictures with high valence ratings is important in order to render these pictures affectively distinct from neutral pictures. A second explanation for failing to detect significant differences relate to the possibility that some of the pictures [sourced from the International Affective Picture Scale (IAPS)] that were included in the task are biased towards Western culture. For example, pictures of sports (e.g. skiing and ice-skating), or people (e.g. Hispanic individuals) might not be readily familiar to individuals residing in Sub-saharan Africa.

The two possible explanations for failing to detect existing differences discussed above can both be refuted by past research in our laboratory. Nestadt & Kantoor (2015) found that the standardised IAPS valence ratings are strongly correlated with those assigned by a South African sample. Therefore, pictures sourced from the IAPS for the emotional declarative memory task do evoke emotions that are congruent with those outlined in the standardised IAPS manual. With regard to the possibility that the pictures included in the task were not culturally appropriate seems unlikely as a recent unpublished doctoral study investigating sleep and memory in Posttraumatic stress disorder successfully utilised this measure in a Sub-saharan African population (Lipinska & Thomas, 2017). Therefore, one can assume with a certain degree of confidence, that the potential bias towards Western culture in the pictures that were included was not problematic in this study, and, secondly, based on previous research, that the pictures were successful in eliciting a sufficiently strong enough emotional response. Based on this, I propose that the most likely explanation for not detecting significant between-group differences relates to the possibility that these differences do not exist in the current sample.

Another possible explanation for not detecting significant between-group differences relates to the possibility that the sample size was too small. Arguments against this possibility have been outlined in preceding sections forming part of Investigation 3, but will be reviewed here again. Post-hoc power analyses on all significant variables of the current study have all indicated that the findings have adequate statistical power. Therefore, I argue that it is highly unlikely that strong results would be detected consistently in the current sample, while the sample size would not suffice in terms of detecting other existing differences. Consequently, I propose that it is more likely that differences with regard to overnight emotional memory consolidation do not exist in the current sample.

The neural underpinnings of overnight emotional memory consolidation overlap with REM sleep mechanisms. Therefore, I propose that one explanation, which is congruent with explanations outlined in Investigation 3, is that REM sleep and its associated parameters are not of particular importance in the current sample. Hypotheses in this investigation were formulated on the suppositions that (a) HFR individuals produce more dreams during REM sleep, (b) increased dream production will be detectable during REM sleep using REM sleep parameters (REM density) and (c) increased REM dreaming would affect other neurobiologically related processes, which include overnight emotional memory consolidation.

However, results from the current study along with results from Vallat et al. (2017) have led to the assertion that the REM sleep hypothesis of dreaming does not suffice as an explanation for the variability in DRF in healthy individuals. Therefore, failing to detect significant between-group differences with regard to overnight emotional memory consolidation, provides further support for the supposition that there is a strong possibility that NREM sleep, as opposed to REM sleep, mechanisms may be of particular importance with regard to increased DRF in this specific population.

Increased Dream Production and Overnight Emotion Regulation. The second set of hypotheses relate to the role that increased dream production during REM sleep play with regard to overnight emotion regulation. There is a commonality between the neural correlates of emotional processes and REM sleep, while REM dreaming is thought to aid in emotion regulatory processes (Walker, 2009). In light of this, I surmised that HFR individuals will be more successful in up-regulating positive and/or down-regulating negative emotions compared to LFR individuals. I proposed that this will be evidenced by significant between-group differences with regard to the morning values of positive and negative emotion based on comparable night-time values. General Positive Emotion (GPE) and General Negative Emotion (GNE) scores were generated by the PANAS-X.

Results showed no significant between-group differences with regard to the morning values of GPE and GNE. Interestingly, both groups showed an overnight decrease in GPE scores; however, this difference was only significant in the HFR group. Furthermore, there was an overnight increase GNE scores in the HFR group, while the converse was true for the LFR group. However, neither of these differences reached significance.

One explanation for the overnight decrease in positive emotion could be related to an increased number of awakenings and WASO observed in the HFR group. Sleep fragmentation and maintenance problems are known to affect positive and negative waking affect, as well as emotional reactivity (Kahn, Sheppes, & Sadeh, 2013; Zohar, Tzischinsky, Epstein, & Lavie, 2005). More specifically, disrupted sleep has been found to lessen the intensity and frequency of positive emotions, while intensifying the experience of negative emotions (Franzen et al., 2008; Paterson et al., 2011). It is important to note that, for both groups, scores on the GPE and GNE scales are in line with normative data (Watson & Clark, 1994). Interestingly, the number of awakenings across the night for both groups also fall within a range that is considered acceptable for healthy young adults (Bonnet & Arand, 2007). Therefore, if one accepts the explanation of fragmented sleep as one mechanism underlying a significant overnight decrease in GPE in the HFR group, the following should be emphasized: an increased number of awakenings and a significant decrease in GPE scores do not reflect a pathological process, it merely represents variation within normal parameters, that appears to be significantly more pronounced in the HFR group compared to the LFR group.

In summary, no between-group differences were detected with regard to overnight up-regulation of positive emotion and/or down-regulation of negative emotion. However, there were within-group differences in relation to a significant overnight decrease in GPE in the HFR group. I proposed that one possible mechanism underlying a decrease in positive emotion might be related to increased sleep fragmentation in the HFR group. Importantly, both the number of awakenings, as well as night-time and morning GPE scores, are in line with normative data. Therefore, the overnight decrease in positive emotion scores in the HFR group does not reflect a pathological process. I propose that is merely indicative of variation occurring within normal parameters; however, the degree of variation appears to be significantly more pronounced in the HFR group compared to the LFR group. Finally, overnight emotion regulation processes are intimately related to the neural underpinnings of REM sleep. In light of this, and in line with assertions in the preceding section, results regarding the lack of significant between-group differences provide further support for the proposition that REM sleep mechanisms are not of paramount importance in the context of this specific population.

The Relationship between Affective Variables & REM Density. The final section of Investigation 4 relates to the relationship between affective variables and REM density in the context of overnight emotion regulation. With regard to the hypotheses, I postulated that increased levels of REM density will be significantly associated with an overnight increase in GPE scores and/or an overnight decrease in GNE scores. The rationale behind these hypotheses relate to various studies demonstrating that there is an intimate relationship between REM density and affect. More specifically, REM density appears to be of particular importance in the context of certain mood disorders that are characterised by a failure of overnight emotion regulation (Buysse et al., 1997; Buysse et al., 2001; Cartwright, 1983; Nofzinger et al., 1994). REM density has been found to positively correlate with depression severity, while increased levels in individuals who are in remission proved to be predictive of a recurring episode in the future.

Interestingly, Cartwright et al. (1998a; 1998b) postulate that certain levels of REM density at specific times of the night might have distinct functional consequences. For example, the authors showed that low REM density values during the first REM sleep period of the night is indicative of a failure of instigating the overnight working-through/regulatory processes. Furthermore, they propose that this failure potentiates depressive symptomatology the following day.

At this stage it is important to note that no significant between-group differences were found with regard to any of the REM density variables and overnight emotion regulation. Consequently, results from this section of Investigation 4 does not pertain to mechanisms involved in DRF (e.g. increased REM dream production in the HFR group); however, it does illuminate the significant role of REM dreams (indexed by REM density) in overnight emotion regulation in healthy individuals. Furthermore, results not only underscore the value of analysing REM density as a marker for overnight emotion regulatory processes, but it also serves to validate the REM density measure that was developed for, and employed in, this study as sensitive and appropriate in terms of the hypotheses of the current study.

The REM density values that were incorporated into the analysis include the following: Total REM density value, 1st REM period density value, Split-Night 1 REM density value (value for the first half of the night), and Split-Night 2 REM density value (value for the second half of the night). The affective variables include the night-time and morning GPE and GNE scores. It is important to note that, due to the chronology of the experimental procedure (PANAS-X Night Condition → REM density generation during sleep → PANAS-X Morning Condition), one can make tentative inferences regarding the causality of the significant relationships that did emerge.

Results showed significant negative relationships between all the REM density variables and night and morning GPE scores. In the context of the chronology of the experimental procedure, lower GPE scores at night are associated with higher REM density values during the night, which in turn are associated with lower GPE scores in the morning. In light of this, one could argue that lower positive mood at night triggered an increase in rapid eye movements (REMs) in an attempt to up-regulate positive emotion. Interestingly, there were no significant relationships between REM density variables and night and morning GNE scores. This finding is unexpected as most studies have found a significant positive relationship between REM density and negative affect (Buysse et al., 1997; Cartwright et al., 1998a; 1998b).

In terms of explaining the discrepancy between results from the current study and those from previous literature, it is imperative to point out that this study only recruited healthy individuals, while previous research mostly utilise patient populations with mood disturbances/disorders. Furthermore, the average GNE scores of both groups in the current study are in line with normative data (Watson & Clark, 1994), and, in addition, all participants had no or very minimal depressive symptomatology as measured by the BDI-II. All participants scored < 14 on the BDI-II, where a score ≥ 14 is indicative of the presence of mild depression and would result in exclusion from participation. The mean BDI-II score for the entire sample is 4.22, which is considerably lower than the average of 9.14 for college students (normative data from Whisman & Richardson, 2015). Therefore, negative affect/mood as measured by the PANAS-X and BDI-II, is minimal in the current sample in its entirety. Essentially, results from the current study supports the notion that, in healthy individuals, REM sleep regulatory processes potentially involve the up-regulation of positive emotion as opposed to the down-regulation of negative emotion which is often seen in the context of mood disturbances/disorders.

However, it appears that the REM sleep regulatory process, in a sense, failed as higher REM density values were associated with *lower* GPE scores in the morning. Put differently, if the REM sleep regulatory process was successful, higher REM density values would be associated with *higher* GPE scores in the morning. There are two possible, potentially overlapping, explanations for lower GPE scores in the morning.

The first explanation relates to the failure of REM sleep with regard to up-regulating positive emotion could, in a way, be regarded as comparable to the failure of down-regulating negative emotion in the context of mood disorders like depression. Cartwright et al. (1998a) postulate that waking negative affect triggers REM sleep regulatory processes in down-regulating negative mood through the frequency and patterning of dreams occurring during REM sleep. Importantly, increased REM density values are positively correlated with the severity of mood disturbances (Buysse et al., 1997). However, when the waking negative affect is higher than what can be accommodated by the regulatory REM sleep mechanisms through the course of the night, it might remain unresolved come morning and potentiate negative affect the following day (Cartwright et al., 1998b). Therefore, there is a ceiling effect with regard to REM sleep mechanism's ability to successfully down-regulate negative affect over the course of the night.

However, if one assumes that REM sleep regulatory mechanisms failed in up-regulating positive emotion, what could explain this failure in a healthy population? I propose that completing the emotional declarative memory task (EDM) before and after a night of sleep could be one important moderating variable in this regard. More specifically, the disturbing nature of this task could be influential in terms of the affective tone measured by the PANAS-X. Before proceeding with delineating the rationale behind this assertion, it is important to review the experimental procedure employed in the current study.

On the experimental night, participants were asked to complete a series of questionnaires, which included the PANAS-X that generated the GPE and GNE scores. Following this, the two neutral declarative memory tasks were administered, followed by the EDM task. The reason for completing the PANAS-X before the memory tasks relates to an attempt to minimise interference from the words contained in the PANAS-X. Following this, participants were prepared for a night's sleep, and completed the recognition components of the two neutral declarative memory tasks and the EDM task, while assigning valence ratings to pictures forming part of the EDM task. Assigning valence ratings in the morning condition of the EDM task entailed a process where participants were asked to rate each picture on a scale from 1 (positive) to 9 (negative). Every picture included in this task has a standardised valence rating that either classify it as a positive, neutral, or negative picture based on the average valence rating. Following this, the PANAS-X was completed for a second time. The procedure can be visualised as follow: PANAS-X → EDM Task → Sleep → EDM Task Recognition & Valence Ratings → PANAS-X.

Furthermore, it is also important to mention the thematic nature of especially the negative pictures sourced from the IAPS that were included in the EDM task. For example, there were pictures reflecting scenes of violence (e.g. murder and sexual assault), scenes from natural disasters (e.g. floods), predators (e.g. snakes), and human excrement (e.g. vomit)[22]. In light of this, I propose that the disturbing nature of the EDM task dramatically increased the affective load on participants and that this intensified the efforts of the REM sleep regulatory

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[22] Please note that participants consented (written and verbal) on three separate occasions that they were willing to continue with the task following being informed of its disturbing nature. In addition, they were also reminded that they can withdraw at any point without penalty before starting the task.

mechanisms when participants went to sleep. Intensified efforts of the REM sleep regulatory mechanisms can be indexed by increased rates of REM density (Cartwright et al., 1998a;1998b). In support of the influential role of the EDM task, it is interesting to note that there were significant relationships between negative and neutral valence ratings from the EDM task and REM density parameters. For example, there was a significant positive relationship between REM density values during the first REM period and negative valence ratings, *r*(34) = .383, *p* = .025, as well as a significant positive relationship between REM density during the first half of the night and neutral valence ratings, *r*(32) = .431, *p* = .014.

Taken together, these results indicate firstly, that the higher the REM density values, the more negative participants tend to rate both negative and neutral pictures (a higher score = increased negativity). Secondly, and, related to this, there is a strong possibility that the disturbing nature of the EDM task could be functioning as a moderating variable with regard to the failure of successfully up-regulating positive emotion overnight in the current sample. Furthermore, the strong positive relationship between REM density during the first REM sleep period further supports the premise that REM regulatory mechanisms were intensified. I base this assertion on a study conducted by Cartwright et al., (1998a) that noted that low REM density values during the first REM sleep period is indicative of a failure to instigate an overnight working through/regulatory process. Therefore, there was an increased drive and intensification of REM sleep regulatory processes in order to up-regulate positive emotion throughout the course of the night. However, this process did not result in higher GPE scores the following morning. As mentioned above, one explanation could be a failure REM sleep regulatory mechanisms in a manner comparable to a failure of down-regulating negative emotion in the context of mood disturbances/depression (Cartwright et al., 1998a). More specifically, in the context of the current study, a failure occurs if the demands of up-regulating positive emotion exceed REM sleep regulatory mechanism’s ability to achieve this by the end of the sleep period.

In addition, there is a second possible explanation for why GPE scores remained low the following morning. Considering the temporal order of the experimental protocol, it seems plausible that completing the PANAS-X following re-exposure to the disturbing picture stimuli of the EDM task could have resulted in lower GPE scores. However, I propose that this is an unlikely explanation as one would expect GNE scores to be affected in addition to GPE scores.

In summary, the current study utilising a sample of healthy individuals, found that REM sleep regulatory mechanisms possibly entail a process of up-regulating positive emotion as opposed to down-regulating negative emotion, as is the case in individuals with mood disturbances/disorders. Furthermore, I propose that the process of up-regulating positive emotion failed in the context of the current study. More specifically, I propose that the exposure to disturbing material before bedtime resulted in an increased demand on REM sleep regulatory mechanisms to successfully up-regulate positive emotion by the end of the sleep period.

Summary of Investigation 4. The main hypotheses of this investigation was not confirmed – there were no significant between-group differences with regard to overnight emotional memory consolidation and emotion regulation. These hypotheses were based on the premise that increased dream production (as measured by REM density) during REM sleep would lead to HFR individuals displaying enhanced overnight emotional memory consolidation and more efficient overnight emotion regulation.

However, results from Investigation 3 revealed no significant between-group differences with regard to REM density and therefore, not finding significant between-group differences with regard to overnight emotional memory consolidation and emotion regulation, provides strong support for the premise outlined and substantiated in preceding investigations: it appears that it is NREM sleep, and not REM sleep as originally thought, that is of particular importance in this specific population. Furthermore, significant findings with regard to REM density variables and affective variables in the sample in its entirety, provides support for the premise that the REM density measurement was sensitive enough to detect existing differences. Therefore, failing to detect between-group differences with regard to REM density is most likely indicative of these differences not existing in the current sample, which in turn provides support for the NREM hypothesis of dream recall.

Integrative Discussion

Taken together, findings from the four Investigations give rise to two related overarching themes of this study. The first proposition is based on existing literature providing strong evidence in support of the premise that there are functional neurophysiological trait differences between HFR and LFR individuals (Eichenlaub et al., 2014a; 2014b). Two of these trait differences include increased brain reactivity, as well as increased cerebral blood flow in areas associated with dream production. These trait-like differences are evident during both wakefulness and sleep. Based on this evidence and in the context of the current study, I propose that the functional neurophysiological sequelae associated with HFR individuals include, but is not limited to, differences in personality traits and dimensions, as well as differences in sleep architecture.

More specifically, in the current study HFR individuals scored significantly higher on the 'agreeableness' personality dimension, as well as on the Boundary Questionnaire. Results suggest that, in the context of a healthy population, HFR individuals compared to LFR individuals tend to more regularly engage in day dreaming and have a more fluid sense of self in relation to the outside world. Furthermore, they also display personality characteristics associated with altruism, empathy, friendliness, and behaviours associated with preserving social harmony. Findings from the Eichenlaub et al. (2014b) neuroimaging study provide an empirical context within which findings from the current study can be situated in. The abovementioned authors found increased cerebral blood flow in an area known as the Default mode network (DMN) during both wakefulness and sleep. The DMN is activated in the absence of goal-directed thinking and is associated with mind wandering and day dreaming for example. Furthermore, the authors also found increased activity in regions of the DMN associated with altruism, empathy, and cooperativeness, which is consistent with aspects of the 'agreeableness' personality dimension, and effectively serving as a neurobiological link between findings of the abovementioned study and the current study.

Furthermore, there are other links between studies from the research group above and the current study. The current study replicated the results from the Eichenlaub et al. (2014a) study by demonstrating that HFR individuals compared to LFR individuals, spend significant more time awake after sleep onset, and, in addition, experience significantly more awakenings, especially from stage 2 NREM sleep. By replicating these results, the current study provides strong support for the validity of the assertion by Eichenlaub et al. (2014a) that increased brain reactivity leads to longer periods of intra-sleep wakefulness in HFR individuals. This assertion is also in support of the arousal-retrieval model of dream recall in the sense that longer periods of intra-sleep wakefulness lead to dream traces being encoded into long-term storage enhancing recall at a later stage. In light of this, I outlined a comprehensive theoretical framework detailing possible mechanisms related to increased brain reactivity in HFR individuals and how these possibly underlie increased DRF in this group.

More specifically, based on findings of the Eichenlaub et al. (2014a) ERP study, I proposed that the electrophysiological component (P3a forming part of the P300 wave) detected in response to novel external stimuli in this study is temporally and morphologically comparable to an electrophysiological component typically measured in response to internal error-detection (Davies, Segalowitz, Dywan, & Pailing, 2001). HFR individuals exhibit significantly larger P3a waves compared to LFR individuals leading to increased brain reactivity and a stronger attention orientation response to novel stimuli. Individuals are believed to be consistent in the kind of P300 waves they produce, whether it is in response to external auditory stimuli, or a response to internal error-detection (Davies, Segalowitz, Dywan, & Pailing, 2001). Therefore, if HFR individuals have a stronger attention orientation response to novel external stimuli during both wakefulness and sleep, one can extrapolate that they also have a stronger attention orientation response to detecting an internal error during wakefulness and sleep.

Furthermore, I proposed that, theoretically, the process of internal error-detection can be likened to becoming conscious of the occurrence of a prediction error. I hypothesised that during NREM sleep recent predictive frameworks are reprocessed and integrated into existing predictive frameworks in a way comparable to memory re-processing and integration during NREM sleep. When there is an incongruence between existing and new predictive frameworks, a prediction error has occurred and consciousness is required in order to revise and update predictive frameworks. One form of consciousness through which predictions can be updated is dreaming, which would be triggered in response to a prediction error. However, heightened brain reactivity in HFR individuals and a stronger attention orientation response to the occurrence of a prediction error, lowers the arousal threshold, making these individuals more susceptible to awakenings. This could serve as one possible explanation for increased number of awakenings, especially from stage 2 sleep, as well as longer periods of intra-sleep wakefulness in HFR individuals.

The explanation outlined above illustrates how increased brain reactivity and altered sleep architecture in HFR individuals form part of the functional neurophysiological sequelae, and, possibly contributes to increased DRF in this group. Interestingly, the evidence discussed above also highlights the possibility that it is especially NREM sleep, as opposed to REM sleep, that is of particular importance in this specific population. This assertion is not only supported by the findings of this study, e.g. increased number of awakenings from stage 2 sleep and significantly higher dream recall rates, but also by the non-findings with regard to REM sleep and related processes. Firstly, there were no between-group differences with regard to REM%, REM latency and awakenings from REM sleep. Furthermore, there were also no significant between-group differences in relation to REM density. Finally, there were no significant between-group differences with regard to overnight emotional memory consolidation and emotion regulation that should, theoretically, be affected by increased dream production during REM sleep.

All of the above provide strong support for the proposition that REM sleep is not of paramount importance in relation to DRF in this specific population. Based on this, I proposed that certain NREM sleep mechanisms could explain the increased number of awakenings from stage 2 sleep in particular. More specifically, I proposed that the cyclic alternating pattern (CAP) occurring during NREM sleep might be especially influential with regard to increased DRF. To my knowledge, there is only one, albeit unpublished, study investigating dream recall in relation to CAP during NREM sleep (Wainstein & Solms, 2013). Results from this study showed that, on average, the highest rates of dream recall are associated with the A_2 subtype of the CAP sequence during stage 2 NREM sleep. When compared to the A_1 subtype, the A_2 subtype is characterised by desynchronised faster waves representing a phasic state where the brain is more connected to the external environment.

Based on these findings, the researchers conclude that periods of sleep that are associated with an increased vulnerability of connecting to the environment are regularly related to dreaming during NREM sleep. Importantly, HFR individuals have been shown to exhibit a stronger attention orientation response in the context of external auditory stimuli. Therefore, increased brain reactivity coupled with the neurophysiology of stage 2 NREM sleep and its relative connectedness to the environment, could serve as one explanation for why HFR individuals experience significantly more awakenings from stage 2 NREM sleep specifically.

In conclusion, there are two overarching, but related themes emerging from this research. Firstly, evidence from this study further validates the supposition that there are functional neurophysiological trait differences between HFR and LFR individuals. Based on evidence from this study, I propose that the functional neurophysiological sequelae associated with HFR individuals include, but are not limited to, differences in personality traits and dimensions, as well as differences in sleep architecture. Furthermore, and in relation to the second theme emerging from this study, I propose that it is especially NREM sleep mechanism, and stage 2 NREM sleep in particular, that are of paramount importance in this specific population. Furthermore, in line with Vallet et al. (2017), this assertion is further supported by the lack of evidence linking REM sleep and related processes to increased DRF in HFR individuals.

Limitations and Directions for Future Research

The first potential limitation relates to the relatively small sample size of the current study. There are several factors that influenced the final sample size. Firstly, this study adopted very stringent exclusion criteria, as one of the main objectives that formed part of the sampling strategy relate to creating a clean and homogenous sample. This was achieved by controlling for several potential confounding factors. The potential confounding factors that were controlled for include, (a) evidence of any past or present psychiatric disturbances (e.g. depression, anxiety), (b) poor sleep quality, (c) differences in cognitive functioning, (d) alcohol abuse and drug use, (e) acute and chronic medical conditions, and (f) any medication that could potentially influence any of the parameters of interest of this study. Understandably, adopting such stringent exclusion criteria led to a reduced sample size; however, creating a clean and homogenous sample was of paramount interest in this study.

The second and most influential factor affecting the sample size relate to the DRF inclusion criteria. This study essentially sampled from opposite ends of the bell curve with regard to DRF. The inclusion criteria included falling into one of two categories: either recalling less than two dreams per month, or recalling more than three dreams per week. This resulted in the exclusion of 1051 potential participants. There was the possibility of relaxing the DRF inclusion criteria, but this was decided against as one of the main aims of this study includes replicating results from previous research. More specifically, to my knowledge, there is only one other study investigating the sleep architecture of healthy HFR and LFR individuals in a design where they are compared to each other directly. Therefore, in order to produce valid results in terms of replicating existing literature, it is imperative that there aren't any major deviations from the sampling strategy employed in earlier research.

Importantly, both a priori and post-hoc analyses revealed that the final sample size of the current sample has adequate power. Furthermore, the *N* of the current study is identical to the *N* of the only other two studies (Eichenlaub et al., 2014a; 2014b) that have adopted an empirical design where healthy HFR and LFR individuals are directly compared to one another.

A second potential limitation relates to the REM density measure that was used to assess rates of dream production across the night in the sense that it was not sensitive enough to detect potential existing differences. Although the design of the measure was based on methods employed successfully by Stanford's Centre for Sleep Sciences (Moore, Mignot, Shenov, Widrow, & Woodward, 2013) it was not identical. However, I argue that it is highly unlikely that the incremental differences between the measure used in this study and the Stanford group resulted in the measure failing to detect existing between-group differences. Firstly, significant results were detected with regard to correlations between REM density parameters and affective variables. Therefore, I find it unlikely that a measure is capable of detecting significant results with regard to one hypotheses, but not in another.

Furthermore, I propose that the most likely explanation is that between-group differences do not exist in the current sample for two reasons. Firstly, REM sleep and related processes do not appear to be of particular importance in the current sample. Secondly, the Eichenlaub (2014a) group did not detect any significant between-group differences with regard to REM density when they conducted additional analyses on the original data (Vallet et al., 2017). Therefore, results from this study is consistent with existing literature, providing strong evidence that the most likely reason for not detecting significant between-group differences is that these differences do not exist in the current sample.

With regard to directions for future research, results from this study in relation to significant between-group differences detected on the 'agreeableness' personality dimension, need to be replicated in a design identical to the one employed in the current study. Findings from the current study with regard to personality dimensions in relation to DRF is incongruent with previous research in the sense that no significant differences were detected with regard to 'extroversion', 'openness', and 'neuroticism'. As discussed previously, this could be due to this study rigorously controlling for psychiatric confounds. However, this can only be confirmed once results are replicated.

A second direction for future research relates to studying the microstructure of, and phasic events associated with, NREM sleep. Contrary to what was expected, NREM sleep as opposed to REM sleep appear to be of importance in relation to DRF in healthy individuals. Therefore, the dream and DRF literature would greatly benefit from a systematic study of NREM sleep features in relation to dream recall frequency.

A third direction for future research relates to including different kinds of memory tests. For example, including autobiographical or prospective memory tests and relating this to dream content in HFR and LFR individuals in a longitudinal fashion could serve as one interesting avenue of investigation.

SUMMARY AND CONCLUSION

The main overarching theme of this study relates to illuminating the different facets of the functional neurophysiological sequelae associated with HFR individuals. In order to achieve this, I conducted four investigations studying the following domains in relation to HFR individuals when compared to LFR individuals: (1) prominence of certain personality traits, (2) differences in sleep architecture, (3) increased rates of dream production during REM sleep, and (4) enhanced overnight emotional memory consolidation and emotion regulation.

Investigation 1 examined whether HFR individuals score significantly higher on certain personality dimensions, as well as on the Boundary Questionnaire. Results showed significantly higher scores on the 'agreeableness' personality dimension, as well as significantly higher scores on the Boundary Questionnaire, indicating the presence of 'thinner' boundaries. The latter finding is in line with previous research; however, the former is not. To my knowledge, this is the first study that have found significant differences with regard to the 'agreeableness' personality dimension, while detecting no significant between-group differences in relation to any of the other personality dimensions. This discrepancy literature could be accounted for by the fact that psychiatric confounds were rigorously controlled for, while the current study also included a control group consisting of LFR individuals, a feature often absent in previous studies.

Furthermore, there is a neurobiological explanation for why higher levels of agreeableness were detected in HFR individuals in the current study. Eichenlaub et al. (2014b) found significantly higher rates of rCBF across vigilance states in an area collectively known as the default mode network DMN. Areas that form part of the DMN include, for example, the mPFC and ACC, while both these regions are implicated in behaviours associated with altruism, empathy, and social awareness (Gusnard et al., 2001), and, in addition, form part of the 'agreeableness' personality dimension.

Investigation 2 focused on characterising the sleep architecture of HFR individuals with two aims in mind. The first aim relates to replicating the results of the Eichenlaub et al. (2014a) study, while the second aim entailed building on these findings by (a) recruiting both males and females, and (b) including additional sleep parameters in the analyses (e.g. awakenings from different sleep stages). Results showed that the sleep architecture of HFR individuals is characterised by significantly longer periods of intra-sleep wakefulness, as well as significantly more awakenings across the night, especially from stage 2 sleep. These results are in line with the Eichenlaub et al (2014a) study and provides support for the arousal-retrieval model of dream recall. Furthermore, it underscores the significance of NREM sleep in relation to DRF in this specific population, not only because of the positive findings in this regard, but also because of a lack of findings in relation to REM sleep and related parameters. No significant between-group differences were found with regard to, REM sleep latency, REM sleep % or awakenings from REM sleep. This is in line with recently published results supporting the notion that increased DRF in this population group cannot be accounted for by REM sleep parameters (Vallet et al., 2017).

Investigation 3 entailed exploring the possibility that HFR individuals not only remember more dreams, but possibly also produce more dreams. The method that was developed to study this proposition entailed measuring the frequency of eye movements during REM sleep. Awakenings from REM sleep yield the highest rates of dream reports (Nielsen, 2000), and therefore utilising measurements of REM density served as a reasonable rationale for measuring rates of dream production during REM sleep. Results revealed no significant between-group differences on any of the REM density parameters. These results further support the proposition that there is a strong possibility that it is NREM sleep, as opposed to REM sleep, that is of importance in relation to DRF in this specific population.

The final investigation, *Investigation 4,* is related to *Investigation 3* in that it is based on the premise that HFR individuals have increased rates of dream production during REM sleep. If this is indeed the case, I surmised that increased REM dreaming will affect other neurobiologically-related processes, namely overnight emotional memory consolidation and emotion regulation. However, results revealed no significant between-group differences with regard to emotional memory performance nor with overnight emotion regulation. These results are congruent with findings from *Investigation 3*, i.e. there were no significant between-group differences with regard to the REM density parameters, which further strengthens the argument that REM sleep and related processes are not of particular importance in this population.

In conclusion, there are three major contributions of this study. Firstly, it replicated findings from the only other study investigating sleep architecture in healthy HFR individuals compared to LFR individuals. Secondly, results indicate that NREM sleep, as opposed to REM sleep, appear to be of particular importance in this population. Thirdly, findings from the current study along with existing literature provide strong evidence for the premise that certain personality characteristics, differences in sleep architecture, as well as increased DRF are an expression of a functional neurophysiological organisation in the brains of HFR individuals. Finally, and importantly, the current study along with the extant literature, have lit the torch needed for future studies to illuminate possibly several other, yet undiscovered, sequelae associated with the functional neurophysiological arrangement believed to be innate to HFR individuals.

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APPENDICES

Appendix A

Dear Students,

INFORMATION: UCT SLEEP STUDY
All UCT students who want to participate in this PAID study, please read:

I am running a PhD study at the Department of Psychology at UCT. The study looks at memory and emotions in relation to sleep and dreaming. This study has been approved by the Humanities Faculty Research Ethics Committee.

The study will consist of three phases: the first phase entails filling out the online questionnaire, if you are deemed eligible, and willing to continue with the study, you will advance to the second phase. At the second phase you will briefly meet with the researcher to fill out additional questionnaires. Following this, and if you are still eligible and willing, you will be invited to participate in the sleep study.

The sleep study will take place over two non-consecutive nights scheduled at your convenience. Before you go to bed you will complete some questionnaires, as well as three memory tasks. The memory tasks will be repeated the following morning. You will not be woken up during the night.

Who can participate?
I am looking for males and females between the ages of 20 and 40 years, who are not on any chronic medication like anti-depressants, anti-psychotics, sleeping pills or any other psychotropic medication.

What are the benefits?
1) You will learn more about your sleeping patterns.

2) You will also receive **R300 payment** upon completion of both sleep testing nights.

Please follow the link below to fill out the consent form and advance to the first phase of the study:

https://www.surveymonkey.com/r/VXBPVGH

Please note that all personal information will be kept strictly confidential and it will not be used for purposes outside of this research study.

Please email sleep.dreamstudy@gmail.com if you have any questions.

Regards,
Mariza (Head Researcher)

Appendix B

Demographic and Medical Information

2. Full name

3. Student number

4. Course code (If applicable)

5. Please provide contact details:
(We need to be able to contact you in order to organise sessions)

6. Highest level of education

7. Sex

Male

Female

Other

8. Age (years)

9. What is your country of origin?

10. What is your primary language?

11. Are you currently on ANY medication? Please list ALL medications.

12. Have you ever had a head injury?

13. Did you lose consciousness?

14. Please list all past and current medical conditions

15. Have you ever been diagnosed with a psychiatric condition?

16. If yes, please list the condition(s)

17. Have you ever been diagnosed with a sleep disorder?
18. Which disorder, please explain

19. If there are any other details about your medical history, that you have not mentioned yet, please add them here:

20. Do you use any substances or drugs, for instance marijuana, cocaine, or MDMA?

21. If yes, please list the substance(s) and how frequently you use them per month

Dream Details

22. If a dream is defined as a long and bizarre story, an image that vanishes rapidly, or a feeling of having dreamt, on average, how many mornings per week over the last couple of months did you wake up with a dream in mind?

23. In general, how interested are you in your dreams, e.g. thinking about them, trying to understand them, discuss them with other people, or write about them?

24. What is your definition of a dream?

25. If you have to give your best guess, how many times do you wake up during the night?

Alcohol Use Questionnaire

The following questions relate to your alcohol use over the last 6 months. If you do not consume alcohol you still need to fill out the questionnaire

26. Do you feel you are a normal drinker? (“normal” – drink as much or less than most other people)?

27. Have you ever awakened the morning after some drinking the night before and found that you could not remember a part of the evening?

28. Does any near relative or close friend ever worry or complain about your drinking?

29. Can you stop drinking without difficulty after one or two drinks?

30. Do you ever feel guilty about your drinking?

31. Have you ever attended a meeting of Alcoholics Anonymous (AA)?

32. Have you ever gotten into physical fights when drinking?

33. Has drinking ever created problems between you and a near relative or close friend?

34. Has any family member or close friend gone to anyone for help about your drinking?

35. Have you ever lost friends because of your drinking?

36. Have you ever gotten into trouble at work because of drinking?

37. Have you ever lost a job because of drinking?

38. Have you ever neglected your obligations, your family, or your work for two or more days in a row because you were drinking?

39. Do you drink before noon fairly often?

40. Have you ever been told you have liver trouble such as cirrhosis?

41. After heavy drinking have you ever had delirium tremens (D.T.'s), severe shaking, visual or auditory (hearing) hallucinations?

42. Have you ever gone to anyone for help about your drinking?

43. Have you ever been hospitalized because of drinking?

44. Has your drinking ever resulted in your being hospitalized in a psychiatric ward?

45. Have you ever gone to any doctor, social worker, clergyman or mental health clinic for help with any emotional problem in which drinking was part of the problem?

46. Have you been arrested more than once for driving under the influence of alcohol?

47. Have you ever been arrested, even for a few hours, because of other behavior while drinking?

PSQI

INSTRUCTIONS
The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

48. During the past month, what time have you usually gone to bed at night?

49. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

50. During the past month, what time have you usually gotten up in the morning?

51. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

For each of the remaining questions, check the one best response. Please answer ALL questions.

During the Past month, how often have you had trouble sleeping because you . . .

52. Cannot get to sleep within 30 minutes.
Not during the past month
Less than once a week

Once or twice a week
Three or more times a week

53. Wake up in the middle of the night or early morning
Not during the past month
Less than once a week
Once or twice a week
Three or more times a week

54. Have to get up to use the bathroom
Not during the past month
Less than once a week
Once or twice a week
Three or more times a week

55. Cannot breathe comfortably
Not during the past month
Less than once a week
Once or twice a week
Three or more times a week

56. Cough or snore loudly
Not during the past month
Less than once a week
Once or twice a week
Three or more times a week

57. Feel too cold
Not during the past month
Less than once a week
Once or twice a week
Three or more times a week

58. Feel too hot
Not during the past month
Less than once a week
Once or twice a week
Three or more times a week

59. Had bad dreams
Not during the past month
Less than once a week
Once or twice a week
Three or more times a week

60. Have pain
Not during the past month
Less than once a week
Once or twice a week
Three or more times a week

61. Other reason(s), please describe

62. How often during the past month have you had trouble sleeping because of the possible reason(s) asked about in the preceding question?
Not during the past month
Less than once a week
Once or twice a week
Three or more times a week

63. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?
Not during the past month
Less than once a week
Once or twice a week
Three or more times a week

64. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?
Not during the past month
Less than once a week
Once or twice a week
Three or more times a week

65. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?
Not during the past month
Less than once a week
Once or twice a week
three or more times a week

66. During the past month, how would you rate your sleep quality overall?
Very good
Fairly good
Fairly bad
Very bad

67. Do you have a bed partner or roommate?
No bed partner or roommate
Partner/room mate in other room
Partner in same room, but not same bed
Partner in same bed

BDI-II

Instructions: This questionnaire consists of 21 groups of statements. Please read each group of statements carefully, then pick out the one statement in each group that best describes the way you have been feeling during the past two weeks, including today. Select the statement you have picked. If several statements in the group seem to apply equally well, select the highest number for that group. Be sure that you do not choose more than one statement for any group, including Item 16 (Changes in Sleeping Pattern) or Item 18 (Changes in Appetite).

68. Sadness.
0 I do not feel sad.
1 I feel sad much of the time.
2 I am sad all of the time.
3 I am so sad or unhappy that I can't stand it.

69. Pessimism.
0 I am not discouraged about my future.
1 I feel more discouraged about my future than I used to be.
2 I do not expect things to work out for me.
3 I feel my future is hopeless and will only get worse.

70. Past Failure.
0 I do not feel like a failure.
1 I have failed more than I should have.
2 As I look back, I see a lot of failures.
3 I feel I am a total failure as a person.

71. Loss of Pleasure.
0 I get as much pleasure as I ever did from the things I enjoy.
1 I don't enjoy things as much as I used to.
2 I get very little pleasure from the things I used to enjoy.
3 I can't get any pleasure from the things I used to enjoy.

72. Guilty Feelings.
0 I don't feel particularly guilty.
1 I feel guilty over many things I have done or should have done.
2 I feel quite guilty most of the time.
3 I feel guilty all of the time.

73. Punishment feelings.
0 I don't feel I am being punished.
1 I feel I may be punished.
2 I expect to be punished.
3 I feel I am being punished.

74. Self-Dislike.
0 I feel the same about myself as ever.
1 I have lost confidence in myself.
2 I am disappointed in myself.
3 I dislike myself.

75. Self-Criticalness.
0 I don't criticize or blame myself more than usual.
1 I am more critical of myself than I used to be.
2 I criticize myself for all of my faults.
3 I blame myself for everything bad that happens.

76. Suicidal Thoughts or Wishes.
0 I don't have any thoughts of killing myself.
1 I have thoughts of killing myself, but would not carry them out.
2 I would like to kill myself.
3 I would kill myself if I had the chance.

77. Crying.
0 I don't cry any more than I used to.
1 I cry more than I used to.
2 I cry over every little thing.
78. Agitation
0 I am no more restless or wound up than usual.
1 I feel more restless or wound up than usual.
2 I am so restless or agitated that it's hard to stay still.
3 I am so restless or agitated that I have to keep moving or doing something.

79. Loss of Interest.
0 I have not lost interest in other people or activities.
1 I am less interested in other people or things than before.
2 I have lost most of my interest in other people or things.
3 It's hard to get interested in anything.

80. Indecisiveness.
0 I make decisions about as well as ever.
1 I find it more difficult to make decisions than usual.
2 I have much greater difficulty in making decisions than I used to.
3 I have trouble making any decisions.

81. Worthlessness.
0 I do not feel I am worthless.
1 I don't consider myself as worthwhile and useful as I used to.
2 I feel more worthless as compared to other people.
3 I feel utterly worthless.

82. Loss of Energy.
0 I have as much energy as ever.
1 I have less energy than I used to have.
2 I don't have enough energy to do very much.
3 I don't have enough energy to do anything.

83. Changes in Sleeping Pattern

0 I have not experienced any change in my sleeping pattern.

1a I sleep somewhat more than usual.

1b I sleep somewhat less than usual.

2a I sleep a lot more than usual.

2b I sleep a lot less than usual.

3a I sleep most of the day.

3b I wake up 1-2 hours early and can't get back to sleep.

84. Irritability
0 I am no more irritable than usual.
1 I am more irritable than usual.
2 I am much more irritable than usual.
3 I am irritable all the time.

85. Changes in Appetite

0 I have not experienced any change in my appetite.

1a My appetite is somewhat less than usual.

1b My appetite is somewhat greater than usual.

2a My appetite is much less than before.

2b My appetite is much greater than usual.

3a I have no appetite at all.

3b I crave food all the time.

86. Concentration Difficulty.
0 I can concentrate as well as ever.
1 I can't concentrate as well as usual.
2 It's hard to keep my mind on anything for very long.
3 I find I can't concentrate on anything.

87. Tiredness or Fatigue.
0 I am no more tired or fatigued than usual.
1 I get more tired or fatigued more easily than usual.
2 I am too tired or fatigued to do a lot of the things I used to do.
3 I am too tired or fatigued to do most of the things I used to do.

88. Loss of Interest in Sex.
0 I have not noticed any recent change in my interest in sex.
1 I am less interested in sex than I used to be.
2 I am much less interested in sex now.
3 I have lost interest in sex completely.

Appendix C

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.

If your responses indicate that you are eligible for the next phase, 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

PARTICIPATION IN UNIVERSITY OF CAPE TOWN RESEARCH STUDY
INFORMATION SHEET

Name of Participant: ____________________________
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 that you will be coming to the sleep lab. You will also be asked to not drink any caffeine containing drinks (e.g. coffee) or alcohol on the days that you come to the sleep lab. Furthermore, we would like for you to avoid sugary foods and excessive exercise on the day. For the first night we will ask you to come to the sleep lab approximately an hour before your usual bedtime, and approximately 2 hours before your usual bedtime on the second night. 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 researcher will then hook you up to a polysomnograph machine. This is a machine that records various aspects of sleep. It consists of a box (which will be placed on your bedside table) that has leads attached to it. Some of these leads are attached to an electrode that will be attached to you with a medically approved paste. The leads will be placed on your scalp, and on certain places on your face in order to measure brain and muscle activity, as well as eye movements. The electrodes will be removed the following morning by dissolving the paste in water for easy removal.

The remaining leads will be attached to medically approved sticker electrodes. The sticker electrodes will be placed on certain places on your face and also on your chest area. These electrodes will measure muscle activity, eye movements and your heart rate.

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 given access to an intercom 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.

Memory Testing

On the second night that you come to the sleep laboratory, we will ask you to complete three memory tasks. Two of the tasks are done verbally, and the third is a computer-based task called an emotional memory task. In this task you will be shown a series of positive, neutral and negative images. Please note that some people might find some of the negative images offensive. If you think this might be a problem for you, please inform the researcher, you are under no obligation to participate in the study. 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. However, through the years in very rare instances people have had a reversible skin reaction to some of the equipment. Please let us know in advance if you have sensitive skin or any medical condition that you think could be affected by the study procedure. 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 upon completion of the second night.

Appendix F

PARTICIPATION IN UNIVERSITY OF CAPE TOWN RESEARCH STUDY CONSENT FORM

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 also confirm that I have supplied the researcher with all relevant medical information, or any information that would be important for the purposes of 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 that will be paid to me upon completion of the second night.

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: ____

Appendix G

P ANAS-X

This scale consists of a number of words and phrases that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this way *right now*. Use the following scale to record your answers:

1 very slightly or not at all

2 a little

3 moderately

4 quite a bit

5 extremely

1. ______ cheerful

2. ______ disgusted

3. ______ attentive

4. ______ bashful

5. ______ sluggish

6. ______ daring

7. ______ surprised

8. ______ strong

9. ______ scornful

10. ______ relaxed

11. ______ irritable

12. ______ delighted

13. ______ inspired

14. ______ fearless

15. ______ disgusted with self

16. ______ sad

17. ______ calm

18. ______ afraid

19. ______ tired

20. ______ amazed

21. ______ shaky

22. ______ happy

23. ______ timid

24. ______ alone

25. ______ alert

26. ______ upset

27. ______ angry

28. ______ bold

29. ______ blue

30. ______ shy

31. ______ active

32. ______ guilty

33. ______ joyful

34. ______ nervous

35. ______ lonely

36. ______ sleepy

37. ______ excited

38. ______ hostile

39. ______ proud

40. ______ jittery

41. ______ lively

42. ______ ashamed

43. ______ at ease

44. ______ scared

45. ______ drowsy

46. ______ angry at self

47. ______ enthusiastic

48. ______ downhearted

49. ______ sheepish

50. ______ distressed

51. ______ blameworthy

52. ______ determined

53. ______ frightened

54. ______ astonished

55. ______ interested

56. ______ loathing

57. ______ confident

58. ______ energetic

59. ______ concentrating

60. ______ dissatisfied with self

_____

Appendix H

BQ-Sh

*Please rate each of the statements from **0 to 4** (0 indicates "not at all true of me"; 4 indicates "very true of me"). Try to respond to all of the statements as quickly as you can.*

1. There is a place for everything and everything should be in its place ____
2. I get to appointments right on time ____
3. In my daydreams, people kind of merge into one another or one person turns into another ____
4. I think I would be a good psychotherapist ____
5. A good parent has to be a bit of a child too ____
6. I am easily hurt ____
7. I have daymares ____
8. I think children need strict discipline ____
9. The movies and TV shows I like the best are the ones where there are good guys and bad guys and you always know who they are ____
10. I am a very open person ____
11. I keep my desk and worktable neat and well organised ____
12. There are no sharp dividing lines between normal people, people with problems, and people who are considered psychotic or crazy ____
13. I think a good teacher must remain in part a child ____
14. I am a very sensitive person ____
15. I wake from one dream into another ____
16. My body sometimes seems to change its size and shape ____
17. In an organisation, everyone should have a definite place and a specific role ____
18. A man is a man and a woman is a woman; it is very important to maintain that distinction ____
19. Things around me seem to change their size and shape ____
20. I trust people easily ____
21. I am good at keeping accounts and keeping track of my money ____
22. I have a clear memory of my past. I could tell you pretty well what happened year by year ____
23. I think an artist must in part remain a child ____
24. In my dreams, people sometimes merge into each other or become other people ____
25. I like stories that have a definite beginning, middle, and end ____
26. Being dressed neatly and cleanly is very important ____
27. I have dreams, daydreams, nightmares in which my body or someone else's body is being stabbed, injured, or torn apart ____
28. I cannot imagine living with or marrying a person of another race ____

29. I have a clear and distinct sense of time ____

Please rate each of the statements from ***0 to 4*** *(0 indicates "not at all true of me"; 4 indicates "very true of me"). Try to respond to all of the statements as quickly as you can.*

30. Every time something frightening happens to me, I have nightmares or fantasies or flashbacks involving the frightening event __
31. Good solid frames are very important for a picture or a painting ____
32. I am always at least a bit on my guard ____
33. I have often had the experience of different senses coming together. For example, I have felt that I could smell a color, or see a sound, or hear an odor ____
34. I like clear, precise borders ____
35. Sometimes I meet someone and trust him or her so completely that I can share just about everything about myself at the first meeting ____
36. I know exactly what parts of town are safe and what parts are unsafe ____
37. A good teacher needs to help a child remain special ____
38. I have had the experience of someone calling me or speaking my name and not being sure whether it was really happening or I was imagining it ____
39. I like houses where rooms have definite walls and each room has a definite function ____
40. I expect other people to keep a certain distance ____
41. Children and adults have a lot in common. They should give themselves a chance to be together without any strict roles ____
42. I have had the experience of not knowing whether I was imagining something or it was actually happening ____
43. East is East and West is West, and never the twain shall meet ____
44. I am careful about what I say to people until I get to know them really well ____
45. I am a down-to-earth, no-nonsense kind of person ____

Appendix I

TIPI

Here are a number of personality traits that may or may not apply to you. Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.

1 = Disagree strongly

2 = Disagree moderately

3 = Disagree a little

4 = Neither agree nor disagree

5 = Agree a little

6 = Agree moderately

7 = Agree strongly

I see myself as:

1. _____ Extraverted, enthusiastic.
2. _____ Critical, quarrelsome.
3. _____ Dependable, self-disciplined.
4. _____ Anxious, easily upset.
5. _____ Open to new experiences, complex.
6. _____ Reserved, quiet.
7. _____ Sympathetic, warm.
8. _____ Disorganized, careless.
9. _____ Calm, emotionally stable.
10. _____ Conventional, uncreative.