University of Cape Town

Faculty of Humanities

ASSIGNMENT COVER PAGE

Research Project

Full name:	Layla Liebetrau
Student number:	LBTLAY001
Course code:	PSY4000W
Course title:	Psychology Honours
Due date:	06 November 2015
Supervisor:	Gosia Lipinska
Co-supervisor:	Siobhan McCreesh
Word count:	
Abstract:	308
Main body:	7821

Plagiarism Declaration

1. I know that plagiarism is wrong. Plagiarism is to use another's work and to pretend that it is one's own.
2. I have used the APA convention for citation and referencing. Each significant contribution to, and quotation in, this essay from the work, or works, of other people has been acknowledged through citation and reference.
3. This essay is my own work.
4. I have not allowed, and will not allow, anyone to copy my work with the intention of passing it off as his or her own work.

Signature:

Layla Liebetrau

Date: 06 November 2015

Promoting Positive Affect using Smartphone Application *Sleep Cycle Alarm Clock*

Layla N. Liebetrau
University of Cape Town

Abstract

Research has illustrated the negative effects of poor sleep quality on emotional functioning. Modern smartphone technology and mobile applications are recognised for holding the potential to promote healthy sleep, but are said to lack scientific validation. In this context I investigated whether the smartphone application, *Sleep Cycle Alarm Clock*, promotes positive affect. ***Objectives:*** I conducted a pilot study to test the actigraphic accuracy of *Sleep Cycle* in terms of its ability to record sleep architecture. I investigated whether participants using *Sleep Cycle* reported an increase in total sleep time over the duration of the study and in comparison with a control group. Additionally, I investigated whether participants using *Sleep Cycle* experienced an increase in positive affect and decrease in negative affect over time and in relation to controls. ***Method:*** I conducted an open-label trial with two phases. The student sample (n = 16) was allocated to an experimental group (using *Sleep Cycle*) or control group (using a standard smartphone alarm). All participants completed sleep diaries and a positive and negative affect scale on a daily basis for 8 days. All participants had their sleep recorded using an electroencephalogram (EEG) during a night spent in the University of Cape Town's (UCT) sleep laboratory. ***Results:*** Results showed that there was no significant agreement between *Sleep Cycle* and EEG recordings of sleep architecture. There were no significant main effects for total sleep time over the 8-day study period or significant between-group differences. Similarly, there were no significant main effects for positive or negative affect over the study period or significant between-group differences. ***Conclusions:*** *Sleep Cycle* is not a reliable mHealth intervention for recording sleep or useful in improving sleep quality and positive affect. The findings are in agreement with current knowledge on the relationship between healthy sleep and emotion.

Keywords: actigraphy, app, open-label trial, positive affect, mHealth, sleep quality, smartphone.

Promoting Positive Affect using Smartphone Application *Sleep Cycle Alarm Clock*

Sleep plays an integral role in our lives. During sleep our bodies disengage from the environment, allowing complex physiological processes to take place that restore and maintain our mental and physical well-being (Blunden & Galland, 2014; Carskadon & Dement, 2011). Although individual and contextual factors result in a variation of sleeping patterns (Buysse, 2014), normal sleep in young and middle-aged adults consists of sleep at regular times for approximately 8 hours. Some of the negative consequences of having a lack of normal sleep or sleep disturbance are reduced cognitive ability (Chee & Chuah, 2008) and control over our emotions is compromised (Deliens, Gilson, & Peigneux, 2014). Severe sleep disorders can lead to health complications, such as cardiovascular problems (Solarz, Mullington & Meier-Ewert, 2012), obesity (Miller & Cappuccio, 2007) or diabetes (Knutson, Spiegel, Penev, & Van Cauter, 2007).

Sleep Patterns in Current Western Society

However insufficient sleep is a significant problem in 21st century Western society and is receiving increased attention due to the financial and economic implications of rising healthcare costs and reduced workforce productivity (Behar, Roebuck, Domingos, Gederi, & Clifford, 2013). Our sleep culture is skewed against prioritising sleep and healthy sleep behaviour. For example, advertisers build brands on the basis of their product's ability to keep you awake. Shift work is endorsed as a viable way to structure work schedules (Åkerstedt, 2003) and corporate cultures perceive sleep as a sign of weakness or lack of ambition (Fryer, 2006). The high number of people diagnosed with clinical sleep disorders and reporting having trouble sleeping indicates that sleep in our society does not follow healthy patterns. Sleep medicine is at an early stage of development in South Africa. There is limited research showing the prevalence of sleep disorders or describing sleep habits in the country. A small survey reported 42% of participants (n = 794) did not obtain enough sleep, with 26% admitting to falling asleep whilst driving (Bentley, Lacovides, & Baker, 2011).

The Consequences of Poor Sleep Quality

From an electrophysiological point of view normal sleep is characterised by 90-minute cycles of non-rapid eye movement (NREM) and rapid eye movement (REM) sleep (Carskadon & Dement, 2011). NREM sleep is characterised by the progression from stage N1 through to deeper stages N2 and N3 (Carskadon & Dement, 2011). REM sleep, by contrast, is not understood in terms of depth of sleep, but is defined by brain activity, muscle atonia and bursts of rapid eye movement (Carskadon & Dement, 2011).

However, in western society this typical progression of sleep is often compromised. Sleep difficulties differ in their level of severity. Moderate sleep disturbances caused by a variety of factors such as work stress or irregular sleeping patterns can lead to chronic sleep loss (Colten & Altevogt, 2006). Whereas insomnia or sleep-related breathing disorders, for example, constitute severe sleep difficulties and are classified in the third edition of the International Classification of Sleep Disorders (Judd & Sateia, 2014).

The role healthy sleep plays in the processing and regulation of emotions is a growing topic of interest (Deliens et al., 2014; Kahn, Sheppes, & Sadeh, 2013). The relationship between sleep and emotion regulation is relevant because of the widespread influence that positive emotions have on our lives (see, e.g., Lyubomirsky, King, & Diener, 2005). Behaviour that elicits positive mood is therefore highly sought after and has brought our attention to the effects of poor sleep quality. Sleep deprivation has been associated with feelings of anxiety, irritability, depression and depressive thinking across age groups (Baum et al., 2014; Kahn-Greene, Killgore, Kamimori, Balkin, & Killgore, 2007; Rose, Manser, & Ware, 2008; Spoormaker & Van Den Bout, 2005). Additionally, sleep deprivation results in a bias for negative emotion and enhanced reactivity to towards negative stimuli (Gujar, Yoo, Hu, & Walker, 2011).

REM sleep is also associated with emotional regulation and having a balance of positive and negative emotions on waking (Gujar, McDonald, Nishida, & Walker, 2011). REM sleep is of particular interest because REM deprivation has been found to negatively impact mood more than NREM sleep deprivation (Cartwright, Luten, Young, Mercer, & Bears, 1998; Rosales-Lagarde et al., 2012). Moreover, individuals who are woken during REM are expected to feel some “grogginess” and disorientation (Tassi & Muzet, 2000). Therefore in relation to NREM sleep, REM is positioned as the intermediate stage of sleep in terms of optimal time to wake (Ferrara & De Gennaro, 2000; Tassi & Muzet, 2000). The current Western culture of sleep and the sleep problems described, negatively effects physical, cognitive and emotional health, which makes interventions that promote healthy sleep an important concern (Pace-Schott, 2014).

Interventions Aimed at Improving Sleep Quality

Despite health risks associated with sleeping problems, the treatment and intervention landscape is expensive and limited by available specialists and facilities (Behar et al., 2013). Objective measures of recording sleep, such as polysomnography or actigraphy require specialist equipment and professional analysis. Additionally, some treatment plans require ongoing involvement which is costly and requires commitment to behaviour change (Behar et

al., 2013; Lawson et al., 2013). As a result, moderate sleeping problems are often overlooked and untreated.

In recent years, the role an individual can play in identifying and managing moderate sleeping problems by improving sleep behaviour through self-knowledge and self-reflection has come to the fore (Lawson et al., 2013). This approach is supported by the community of sleep organisations and practitioners and is illustrated by the proliferation of tips and guidelines published in popular media by recognised institutions such as the American Academy of Sleep Medicine (AASM), the National Health Service or the World Association of Sleep Medicine.

Improving Sleep Quality Using mHealth

One avenue of self-treatment for moderate sleeping problems is through the use of technology. Improvements in technology have made digital health initiatives, broadly known as mHealth, a new area for investigation, product development and appraisal (Lupton, 2014). Examples include actigraph wrist watches, such as *Fitbit* or *SleepTracker*, or mobile applications (apps) for smartphones (Choe et al., 2010; Lawson et al., 2013). These devices and apps add to individual knowledge about sleep by capturing personally relevant information and enabling us to monitor whether our behaviour promotes healthy sleep (Behar et al., 2013; Lawson et al., 2013).

Sleep Applications

There has been a profound increase in the number of sleep apps that claim to help people sleep. The variety includes simple digital diaries that allow you to record your sleep habits e.g., *Sleep Diary*, or apps that generate calming sounds e.g., *Relax Melodies* or meditative stimuli before you sleep e.g., *Sleep Soundly Hypnosis*. Some of these apps are more complex and make use of advanced smartphone technology that can sense, video and track movement and sound e.g., *Sleep Cycle Alarm Clock* and *SleepBot*. Traditionally actigraphy and audio technology are used for screening sleep disorders (Behar et al., 2013). However, several authors have identified the potential smartphones have to monitor sleep and noted the advantages as being a less expensive source of information and guidance, less resource intensive, self-managed and an easy extension of people's lifestyles in familiar environments (Lawson et al., 2013; Luxton, McCann, Bush, Mishkind, & Reger, 2011; Natale et al., 2012). However, few studies have tested whether smartphone sleep algorithms are reliably monitoring sleep in comparison to standard sleep measurements generated using actigraph devices or polysomnography. One such study, comparing actigraph sleep recordings of an *Actiwatch* against an iPhone, concluded that smartphone accelerometers

could reliably assess sleep but future studies should compare polysomnograph against smartphone data and suggested that sleep-specific algorithms should be developed for smartphones (Natale et al., 2012).

Sleep Cycle Alarm Clock. *Sleep Cycle* is a popular sleep app available for iPhone and Android operating systems. Its aim is to promote healthy sleep by capturing your sleep patterns and providing personally relevant feedback on your sleep behaviour. It does this by generating sleep graphs, recording your time in bed and calculating a sleep quality percentage. As an option, you are able to rate and monitor your mood on waking. Additionally, the app aims to improve the transition from a state of sleep to wakefulness by regulating your alarm clock to activate during your lightest stage of sleep, within a predefined timeframe. The lightest stage of sleep refers to a stage of NREM – stage N1 or N2 – rather than REM sleep. The rationale for waking in the lightest stage of sleep relates to being "natural, feeling rested and relaxed" which establishes positive emotion from the start of your day (Northcube AB, 2015).

The Lack of Scientific Testing

Critics of mHealth argue that knowledge and behavioural prompts disseminated via mobile applications are not verified or regulated by medical authorities (Lupton, 2014). A lack of regulation results in sleep apps that have not been scientifically tested against established sleep recording methods (Behar et al., 2013; Lawson et al., 2013). In addition to this, the accuracy of health information given in sleep apps goes unchecked and is open to the interpretation and implementation of the user (Lupton, 2014). Despite the potential *Sleep Cycle* has to promote healthy sleep and the subsequent benefits on well-being, there is a need to scientifically evaluate the app as it is currently available and being used by the public.

Aims and Hypotheses

My study aims to explore the relationship between healthy sleep and improved emotional functioning. To begin with, I will investigate the efficacy of *Sleep Cycle* by testing the assumption that the app accurately records sleep architecture and therefore won't wake you during REM sleep. Thereafter I will assess whether using the app enhances sleep quality and whether using the app is associated positive mood rather than negative mood. For the scope of my study, sleep quality is operationalised in terms of total sleep time and NREM, as opposed to REM, awakenings. The practical implication of my research is to understand if *Sleep Cycle* can reliably be used to promote positive affect by improving sleep quality. Broadly, the study will add to the theoretical debate around whether mHealth initiatives are

effective interventions for promoting normal sleep and reducing problems associated with disrupted sleep.

Manipulation checks. Manipulation checks differ from my hypotheses in that they are designed to test the technical functionality of *Sleep Cycle*. I will conduct two app manipulation checks:

1. *Sleep Cycle* and electroencephalogram (EEG) recordings of a participant's sleep architecture do not differ.
2. The *Sleep Cycle* alarm clock will not activate during a REM cycle.

Hypotheses. I will investigate three hypotheses in the experiment as follows:

1. Participants in the *Sleep Cycle* group will have increased total sleep time (a) over time and (b) in comparison with controls.
2. Participants in the *Sleep Cycle* group will have increased positive affect (a) over time and (b) in comparison with controls.
3. Participants in the *Sleep Cycle* group will have decreased negative affect (a) over time and (b) in comparison with controls.

Method

Research Design

To achieve the aims of the study, a pilot open-label trial was conducted in two phases. The design facilitated preliminary investigation on the effect of *Sleep Cycle* by comparing similar treatments in two groups. Participants in the experimental group used *Sleep Cycle* as their alarm clock, whereas participants in the control group used their standard smartphone alarms. All participants took part in both phases. Phase 1 was a 7-day home-week where participants self-recorded measures of sleep-wake cycles and affect. For Phase 2, participants slept one night in UCT's sleep laboratory (lab) during which objective measures of sleep were recorded using EEG equipment. Self-reported measures of sleep and affect were also collected on the 8th day.

Participants

University students were recruited via UCT's student intranet and email. Out of 73 candidates screened, 16 male and female participants aged 19-29 years were allocated to an experimental or control group (9 females, 8 males; $n = 8$ per group). The majority of participants were undergraduates. There were three participants completing a postgraduate level of education (Masters degree or higher). An analysis of power revealed the sample size was too small to demonstrate effects. Therefore the study should be considered a pilot to investigate trends in the data to inform future research. In order to evidence improvement in sleep and mood, a student sample was recruited. Research has shown that students tend to have sleeping difficulties due to a variety of higher education stressors and experience mild levels of depression (Baum et al., 2014; Roberts & Duong, 2014; Robotham & Julian, 2006; Sarchiapone et al., 2014).

Inclusion criteria. The following list of inclusion criteria was applied:

1. Potential participants with mild or moderate depression were included in the study.
2. Potential participants with mild or moderate sleeping difficulties were included in the study.
3. Participants were required to have a personal smartphone. Apple iPhone 5 or higher was required. Android operating devices required Android 4.0 or later.

Exclusion criteria. The following list of exclusion criteria is exhaustive and was applied rigorously:

1. Potential participants diagnosed with any DSM-5 (Diagnostic and Statistical Manual of Mental Disorders, 5th ed., APA, 2013) disorder, other than Major Depression

Disorder (MDD), were excluded. The severity of disrupted sleep patterns and mood irregularity associated with clinical diagnoses are potential confounds.

2. Potential participants, who at the time of screening were taking sedative medication to regulate their sleeping patterns, or were taking prescribed psychoactive medication, were excluded. Sleeping pills alter natural sleep cycles and psychoactive medication has effects on brain structure and function, which may have confounded results (see, e.g., Vermetten, Vythilingam, Southwick, Charney, & Bremner, 2003).
3. Potential participants with a previous history of alcohol or other substance abuse were excluded, because of the association with disordered sleep and mood irregularity which may have acted as confounding variables (Johnson & Breslau, 2001).
4. Potential participants, who at the time of the screening, were smokers were excluded as smoking leads to fragmented sleep (Stepanski & Wyatt, 2003).
5. Potential participants who carried neurological conditions or disability that restricts mobility (e.g., epilepsy or paralysis) and with the potential to influence the outcomes of the study were excluded.
6. Potential participants who worked night shifts were excluded because shift work has been shown to compromise sleeping patterns in relation to circadian rhythms (Åkerstedt, 2003).

Materials, Measures and Apparatus

Diagnostic and screening instruments. The *Mini International Neuropsychiatric Interview* (*M.I.N.I. version 7.0*; Sheehan, et al., 1998) is a structured diagnostic interview that was used to assess the presence of major DSM-5 psychiatric disorders. The developers report that the instrument has good psychometric properties, and can be administered within approximately 15 minutes.

The *Beck Depression Inventory – Second Edition* (*BDI-II*; Beck, Steer, & Brown, 1996) is a standardised 21-item self-report questionnaire that measures symptoms of depression on a 4-point Likert scale of 0 to 3. The BDI-II is suitable for use as a research tool and has a high reported internal consistency ($\alpha = .92$). It takes approximately 5 minutes to complete and was used to determine the level of depression reported by participants. Participants with severe depression that scored 29 or above were excluded from the study. Participants who had minimal levels of depression and scored 13 or less were also excluded.

The *Pittsburgh Sleep Quality Index* (*PSQI*; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) is a 19-item self-report questionnaire and was used to assess the quality of sleep and sleep disturbances of potential participants. It has been used in clinical and research

settings and has a statistically significant diagnostic sensitivity of 89.6% for distinguishing between healthy and poor sleep (Buysse et al., 1989). The PSQI takes approximately 10 minutes to complete. Participants with mild to moderate sleep disturbance who scored between 5 and 15 on the index were included.

Experimental Measures: *Sleep Cycle*. The app uses a smartphone's built-in accelerometer as an actigraphy sensor (Northcube AB, 2015). The accelerometer allows the app to detect which stage of sleep one is in, based on one's movement whilst sleeping (Littner et al., 2003). Data recorded by the app during the lab night was used for analysis.

Sleep adapted electroencephalography. Objective measures of sleep were recorded with an electroencephalograph (EEG) adapted for sleep research[1]. This equipment maps out sleep architecture and consists of EEG electrodes that measure brain activity, electrooculograph (EOG) electrodes that monitor eye movements, electromyograph (EMG) electrodes that measure muscle tone, and electrocardiograph (ECG) electrodes that measure heartbeat. These measures were essential in identifying REM sleep, as it is not always reliably identified through brain activity measures alone (Keenan, 2009).

A Nihon Kohden NeuroFax EEG9000 was used for the sleep-adapted EEG recording. The laboratory equipment meets the requirements of all (a) the digital system regulations (such as filters on each channel), (b) the rules for display and display manipulation (such as the ability to view the sleep data in variable time frames, from 5 seconds to 2 minutes), as well as (c) the digital analysis specifications (such as the ability to score the data either electronically or manually). The montage uses recommendations provided by the latest technical specifications manual of the AASM (2007).

Sleep diary. An 8-day, self-report sleep diary was used to assess participants' total sleep time each night during the course of the study. The sleep diary was adapted from an AASM version that is frequently used in clinical and research settings. Participants were asked to complete the sleep diary in the morning about the night prior. The sleep diary asked for information such as bed-time, time taken to fall asleep, wake time and number of awakenings during the night.

Measuring emotion. The *Positive and Negative Affect Schedule* (PANAS; Watson, Clark, & Tellegen, 1988) is a 20-item mood scale that was used to self-report emotional aspects of well-being along two dimensions of mood namely, Positive Affect (PA) and

[1] Sleep data from an EEG adapted to record sleep refers to a polysomnograph recording. The montage is based on AASM guidelines but does not include an exact replica of the channels and specifications, therefore it referred to as an EEG adapted for sleep research.

Negative Affect (NA; Watson et al., 1988). PA is the extent to which a person feels enthusiastic, attentive and alert, whereas NA characterises sadness, lethargy and general feelings of distress (Watson et al., 1988). The scale can be used for different time instructions for example, *Past Few Days*, *Past Few Weeks* or *This Moment*. Internal consistency reliabilities are unaffected by time instructions used (PA $\alpha = .86$ to $\alpha = .90$; NA $\alpha = .84$ to $\alpha = .87$). All participants completed a daily PANAS questionnaire during Phase 1 and at the end of Phase 2, for the time instruction *Today*.

Procedure

The procedure began with screening which took place on a one-to-one basis in a private room at UCT. I explained to participants I was investigating changes in affect in relation to different alarm-regulated waking experiences and that they would be allocated to an experimental or control group. My explanation of the study was in accordance with the parameters of an open-label trial. Each participant consented to participation (see Appendix A) and completed a questionnaire that captured demographic and criteria-specific information (see Appendix B). Thereafter, I administered the diagnostic and screening instruments. Screening measures were scored at the end of each appointment following which eligible candidates were assigned to a group. I allocated every second participant to the experimental group so that there was random group allocation. Participants in the experimental group were reimbursed R21 to cover the cost of the app and were assisted with downloading *Sleep Cycle*. I demonstrated how to use the app and configured the feature settings with each participant so that settings were standardised for the whole group. The alarm time and alarm tone were not standardised. However, I requested that the same tone be used each day.

Phase 1. I asked participants to set their alarm clocks for the normal time they needed to wake during the week (including weekends). Those participants using *Sleep Cycle* used the app to wake up. Participants completed the sleep diary and PANAS questionnaires every morning within 2 hours of waking.

Phase 2. I booked sleep lab sessions for the night directly following each participant's home-week. Participants received an email reminding them of the appointment and providing necessary information related to behaviours that had the potential to confound study results. For example, they were advised not to drink caffeine during the afternoon and to eat supper before arrival. Participants arrived at the sleep lab 2 hours before their normal bed-time. Upon arrival, I invited participants to their rooms and briefed them about the evening and morning procedures. Participants were given details about their environment, such as the use

of the bathroom and security precautions, as well as emergency procedures should they require assistance during the night. I encouraged participants to feel comfortable and behave as they normally would at home.

I prepared participants for a night's sleep using the adapted EEG equipment. EEG and EMG electrodes were attached to the head using EC-2 paste, and the EOG and ECG electrodes to the face and chest using sticker electrodes. Once the sleep equipment was set up, all channels were tested by asking the participant to perform simple actions such as blinking and biting. Impedance (or amount of signal interference) was recorded to ensure that clear readings were obtained. Participants were then given a final briefing about sleeping the night with the adapted EEG equipment. For example, they were assured that they could sleep in their normal body positions.

Experimental group participants used *Sleep Cycle* to wake them as they had done during home-week, while control participants used their standard smartphone alarms. On waking, all EEG equipment was removed and participants got ready for the day. Thereafter participants completed their sleep diary and PANAS questionnaire.

Statistical Analysis

Before statistical analyses were conducted on sleep variables record names were recoded so that sleep data was scored blind to the group allocation of each participant. Senior members from the UCT sleep sciences team reviewed one-quarter of the records to ensure inter-rater reliability.

***Sleep Cycle* and sleep electroencephalography.** *Sleep Cycle* sleep graphs were analysed by scoring the sleep stage at each hourly interval illustrated in the app's graphic (see Figure 1). Adapted EEG sleep stages, as determined by the standard measurements of EEG, EOG, and EMG, were classified according to the latest specification provided by the AASM (2007). Thereafter, I compared the sleep graphs generated by *Sleep Cycle* and the adapted EEG at hourly intervals to determine consensus between the data. The frequency of sleep stage agreement was nominally coded and counted. I analysed trials using a binomial probability formula to measure whether the probability occurred by chance ($\alpha = .05$) or the relationship of agreement was significant. NREM and REM awakenings were counted from scored EEG records to determine participants' sleep stage on waking.

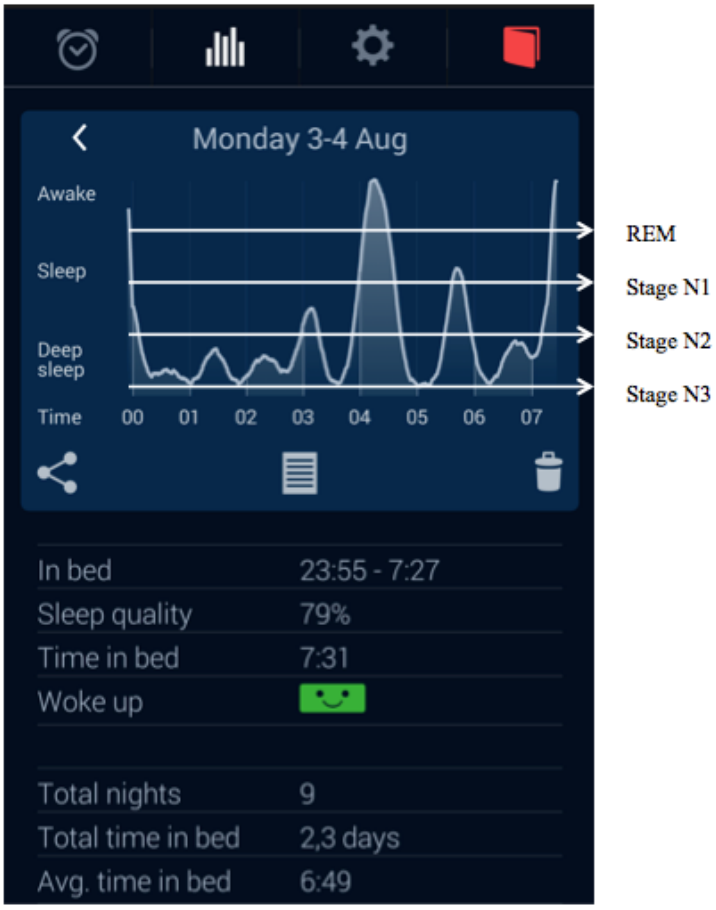

Figure 1. Image of the *Sleep Cycle* sleep graph and corresponding interpretation of sleep stages used for analysis. Adapted from *Sleep Cycle Alarm Clock*. Copyright 2015 by Northcube AB.

Sleep quality and affect. Before total sleep time and positive and negative affect variables were analysed, I examined the data for deviations from normality, variance distribution, and the presence of outliers to determine whether the assumptions underlying respective inferential analyses were met.

A mixed design analysis of variance (ANOVA) was used to measure changes in total sleep time within each group over the 8-day study period as well as compare overall differences between group means. Similarly, a mixed design ANOVA was used to measure whether there were changes in the mean scores of positive or negative affect within each group over the study period. The same ANOVA test was used to compare overall differences in positive and negative affect between-groups and investigate whether there was a

significant relationship between group allocation and time. All inferential statistical analyses were completed using SPSS version 22. Level of significance was set at .05.

Ethical Considerations

Participants signed consent forms before being formally enrolled in the study. These ensured they were fully informed about the study procedures, its risks and benefits and provided participants with the assurance that they could opt out of the study at any stage. Participants were assured that the measures and sleep lab tests would not harm them in any way. Additionally, in the event that participants experienced distress or depressive symptoms worsened, I would have referred the individual to the UCT Student Wellness Service. This however, did not happen during my research. I concluded the sleep lab sessions by debriefing participants about the study procedures. Each participant was compensated R150 and provided with a sleep report of their night's sleep. The EEG scoring software generated the sleep reports.

All personal details are kept confidential and information related to each participant is stored securely. Research records will not be released without participant permission unless required by law. All study procedures were approved by the Research Ethics Committees of UCT's Department of Psychology and Faculty of Health Sciences.

Results

There were 16 participants eligible to participate in the study. Regarding demographic variables, Table 1 shows the two groups were matched on age, gender and education. Regarding age, the mean of the entire sample was 21.5 years (*SD* = 2.53, range 19-29). Regarding gender, the majority of participants were female (*n* = 56.3%). Regarding education, most participants were completing their undergraduate degree (*n* = 75%). Regarding BDI-II scores, there were no significant between-group differences. The mean of the entire sample was 17.75 (*SD* = 8.84). Regarding PSQI scores, there no significant between-group differences. The mean of the entire sample was 8.56 (*SD* = 2.31).

Table 1

Sample Demographic and Psychiatric Characteristics (n = 16)

	Group				
	Sleep Cycle	Control			
Variable	(*n* = 8)	(*n* = 8)	t / χ^2	*p*	ESE
Age	20.63 (1.06)	22.38 (3.29)	1.43[a]	.18	.44
Gender			.25	.61	.12
Male	50%	37.5%			
Female	50%	62.5%			
Education			1.33	.24	.28
Undergraduate	87.5%	62.5%			
Postgraduate	12.5%	37.5%			
BDI-II	18.75 (3.37)	16.75 (4.23)	.002[b]	.31	.26
PSQI	8.63 (2.26)	8.50 (2.51)	.044 [b]	.91	.03

Note. For all variables except Gender and Education, means are presented with standard deviations in parentheses. ESE = effect size estimate (in this case, either Cohen's *d* for *t* tests on Age, BDI-II and PSQI scores or Cramer's *V* for χ^2 tests on Gender and Education); BDI-II = Beck Depression Inventory – Second Edition; PSQI = Pittsburgh Sleep Quality Index.
[a] $df = 8$
[b] $df = 14$

Manipulation checks

***Sleep Cycle* in relation to the EEG**. Scored sleep stages from *Sleep Cycle* and the EEG were compared at hourly intervals, for 7 hours of sleep. Therefore, seven trials per participant were coded according to whether there was agreement in sleep stage or not. A binomial distribution formula revealed there was no significant agreement between *Sleep Cycle* and the EEG per participant or overall (see Table 2). This result suggests that agreement between the two measures occurred by chance.

Table 2

Frequencies of Sleep Stage Agreement between EEG and Sleep Cycle Data

Sleep Cycle participant	Instances of agreement
1	2
2	0
3	1
4	3
5	2
6	3
7	3
8	2

REM awakenings. In the control group, most people (n = 62.5%) were woken by their alarms whilst in stage N1 sleep. In the experimental group, an equal number of participants were woken whilst in stage N1 or N2. The two counts of REM awakening occurred in the *Sleep Cycle* group, where the alarm activated within 5 minutes of a movement or a micro-arousal, however participants were still in REM sleep. All participants in the control group were woken during NREM sleep. Table 3 illustrates the waking conditions for each group.

Table 3

Description of Waking Conditions

	Sleep Cycle group			Control group		
Participant	Waking stage	Preceding waking	Sleep feature	Waking stage	Preceding waking	Sleep feature
1	Stage N2	Stage N1	No	Stage N1	Stage N1	Yes
2	Awake	Stage N1	Yes	Stage N1	Stage N1	Yes
3	Stage N1	Stage N1	Yes	Stage N2	Stage N1	Yes
4	REM	Stage N2	Yes	Stage N2	Stage N1	No
5	REM	Stage N2	Yes	Stage N1	Stage N1	No
6	Stage N1	Stage N1	Yes	Stage N1	Stage N1	No
7	Movement	Stage N1	Yes	Stage N1	Stage N1	Yes
8	Stage N2	Stage N1	No	Stage N2	Stage N1	No

Note. Waking stage indicates the sleep stage the participant was in when their alarm activated; preceding waking indicates the lightest stage of sleep in the 30 minutes prior to waking (i.e., the optimal stage of sleep for waking); sleep feature indicates if a movement or micro-arousal occurred 5 minutes prior to waking.

Hypotheses Testing

Analyses focus on within group changes over 8 days and between-group differences on measures of total sleep time and affect. Scores for Positive Affect (PA) and Negative Affect (NA) were investigated separately. Assumptions of normality, homogeneity of variance and sphericity were upheld.

Hypothesis 1: Participants in the *Sleep Cycle* group will have increased total sleep time (a) over time and (b) in comparison with controls.

The sleep diaries completed by participants' in both groups were used to calculate total sleep time means over 8 days (see Table 4). Results showed that there was no significant increase in total sleep time within either group. There were also no significant between-group differences (see Table 5).

Table 4

Contrast of Total Sleep Time from Day 1 to Day 8

Group	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Sleep Cycle	7.5 (1.78)	6 (2.46)	6.25 (1.63)	6.5 (1.77)	5.75 (1.23)	6.5 (2.29)	6 (0.83)	6.5 (0.62)
Control	7 (1.14)	6.5 (0.62)	5 (1.06)	7 (1.48)	7 (2.08)	6 (1.72)	6.5 (0.88)	6.5 (1.01)

Note. *M* = mean in hours; *SD* = standard deviation.

Table 5

Total Sleep Time Group Means and Significance of Difference

Group	*M (SD)*	*df*	*F*	*p*	η^2
Sleep Cycle	6 (0.62)	1, 14	.939	.349	.063
Control	6.5 (0.62)				

Note. *M* = mean; *SD* = standard deviation; *df* = degrees of freedom; η^2 = eta squared effect size.

Hypothesis 2: Participants in the *Sleep Cycle* group will have increased positive affect (a) over time and (b) in comparison with controls.

Participants in both groups completed positive affect ratings over 8 days (see Table 6) to assess whether participants using *Sleep Cycle's* alarm clock experienced better mood than participants using standard smartphone alarms. Results showed that the variation in mean scores was not significant. Additionally, there was no significant difference in PA between participants using *Sleep Cycle* (*M* = 24.57; *SD* = 6.99) and participants not using *Sleep Cycle* (*M* = 25.06; *SD* = 6.99). Table 7 illustrates the ANOVA results for between-group differences. The analysis suggests that using *Sleep Cycle* has no influence positive affect.

Table 6

Contrast of Positive Affect from Day 1 to Day 8

Group	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Sleep Cycle	24.13 (9.41)	19.63 (4.27)	23 (8.21)	28.75 (8.69)	27.5 (6.76)	22.5 (7.25)	24.75 (9.09)	26.37 (9.08)
Control	26.38 (7.96)	25.5 (7.92)	28.13 (6.85)	24.88 (13.13)	24 (10.15)	20.75 (8.24)	22.75 (11.42)	28.12 (9.73)

Note. *M* = mean; *SD* = standard deviation. Positive affect scores range from 10-50 with higher scores representing higher levels of positive affect.

Table 7

Positive Affect Group Means and Significance of Difference

Group	*M (SD)*	*df*	*F*	*p*	η^2
Sleep Cycle	24.57 (6.99)	1, 14	.019	.892	.001
Control	25.06 (6.99)				

Note. *M* = mean; *SD* = standard deviation; *df* = degrees of freedom; η^2 = eta squared effect size.

Hypothesis 3: Participants in the *Sleep Cycle* group will have decreased negative affect (a) over time and (b) in comparison with controls.

Participants in both groups completed negative affect ratings for 8 days (see Table 8) to assess whether participants using *Sleep Cycle's* alarm clock experienced a decrease in negative affect in comparison with participants using their standard smartphone alarms. The results for this investigation revealed that the variation in mean scores of NA was not significant. ANOVA tests showed that overall, Day 8 (M = 11.7, SD = 2.5) had a significantly lower mean in both groups compared to Day 1 (M = 15.9), Day 2 (M = 15.8) and Day 7 (M = 15.7), $F(7, 98) = 1.12$, $p = .041$, $\eta^2 = .17$. No significant difference in mean scores of NA was found between groups (see Table 9).

Table 8

Contrast of Negative Affect from Day 1 to Day 8

Group	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Sleep Cycle	17.63 (5.42)	16.5 (5.63)	15.75 (3.69)	13.88 (5.86)	13.75 (6.38)	19 (10.31)	15.25 (3.88)	10.88 (1.45)
Control	14.25 (3.11)	15 (3.96)	13.13 (4.54)	15.87 (5.38)	12.75 (1.83)	15.5 (6.52)	15.88 (5.11)	12.5 (3.16)

Note. *M* = mean; *SD* = standard deviation. Negative affect scores range from 10-50 with lower scores representing lower levels of negative affect.

Table 9

Negative Affect Group Means and Significance of Difference

Group	*M (SD)*	*df*	*F*	*p*	η^2
Sleep Cycle	15.32 (3.47)	1, 14	.311	.586	.022
Control	14.35 (3.47)				

Note. *M* = mean; *SD* = standard deviation; *df* = degrees of freedom; η^2 = eta squared effect size.

Discussion

This study set out to investigate whether *Sleep Cycle* is an effective intervention for (a) improving sleep quality and (b) improving affect regulation. The interest in the question was based on the knowledge that healthy sleep improves emotional functioning and conversely, that sleep deprivation has a negative impact on mood. There is a growing body of literature on behavioural health apps with arguments both for and against app development and use. In this context, assessing *Sleep Cycle's* technical reliability is an important consideration. I therefore began my investigations by conducting two manipulation checks to test the technical functioning of the app in terms of its ability to accurately record sleep architecture and for its alarm not to activate during REM sleep. In so far as sleep quality is concerned, the manipulation checks provided a basis for comment on the effects of regulating optimal sleep-wake experiences. Following the manipulation checks, I proceeded to investigate whether there was an increase in total sleep time based on the premise that continually monitoring personal sleep patterns would lead to improvements in sleep quality. Thereafter, I assessed the influence of sleep quality on mood by measuring changes in positive or negative affect.

Participants reporting having trouble sleeping or suffering from mild or moderate depression provided the opportunity to assess whether there were improvements in sleep quality and affect. The student sample in this study experienced greater sleeping difficulties (M = 8.56; SD = 2.31) than the scores of healthy individuals (M = 2.67; SD = 1.7) (see, Buysse et al., 1988). Additionally, participants in my study reported higher levels of depression (M = 17.75, SD = 3.83) in comparison with the scores of healthy individuals (n = 120; M = 12.6; SD = 9.9) (see, Wang & Gorenstein, 2013). Overall, positive affect was also lower amongst participants (M = 24.82; SD = 6.99) in comparison with healthy controls (M = 29.1; SD = 8.3) (see, Watson et al., 1988).

Manipulation Checks: Findings Regarding Technical Reliability

Binomial probability calculations revealed that there was no significant agreement in sleep architecture between *Sleep Cycle* and the EEG. That is to say, the probability of consensus in sleep stage data was due to random chance. This finding invalidates the sleep graphs generated by *Sleep Cycle* and puts into question the app's functionality overall. In addition, the finding offers an explanation for the counts of REM awakening that occurred in the experimental group. *Sleep Cycle* was not able to monitor the difference between movement during a REM cycle and the transition to a different stage of sleep. Therefore, the instances of REM awakening were contrary to the assumption that participants using *Sleep*

Cycle would wake in a stage of NREM sleep. As a result the app failed on account of the second manipulation check.

Literature regarding sleep screening apps for smartphones highlights that developers do not provide details about the actigraphy analysis algorithms used to detect motion – the basis on which sleep architecture is graphed (Behar et al., 2013). This critique is pertinent to the current investigation, because a possible reason for *Sleep Cycle's* ineffectiveness could be explained by defective motion sensing. The results of my study revealed that in most cases (n = 6) there was movement within 5 minutes prior to *Sleep Cycle's* alarm activating irrespective of whether the participant was in NREM or REM sleep. This data supports the possibility that *Sleep Cycle's* actigraphy algorithms are problematic.

The differences between actigaphy measures and polysomnography (PSG) have also been noted in sleep research studies. PSG is seen as the gold standard for the measurement of sleep because of its ability to objectively record various physiological characteristics. Actigraphy, on the other hand, relies solely on body movement. Although published reports have shown that PSG and actigraphy are relatively consistent in measuring sleep cycles (Mccall & Mccall, 2012; Sivertsen et al., 2006), discrepancies in sleep onset latency and subsequent estimates of total sleep time have been found (Sadeh & Acebo, 2002). A study conducted by Natale et al. (2012) found an overall agreement between actigraph and smartphone sleep recordings when configuring the smartphone (i.e., not the app alone) with sleep specific algorithms so that the devices were matched. It is possible that the reliability of *Sleep Cycl*e may be improved by using the app on a configured smartphone, however it seems that technology still has some way to go before approximating PSG. The manipulation checks set out to confirm whether *Sleep Cycle* reliably records sleep and on this basis, improvements in sleep quality and positive affect could be evaluated. The findings illustrate that the app has failed in this regard therefore the ability to draw conclusions about whether *Sleep Cycle* is useful for promoting healthy sleep is limited.

Hypothesis 1: Findings Regarding Sleep Quality

This study investigated whether using *Sleep Cycle* improved total sleep time as a measure of sleep quality. The statistical analysis for total sleep time did not confirm hypothesis 1. That is to say there were no significant increases in total sleep time within the experimental group or the control group over the duration of the study. There were also no significant between group differences. Both groups monitored sleep patterns on a daily basis using a sleep diary. Participants in the experimental group had greater awareness of sleep behaviour because they monitored sleep patterns by way of the sleep diary and relying on

Sleep Cycle as a personal feedback tool. The findings suggest that recording sleep-wake behaviour in itself is insufficient in improving sleep quality. The findings also undermine the premise that monitoring sleep using *Sleep Cycle* will lead to healthier sleep. Possible explanations for this take into consideration that knowledge about good sleep habits alone does not bring about behaviour change (Brown, Buboltz, & Soper, 2002). Behavioural intent and goal-setting are seen as necessary variables involved in improving health practices (Abraham & Sheeran, 2000). Alternatively, the restricted operational definition of sleep quality – in terms of total sleep time – limits this study's ability to provide a comprehensive appraisal of factors that influence sleep. The consequence of poor sleep quality on emotional functioning introduces the remaining hypotheses.

Hypotheses 2 and 3: Findings Regarding Affect

To fulfil the aim of investigating the association between healthy sleep and emotion, this study examined changes in PANAS mood scale ratings (along dimensions of positive and negative mood states) for the experimental and control group.

Positive affect. For the positive mood score dimension, results showed no significant main effects over time and no main effect of condition (i.e., *Sleep Cycle* and control). This finding was contrary to hypothesis 2 stating that participants using *Sleep Cycle* would have increased positive affect over time and in comparison with controls.

Negative affect. For the negative mood score dimension, this study showed no significant main effects for the interaction between group and time and no main effect of condition (i.e., *Sleep Cycle* and control). This finding was contrary to hypothesis 3 stating that participants using *Sleep Cycle* would have decreased negative affect over the duration of the study and in comparison with controls. There were however, significantly lower negative affect scores recorded overall on Day 8 in comparison with Day 1, Day 2 and Day 7. Research has shown that people with psychopathology tend to sleep better in a lab environment than they do at home which provides a possible explanation for decreased negative affect after a night spent in the sleep lab (Herbst et al., 2010).

Together, the study has shown that using *Sleep Cycle* does not improve mood by way of increasing positive affect or decreasing negative affect. This could be expected because there was no data in support of *Sleep Cycle* improving participants' quality of sleep. The fact that there is no improvement in sleep quality and concurrently no improvement in mood is congruent with studies that evidence a close relationship between sleep and emotional brain processing (Walker & van der Helm, 2009), where sleep deprivation enhances one's

reactivity to aversive experiences (Gujar, Yoo, et al., 2011) and tendency toward negative emotional valence (Gujar, McDonald, et al., 2011).

Recent research investigating the relationship between healthy sleep and emotion has drawn attention to the unique nature of REM physiology. An episode of REM sleep has been associated with enhanced recognition of positive expressions and regulating emotional functioning (Gujar, McDonald, et al., 2011). The current study has shown that *Sleep Cycle* alarms caused REM awakenings and prematurely shortened a REM cycle. This finding foregrounds the concern that *Sleep Cycle* is ineffective in using sleep data to improve the quality of sleep with the aim of improving emotional functioning.

Strengths and Limitations

The strength of this study lies in piloting a methodological framework and establishing provisional results for further investigation into the efficacy of *Sleep Cycle* in promoting healthy sleep. In response to critics of mHealth interventions (see, e.g., Lupton, 2014) and evaluations of smartphone apps in particular (see, e.g., Behar et al., 2013) this research has added to an insubstantial body of literature that scientifically validates a multitude of behavioural health apps available to the public. Despite areas for improvement in this study, the research has exposed the possible technical malfunctioning of *Sleep Cycle,* which serves to benchmark the progress that needs to be made before we can rely on smartphone actigraphy as a reliable measure of sleep.

The limitations that may have influenced results primarily concern the methods. The small sample compromises the generalisability of my results and limited the statistical power to detect significant effects. A larger sample size would be needed to enhance external validity and detect significant interactions. In terms of research design, the transparent nature of an open-label trial created an opportunity for bias because participants were aware of the group conditions to which they were allocated. Additionally, data collection comprised substantially of self-reported data recorded in an uncontrolled environment. This limitation is primarily with regard to information captured in the sleep diaries and less of a concern for the PANAS questionnaires, because mood is a subjective aspect of cognition which is appropriate for the purpose of this study. Moreover, although the setting was uncontrolled, a home environment is favourable because it is the natural sleep context of participants. Studies evaluating mood should, however, be conducted over a longer period of time and the short duration of this study may have limited the evaluation of affect.

In terms of the lab night procedure, I suggest an adaptation night be held so that participants can become accustomed to the sleep environment. To minimise unfamiliarity, at

the end of screening sessions each participant was shown photos of the sleep room and the EEG setup where I was the participating subject. Where possible, screening appointments were held in the sleep lab itself. There was no opportunity to confirm participants used *Sleep Cycle* correctly during home-week, which would have compromised the app's ability to calibrate to body movement. This limitation could be countered for by having the adaptation night before home-week commences, as it would serve as a practical opportunity for learning how to use the app in the presence of the researcher. Lastly, experimenter bias effects could have influenced results after the night in the lab, because participants may have felt obliged to report that they had slept well and rate affect scales more positively. Significantly lower negative affect scores on Day 8 supports this consideration.

Directions for Future Research

One of the intentions behind this study was to investigate whether mHealth interventions are a worthwhile and cost-effective strategy to improve sleep and emotion. Although there has been progress, technological ways of monitoring sleep are currently not as effective as they can be and future research in this area is necessary for advances to be made.

Regarding sleep quality, the negative consequences of sleep loss on emotional regulation and research highlighting that emotions are subject to remodulation after sleep (for e.g., increasing overall sleep time by having daytime naps), provided reason for investigating total sleep time as an indicator of healthy sleep. Future studies could examine different variables associated with sleep quality, such as sleep efficiency (i.e., the proportion of time asleep in relation to time in bed), sleep hygiene practices (i.e., the theory around best practice behaviour prior to sleep) and waking from a stage of NREM as opposed to REM sleep. Current knowledge on the effects of sleep stage on waking and affect is limited.

Conclusion

In conclusion, the current study found that there was no significant agreement between *Sleep Cycle* sleep graphs and EEG generated sleep architecture. Additionally, the *Sleep Cycle* alarm clock activated during a REM cycle on two occasions when the EEG was measuring sleep. The results of the manipulation checks suggest that the actigraphic measures of *Sleep Cycle* are unreliable. Contrary to the hypothesis, this study showed there was no significant increase in total sleep time amongst participants using *Sleep Cycle* and in comparison with the control group. For the purposes of this study, total sleep time was used as a measure of sleep quality. Regarding affect, this study showed no significant increase in positive affect or decrease in negative affect amongst participants using *Sleep Cycle* during the course of the study. There were no significant between-group differences in positive or negative affect when comparing participants' using *Sleep Cycle* with control group participants. Despite non-significant associations between participants using *Sleep Cycle* and (a) sleep quality and (b) affect, the findings are in agreement with current knowledge of the intimate relationship between the nature of sleep and emotion.

References

AASM (2007). The AASM manual for the scoring of sleep and associated events. In 2007 (Ed.): American Academy of Sleep Medicine

Abraham, C., & Sheeran, P. (2000). Understanding and changing health behaviour: From health beliefs to self-regulation. In P. Norman, C. Abraham, & M. Conner (Eds.), *Understanding and changing health behaviour* (pp. 3–24). Amsterdam, Holland: Harwood.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington: American Psychiatric Association.

Åkerstedt, T. (2003). Shift work and disturbed sleep/wakefulness. *Occupational Medicine*, *53*, 89–94. doi:10.1093/occmed/kqg046

Baum, K. T., Desai, A., Field, J., Miller, L. E., Rausch, J., & Beebe, D. W. (2014). Sleep restriction worsens mood and emotion regulation in adolescents. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *55*, 180–190. doi:10.1111/jcpp.12125

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for the Beck Depression Inventory-II*. San Antonio: Psychological Corporation.

Behar, J., Roebuck, A., Domingos, J. S., Gederi, E., & Clifford, G. D. (2013). A review of current sleep screening applications for smartphones. *Physiological Measurement*, *34*, 29–46. doi:10.1088/0967-3334/34/7/R29

Bentley, A., Lacovides, S., & Baker, F. (2011). How sleepy are South Africans? *Sleep Matters*, *2*(1), 7-8.

Blunden, S., & Galland, B. (2014). The complexities of defining optimal sleep: Empirical and theoretical considerations with a special emphasis on children. *Sleep Medicine Reviews*, *18*(5), 371–378. doi:10.1016/j.smrv.2014.01.002

Brown, F. C., Buboltz, W. C., & Soper, B. (2002). Relationship of sleep hygiene awareness, sleep hygiene practices, and sleep quality in university students. *Behavioral Medicine*, *28*(1), 33–38. doi:10.1080/08964280209596396

Buysse, D. J. (2014). Sleep health: Can we define it? Does it matter? *Sleep*, *37*, 9–17. doi:10.5665/sleep.3298

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193-213. doi:10.1016/0165-1781(89)90047-4

Carskadon, M. A., & Dement, W. C. (2011). Normal human sleep: An overview. *Principles and Practice of Sleep Medicine*, *5*, 16–26. doi:10.1016/B978-1-4160-6645-3.00002-5

Cartwright, R., Luten, A., Young, M., Mercer, P., & Bears, M. (1998). Role of REM sleep and dream affect in overnight mood regulation: A study of normal volunteers. *Psychiatry Research*, *81*, 1–8. doi:10.1016/S0165-1781(98)00089-4

Chee, M. W. L., & Chuah, L. Y. M. (2008). Functional neuroimaging insights into how sleep and sleep deprivation affect memory and cognition. *Current Opinion in Neurology*, *21*, 417–423. doi:10.1097/WCO.0b013e3283052cf7

Choe, E., Fonville, A., Sakaguchi, D., Halko, S., Watson, N., & Kientz, J. (2010, April). Opportunities for computing technologies to support healthy sleep behaviors. In E. Mynatt (Chair), *Conference on Human Factors in Computing Systems.* Symposium conducted at the meeting of SIGCHI, Atlanta.

Colten, H. R., & Altevogt, B. M. (Eds.). (2006). *Sleep disorders and sleep deprivation: An unmet public health problem.* [Adobe Digital Editions version]. Retrieved from http://www.nap.edu/catalog/11617.html

Deliens, G., Gilson, M., & Peigneux, P. (2014). Sleep and the processing of emotions. *Experimental Brain Research, 232,* 1403–1414. doi:10.1007/s00221-014-3832-1

Ferrara, M., & De Gennaro, L. (2000). The sleep inertia phenomenon during the sleep-wake transition: Theoretical and operational issues. *Aviation, Space, and Environmental Medicine*, *71*(8), 843–848. Retrieved from http://europepmc.org/abstract/MED/10954363

Fryer, B. (2006). *Sleep deficit: The performance killer*. Harvard Business Review. Retrieved from https://hbr.org/2006/10/sleep-deficit-the-performance-killer

Gujar, N., McDonald, S. A., Nishida, M., & Walker, M. P. (2011). A role for REM sleep in recalibrating the sensitivity of the human brain to specific emotions. *Cerebral Cortex*, *21*(1), 115–123. doi:10.1093/cercor/bhq064

Gujar, N., Yoo, S., Hu, P., & Walker, M. P. (2011). Sleep deprivation amplifies reactivity of brain reward networks, biasing the appraisal of positive emotional experiences. *Journal of Neurosciences, 31*(12), 4466-4476. doi:10.1523/JNEUROSCI.3220-10.2011

Herbst, E., Metzler, T. J., Lenoci, M., McCaslin, S. E., Inslicht, S., Marmar, C. R., & Neylan, T. C. (2010). Adaptation effects to sleep studies in participants with and without chronic posttraumatic stress disorder. *Psychophysiology, 47,* 1127–1133. doi: 10.1111/j.1469-8986.2010.01030.x

Johnson, E. O., & Breslau, N. (2001). Sleep problems and substance use in adolescence. *Drug and Alcohol Dependence, 64*(1), 1–7. doi:10.1016/S0376-8716(00)00222-2

Judd, B. G., & Sateia, M. A. (2014). *International classification of sleep disorders* (3rd ed.). Darien: American Academy of Sleep Medicine.

Kahn, M., Sheppes, G., & Sadeh, A. (2013). Sleep and emotions: Bidirectional links and underlying mechanisms. *International Journal of Psychophysiology, 89*(2), 218–228. doi:10.1016/j.ijpsycho.2013.05.010

Kahn-Greene, E. T., Killgore, D. B., Kamimori, G. H., Balkin, T. J., & Killgore, W. D. S. (2007). The effects of sleep deprivation on symptoms of psychopathology in healthy adults. *Sleep Medicine, 8,* 215–221. doi:10.1016/j.sleep.2006.08.007

Keenan, S. (2009). Polysomnographic technique: An overview. In S. Chokroverty (Ed.), *Sleep disorders medicine* (pp. 137-156). Philadelphia: Saunders Elsevier.

Knutson, K. L., Spiegel, K., Penev, P., & Van Cauter, E. (2007). The metabolic consequences of sleep deprivation. *Sleep Medicine Reviews, 11*(3), 163–178. doi:10.1016/j.smrv.2007.01.002

Lawson, S., Jamison-Powell, S., Garbett, A., Linehan, C., Kucharczyk, E., Verbaan, S., … Morgan, K. (2013, April). Validating a mobile phone application for the everyday, unobtrusive, objective measurement of sleep. In W. Mackay (Chair), *Conference on Human Factors in Computing Systems.* Symposium conducted at the meeting of SIGCHI, Paris.

Littner, M., Kushida, C. A, Anderson, W. M., Bailey, D., Berry, R. B., Davila, D. G., … Johnson, S. F. (2003). Practice parameters for the role of actigraphy in the study of sleep and circadian rhythms: An update for 2002. *Sleep, 26*(3), 337–341.

Lupton, D. (2014). Health promotion in the digital era: A critical commentary. *Health Promotion International, 30,* 174–183. doi:10.1093/heapro/dau091

Luxton, D. D., McCann, R. A., Bush, N. E., Mishkind, M. C., & Reger, G. M. (2011). mHealth for mental health: Integrating smartphone technology in behavioral healthcare. *Professional Psychology: Research and Practice, 42*(6), 505–512. doi:10.1037/a0024485

Lyubomirsky, S., King, L., & Diener, E. (2005). The benefits of frequent positive affect: Does happiness lead to success? *Psychological Bulletin, 131*(6), 803–55. doi: 10.1037/0033-2909.131.6.803

Mccall, C., & Mccall, W. V. (2012). Comparison of actigraphy with polysomnography and sleep logs in depressed insomniacs. *Journal of Sleep Research, 21*(1), 122–127. doi:10.1111/j.1365-2869.2011.00917.x

Miller, M. A, & Cappuccio, F. P. (2007). Inflammation, sleep, obesity and cardiovascular disease. *Current Vascular Pharmacology, 5*, 93–102.

Natale, V., Drejak, M., Erbacci, A., Tonetti, L., Fabbri, M., & Martoni, M. (2012). Monitoring sleep with a smartphone accelerometer. *Sleep and Biological Rhythms, 10*(4), 287–292. doi:10.1111/j.1479-8425.2012.00575.x

Northcube AB (2015). *Sleep Cycle.* Retrieved from http://www.sleepcycle.com/

Pace-Schott, E. (2014). Foreword: Interrelationships between sleep and affect. doi:10.1016/B978-0-12-417188-6.09997-7

Roberts, R. E., & Duong, H. T. (2014). The prospective association between sleep deprivation and depression among adolescents. *Sleep, 37*, 239–44. doi:10.5665/sleep.3388

Robotham, D., & Julian, C. (2006). Stress and the higher education student: A critical review of the literature. *Journal of Further and Higher Education, 30*(2), 107-117. doi:10.1080/03098770600617513

Rosales-Lagarde, A., Armony, J. L., del Río-Portilla, Y., Trejo-Martínez, D., Conde, R., & Corsi-Cabrera, M. (2012). Enhanced emotional reactivity after selective REM sleep deprivation in humans: An fMRI study. *Frontiers in Behavioral Neuroscience*, *6*, 1–13. doi:10.3389/fnbeh.2012.00025

Rose, M., Manser, T., & Ware, J. C. (2008). Effects of call on sleep and mood in internal medicine residents. *Behavioral Sleep Medicine*, *6*, 75–88. doi:10.1080/15402000801952914

Sadeh, A., & Acebo, C. (2002). The role of actigraphy in sleep medicine. *Sleep Medicine Reviews*, *6*(2), 113–124. doi:10.1053/smrv.2001.0182

Sarchiapone, M., Mandelli, L., Carli, V., Iosue, M., Wasserman, C., Hadlaczky, G., & Wasserman, D. (2014). Hours of sleep in adolescents and its association with anxiety, emotional concerns, and suicidal ideation. *Sleep Medicine, 15*(2), 248–254. doi:10.1016/j.sleep.2013.11.780

Sheehan, D. V., Lecrubier, Y., Sheehan, K. H., Amorim, P., Janavs, J., Weiller, E. (1998). The Mini-International Neuropsychiatric Interview (M.I.N.I.): The development and validation of a structured diagnostic psychiatric interview. *Journal of Clinical Psychiatry, 59*, 22-33.

Sivertsen, B., Omvik, S., Havik, O. E., Pallesen, S., Bjorvatn, B., Nielsen, G. H., … Nordhus, I. H. (2006). A comparison of actigraphy and polysomnography in older adults treated for chronic primary insomnia. *Sleep*, *29*(10), 1353–1358.

Solarz, D. E., Mullington, J. M., & Meier-Ewert H. K. (2012). Sleep, inflammation and cardiovascular disease. *Frontiers in Bioscience, 4,* 2490-2501. doi:10.2741/E560

Spoormaker, V. I., & Van Den Bout, J. (2005). Depression and anxiety complaints: Relations with sleep disturbances. *European Psychiatry*, *20*, 243–245. doi:10.1016/j.eurpsy.2004.11.006

Stepanski, E. J., & Wyatt, J. K. (2003). Use of sleep hygiene in the treatment of insomnia. *Sleep Medicine Reviews*, *7*(3), 215–225. doi:10.1053/smrv.2001.0246

Tassi, P., & Muzet, A. (2000). Sleep inertia. *Sleep Medicine Reviews*, *4*(4), 341–353. doi:10.1053/smrv.2000.0098

Vermetten, E., Vythilingam, M., Southwick, S. M., Charney, D. S., & Bremner, J. D. (2003). Long-term treatment with paroxetine increases verbal declarative memory and hippocampal volume in posttraumatic stress disorder. *Biological Psychiatry*, *54*(7), 693-702.

Walker, M. P., & van der Helm, E. (2009). Overnight therapy? The role of sleep in emotional brain processing. *Psychological Bulletin*, *135*(5), 731–748. doi:10.1037/a0016570

Wang, Y. P., & Gorenstein, C. (2013). Psychometric properties of the Beck Depression Inventory-II: A comprehensive review. *Revista Brasileira de Psiquiatria*, *35*(4), 416–431. doi:10.1590/1516-4446-2012-1048

Watson, D., Clark, L. A, & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. doi:10.1037/0022-3514.54.6.1063

Appendix A

Informed Consent to Participate in Research

You are being asked to take part in a research study. This form provides you with information about the study and seeks your authorisation for the collection, use and disclosure of your sleep patterns, sleep behaviour, mood and emotion as well as other information necessary for the study. The Principal Investigator (the person in charge of this research) will describe this study to you and answer all of your questions. Your participation is entirely voluntary. Before you decide whether or not to take part, read the information below and ask questions about anything you do not understand. For your information – this study is covered by UCT's No Fault Insurance Policy.

1. Title of Research Study

Promoting Positive Affect using Smartphone Application *Sleep Cycle Alarm Clock*

2. Principal Investigator and Telephone Number(s)

Layla Liebetrau
University of Cape Town (UCT)
Contact number: 074 6888 081
Email address: lbtlay001@gmail.com

3. What is the purpose of this research study?

This research aims to investigate the relationship between sleep quality and affect and the effectiveness of a sleep application called *Sleep Cycle Alarm Clock.*

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

In this experiment you will be asked to take part in two phases. Phase 1 is a home-week, lasting for 7 days. This week is entirely self-managed from your home. On daily basis, you will record your basic sleep behaviour, mood as you wake to your alarm clock and emotion. You may be assigned to a group where you will be required to use a specific smartphone app to record sleep behaviour and as your alarm clock.

For Phase 2, you will be asked to spend 1 night sleeping in the UCT Department of Psychology's sleep laboratory immediately after your home-week so there are no time delays between Phase 1 and Phase 2.

Before commencing the actual study, you will undergo a screening process whereby the Principal Investigator listed in # 2 of this form, will administer a number of short psychiatric questionnaires, a sleep quality test and an emotion test. They are merely research instruments that allow us to identify certain patterns of interest. We will also ask you to provide us with details of any medication you are currently on and any other things we should be aware of.

If you are allocated to the group using the smartphone app, you will be asked to attend a 1 hour training session held in UCT's PD Hahn building to install and setup the app before you commence Phase 1. If you are not allocated to this group you will be asked to collect a questionnaire pack from the Principal Investigator before commencing Phase 1. I will inform you of your group allocation via email, following the screening process.

For Phase 2, we will book a sleep appointment at a time that is suitable and you will be asked to come to UCT's sleep laboratory (PD Hahn building) 2 hours before your normal bed-time. During the 2 hours you will be asked to return the questionnaires you completed during your Phase 1 home-week and you will be briefed in detail, on the procedure for the night. You will be attached to a polysomnograph (PSG) which is an EEG machine designed to monitor your sleep pattern. Electrodes will be placed on your head, chest, near your chin and temples; these are completely safe and present no danger whatsoever to your health. They are designed to transmit physiological indications of the stage of sleep you are experiencing at a given point in time, to a computer monitor. The Principal Investigator will be available to you for assistance throughout the night.

In the morning all the equipment will be removed and you will have time to get ready and prepare for the day. Thereafter, you will be informed in detail about the design of the study and the research questions that are addressed. You will also have the opportunity to ask questions and thus learn more about psychological research. If you have any questions now or at any time during the study, you may contact the Principal Investigator listed in #2 of this form.

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

Screening and interview session: approximately 50 minutes. Phase 1 home-week: 7 days at home. Phase 2: One full night in the sleep laboratory followed by a 30 minute debriefing session the morning after.

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

20

7. What are the possible discomforts and risks?

Sleeping in an environment other than your own bedroom might feel strange and uncomfortable initially. Great precautions will be taken to ensure your safety and comfort. The Principal Investigator listed in #2 of this form will be available at any point throughout the night. The sleep laboratory at UCT is fully equipped with a proper bed, clean bedding, and restrooms. It is situated in the PD Hahn building with adequate security. Attempts will be made to familiarise you with the polysomnograph and the electrodes used will be padded and lubricated so as to be as non-intrusive as possible.

For those participants allocated to the group using the smartphone sleep application, it may feel strange at first to become accustomed to sleeping with your phone near your pillow.

You may feel that the screening questions or recording your sleep, behaviour, mood and emotion on a daily basis is personal. Please be assured this information is completely confidential between you and the Principal Investigator and is only used for the purposes of assessing healthy sleep behaviour that promotes positive mood.

10a. What are the possible benefits to you?

You may or may not personally benefit from participating in this study. Participation in this study may, however, improve your understanding of some factors that affect sleep and may influence your management of your sleep health generally.

10b. What are the possible benefits to others?

The information from this study may help improve our understanding of the importance of sleep behaviour on mood and emotion.

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

Participating in this study will not cost you anything.

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

You will be compensated R150.

13a. Can you withdraw from this research study?

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

If you have any questions regarding your rights as a research subject, you may phone the Psychology Department offices at 021-650-3430.

13b. If you withdraw, can information about you still be used and/or collected?

Information already collected may be used.

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

Information collected will be stored in locked filing cabinets or in computers with security passwords. Only certain people have the right to review these research records. These people include the researcher for this study and certain University of Cape Town officials. Your research records will not be released without your permission unless required by law or a court order.

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

This information gathered from you will be demographic information, information on levels of depression, sleep quality and emotion as well as scores on a psychiatric inventory. If you agree to be in this research study, it is possible that some of the information collected might be copied into a “limited data set” to be used for other research purposes. If so, the limited data set may only include information that does not directly identify you. For example, the limited data set **cannot** include your name, address, telephone number, ID number, or any other photographs, numbers, codes, or so forth that link you to the information in the limited data set.

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

In general, presenting research results helps the career of a scientist. Therefore, the Principal Investigator and others may benefit if the results of this study are presented at scientific meetings or in scientific journals. This study is being undertaken for the Principal Investigator's Honours degree.

Signatures

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

Signature of Person Obtaining Consent and Authorisation Date

_____ _____

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

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

Signature of Person Consenting and Authorising Date

_____
_____

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

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

Method of contact:
Phone number: _____
E-mail address: _____

Appendix B

Screening Questionnaire

Thank you for your interest in my study. I have a few questions that will help me determine whether it's ok for you to take part. They have to do with conditions or behaviours that may influence your sleep in a way that could compromise the findings of this research.

If you have any questions, or are concerned about answering something please let me know or leave it blank. Information you provide will be kept confidential.

You will have included some of the personal information in your consent document, but if you could fill it in here again, it will be helpful. Please circle answers if there are options.

Name:	Preferred method of contact: **SMS | Whatsapp | Call | Email**
Cellphone number:	Preferred email address:
Gender: **Male | Female**	Age:
Current education: **Undergraduate | Postgraduate**	Do you currently smoke: **Yes | No**
Are you currently taking any medication that may have side-effects of sleepiness? **Yes | No.** If yes, please specify:	For the purposes of the study, potential participants who carry a neurological condition or disability that would restrict mobility cannot take part. Please indicate if you suffer from such a condition. **Yes | No**
Do you have a history of alcohol or substance abuse? **Yes | No**	Are you currently taking any sedative medication to help you sleep? **Yes | No**
Do you work night shifts? **Yes | No.** If yes, please detail how frequently and the hours associated with the shift:	Please indicate which type of cellphone you use?