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Can Behavioral Economics strategies improve sleep quality in people with sleep problems?

Master Thesis

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Abstract

This study focused in two main goals. The first one was to analyze the most important habits in the quality of sleep using the Sleep Hygiene Index (SHI) in a selected population. The second one was to test an intervention that utilizes Behavioral Economics (BE) principles in order to improve the sleep quality by modifying some habits found in the first part of the study. The results showed that five among the thirteen habits of the SHI had significant effect on the sleep quality. Interestingly, two of those showed inconsistency with the SHI, showing a positive impact in the sleep quality the more they were done, while SHI defends that they would have negative impact. The two most impactful habits were selected for the intervention. The intervention used two BE principles, *social norm,* and *choice overload,* aiming to improve the sleep quality of the participants with lower than good sleep quality. Although no significant finding was seen in the analysis, the treatment group showed a tendency to sleep quality improvement. Therefore, it is not possible to conclude that the intervention had a real impact in the sleep quality of the subjects. Further studies are needed to establish the real effect of interventions based on BE principles on sleep quality.

Keywords: Behavior Economics, Sleep Quality, Sleep Hygiene

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1. Introduction

Sleep deprivation is a significant public health issue that has been linked to various negative outcomes, including decreased productivity, vigilant performances, impaired cognitive functioning, and increased risk of developing chronic diseases such as diabetes and cardiovascular disease (Cappuccio et al., 2010; Knutson & Lauderdale, 2008; Lim & Dinges, 2008). Despite the importance of sufficient sleep for overall wellbeing, a significant portion of the population struggles to get enough rest (National Sleep Foundation, 2020).

Behavioral economics (BE) is a field of economics that uses psychology and sociology to create insights and understand how people make decisions (Thaler, 2015). According to Thaler and Sunstein (2008), BE offers excellent tools to analyze and understand sleep deprivation due the consideration of cognitive and emotional factors that influence behavior.

One purpose of this thesis is to examine the literature on BE and sleep deprivation, and use this information to design an intervention that employs BE principles to improve sleep quality, by changing people habits. The literature review will discuss the impact of sleep deprivation on various outcomes, including physical and mental health, productivity, and decision-making. It will also explore BE approaches that have been successfully used in health issues, such as in the adoption of a healthier lifestyle and regular physical exercises (Thorgeirsson and Kawachi, 2013; Shuval et al., 2017), and how these approaches may be applied to the specific context of sleep deprivation.

In addition to the literature review, this thesis will include an analysis of the habits that have the biggest impact on the sleep quality of the subjects, and an original study that involves the development and implementation of an intervention that utilizes BE principles to encourage healthy sleep habits. The effectiveness of the intervention will be evaluated through pre- and post-intervention assessments of the sleep quality of the subjects.

Overall, this thesis intends to better understand the habits that impact most the sleep quality, and to test BE derived interventions in modifying these habits and improving sleep quality. By identifying and appropriately addressing the habits that influence sleep behavior, it is expected that those BE interventions will lead to improvements in overall health and well-being for individuals struggling with sleep deprivation.

2. Literature Review

Sleep is an important and common function in all living animals in the world. There is still no consensus on all the functions of sleep. A well-known function of sleep is that sleep has restorative function by helping to clear the brain of metabolic waste that builds up during wakefulness (Xie et al., 2013). Even if all the sleep functions are still unclear, the lack of sufficient sleep has a clear bad interference on us. Even non-expert people realize that a bad night of sleep can influence your productivity, mood, and alertness. The lack of sufficient sleep is wider than most people think, in Australia between 33 to 45 percent of the adults have complaints of inadequate sleeping (Adams et al., 2016) and more than a third of American adults are not sleeping enough (Liu et al., 2014). Other research shows the same pattern in other developed countries (Ford et al., 2015; Kronholm et al., 2016).

According to David F. Dinges, the modern pressure to use time 24 hours a day led many aspects of society to work 24/7, such as law enforcement, airports, and transports. So, people started to value time so much that sleep is often seen as a wasteful state that you enter into when you do not have enough willpower to work harder and longer (Worley, 2018).

2.1 Health Problems of sleep deprivation

The severe consequences of sleep deprivation in our safety, mental and physical well-being is becoming clearer with new studies. The American Academy of Sleep Medicine (AASM) and Sleep Research Society (SRS) developed a consensus for the amount of sleep needed for a regular adult, that a regular adult should sleep 7 or more hours per night on a regular basis. In different cases, such as young adults, individuals recovering from sleep debt, and individuals with illnesses, sleeping more than 9 hours per night on a regular basis may be appropriate (Watson et al., 2015).

One of the most studied effects of sleep deprivation is the loss in vigilant responses. Dinges and Powell (1985) created a method to evaluate alertness and vigilance, called Psychomotor Vigilance Test (PVT). It consists of a 10 minutes reaction time (RT) test that repeats visual cues in random intervals between 2-10 seconds. It became the standard method due to its reliability and the little learning effect (Dinges et al., 1997; Van Dongen et al., 2003). Lim and Dinges (2008) used the PVT in order to measure the effects of sleep deprivation on vigilant performances. They admit that people in deprived sleep have slower response time on average reaction time. Also, the fastest responses were 10% slower than the fastest for people without

sleep deprivation. This point is important, because it shows a decrease in attention on average, but also for the best performances. They have also verified that 'time on task effect', i.e., the deteriorating performance with sustained focus on a cognitive task, increases during sleep deprivation.

Basner and Dinges (2011) conducted a study using the PVT to measure cognitive performances for different hours of continuous wakefulness. They concluded that cognitive performance and vigilant attention decline quickly after 16 hours without sleep, but also that partial sleep deprivation can accumulate over time, resulting in great deterioration in alertness. Van Dongen et al. (2003) went deeper into the cumulative effect of sleep deprivation. They found out that restricting sleep by a few hours per night (e.g., 6h of sleep per night) could possibly lead to a slowing response time and that the sleep restriction is prolonged for up to 2 weeks, the level of response is comparable to two nights of no sleep. Restricted sleep, approximately 5 hours per night, appears to significantly reduce vigilance performance. Additional restrictions to less than 4 hours per night appear to result in even worse vigilance performance.

Sleep is very important for the capacity to remember and create memories and the literature about it is quite large (Rasch and Born, 2013; Inostroza and Born, 2013; Walker and Stickgold, 2006; Diekelmann and Born, 2010). The relationship between sleep and memory is linked in two major ways. The first one is that sleep is important before learning, because sleep prepares the brain to receive and store new information. The second part is sleep after learning helps the consolidation and assimilation of new information into the already existing memory (Diekelmann and Born, 2010; Walker, 2009).

Difficulty in learning and remembering due to sleep deprivation is also well documented in literature. Walker and Sitckgold (2006) researched the effects of sleep deprivation on memory. The experiment consisted in two groups, the participants that were deprived of sleep for 36 hours and those that were allowed to sleep normally. The memory task included words that were emotionally positive, negative or neutral. Then participants were called back after two nights of regular sleep at home, for a surprise test. Participants that were sleep deprived had a 40% decrease in their recognition score, compared to participants that were not sleep deprived before the test. However, another result of that experiment was also shocking. The subjects that slept normally before the test remembered better the positive and negative emotional words than the neutral ones, which is consistent with other works that showed that emotional content was easier to remember. The participants that could not sleep for 36h before the test had a much

lower performance for both neutral and positive words, reaching a 59% recognition deficit for positive words when compared to the other participants. Nevertheless, for negative words, the retention did not have a significant drop in performance. Those results indicate that a possible bias could appear in people suffering sleep deprivation, that is a bias favouring negative memories over the others, leading to other implications such as the development of mental diseases like depression (Walker and van der Helm, 2009).

In accordance with the increase of the negative emotional words in sleep deprived people, there are different works that associate sleep deprivation with mental diseases and behavior changes. Minkel et al. (2012) found that people with sleep deprivation had an increase in stress, anxiety, and anger in low-stress conditions. In high stress conditions, people with normal sleep had similar results than people with sleep deprivation. Those results suggest that sleep deprivation decreases the point for the perception of stress, but it does not increase the magnitude of the responses in high stress conditions. Bernet and Joiner (2007) made a review about the link of lack of sleeping with depression and suicide. They conclude that people with sleep deprivation have higher chance to develop depression and to have suicidal thoughts.

Impulsivity is defined here as a disposition to rapid, unplanned reactions to internal or external stimuli regardless of the negative consequences of these reactions for the impulsive person or for others (Moeller et al., 2001). Impulsiveness was linked to many psychiatric disorders, such as addiction, attention deficit / hyperactivity disorder (ADHD), and others (Bevilacqua & Goldman, 2013). Impulsive behavior has also been associated with sleep deprivation. Romer (2010) was able to link restricted sleep in young adults with impulsive behavior. The author says that young adults that experience lack of sleep do not develop their brain as they were supposed to and this can impact the person's life, being the increase in impulsivity is one of the effects of sleep deprivation. Anderson and Platten (2011) found out that one night of sleep loss leads to increased impulsivity to negative stimuli, fast incorrect responses and failure to inhibit undesired reactions. Tashjian et al. (2017) made an experiment tracking the quality of sleep in different adolescents, but also controlling for personal traits. The authors found out that a poor quality of sleep increases impulsiveness.

Beyond the influence in our emotions, moods, and behavior, sleep deprivation also has deep effects on our physical well-being. Xu et al. (2021) classified the top 15 causes of death in the United States and some of those have been linked with sleep deprivation, including cardiovascular disease, cancer, accidents, diabetes and hypertension. Kecklund and Axelsson

(2016) made a review that summarizes the literature on shift work and its relation to insufficient sleep, chronic diseases, and accidents. The conclusion made by the authors was that there is a relationship between shift work, sleep deprivation with occupational accidents/injuries, worse job performance, obesity, type 2 diabetes, coronary heart disease, stroke, and cancer of the breast, prostate, and colorectum.

Bertisch et al. (2018) did research to quantify the association between lack of sleep and incident cardiovascular disease (CVD). The research had 4994 participants and 14.1 percent reported having insomnia or poor sleep, and 50.3 percent of those participants slept less than six hours. The results showed that people with poor sleep or insomnia had 29 percent higher risk of an incident of CVD.

Diabetes is also linked with sleep deprivation. Yaggi et al. (2006) conducted a cohort of men from Massachusetts aged between 40-70s at baseline (1987–1989) who were followed until 2004, to analyze the long-term relationship between sleep duration and the incidence of clinical diabetes. They found that men reporting short sleep duration were twice as likely to develop diabetes. Meisinger, Heier and Löwel (2005) found a similar result, that difficulty in maintaining sleep is associated with an increased risk of type 2 diabetes in both men and women. Knutson and Van Cauter (2008) and Spiegel et al. (2009) also found similar results, but they also studied the link with obesity. They suggested that chronic partial sleep loss may increase the risk of obesity and diabetes in many ways, including adverse effects on glucose control, decreased neuroendocrine control of appetite, leading to overeating, and reduced energy intake.

Jiang et al. (2017) did research with rats that indicates a higher chance of hypertension in sleep deprived rats. Bain et al. (2017) found the same results in a study with 30 adult men. The results of the study showed that short nightly sleep duration is associated with increased cardiovascular risk and hypertension.

One of the major problems about insufficient sleep is the increased risk of car accidents. Drake et al. (2010) conducted a study to determine the risk of car crashes associated with sleepiness. The data used were from 1995-2005 from the Department of Motor Vehicles (DMV) of the United States. The authors divided the accidents into 3 groups, varying the multiple sleep latency test (MSLT) level of crash authors; the 3 groups were: ‘excessively sleepy’, ‘moderately sleepy’ and ‘alert’. The subjects classified as ‘excessively sleepy’ were in statistically significant greater risk of an accident compared to the subjects that were classified

as ‘alert’. When limited to accidents with severely injured victims, and when there was only one occupant of the car, the results were similar. The authors conclude that the MSLT, a test to measure sleepiness, is a predictor of an increased risk of automotive crashes. De Mellor et al. (2013) did a review of the literature between sleep disorders as a cause of motor vehicle collisions. The conclusion of the authors was that excessive sleepiness is a public health concern that has direct influence on the safety of all motor vehicles drivers. The authors even recommend that all disorders that are potentially linked with sleep deprivation should be investigated and monitored to diminish accidents.

Hafner et al. (2017) calculated the risk of mortality, that includes fatal car accidents, strokes, cancer or due to cardiovascular diseases, is even increased by up to 13 Per Cent for people that sleep less than six hours, on average. An individual who sleeps between six to seven hours per night has a 7 per cent higher mortality risk.

Not only health issues are associated with sleep disorders. Kalmbach et al. (2017) conducted an experiment with training physicians in their first year of residency. The authors collected data on 1215 nondepressed interns in 3 or 6 months in their internship, with a further survey after 3 months. The trainees that were poorly sleeping had elevated risk of depression and higher medical errors rate. In another study, Hafner et al. (2017) calculated that workers that sleep less than six hours per day have a loss in productivity of 2.4% than workers that sleep between seven to nine hours. Burnout has also been linked with insufficient sleep (Söderström et al, 2012).

A Study conducted by Barnes and Wagner (2009) linked the effect of the lesser amount of sleep in the first day of the Daylight Saving Time and work place injuries. The authors used a National Institute for Occupational Safety and Health of the United States database of mining injuries for the years 1983-2006. They found that on Mondays that followed the switch to Daylight Saving Time, where one hour of the night is lost, workers have more workplace injuries and also more severe ones.

2.2 Economic problems of sleep deprivation

All the effects of sleep deprivation are worryingly for a health aspect, but also for an economic view. The higher risk for mental and physical diseases, the increased error rate by workers, the higher risk of mortality and other effects have a great economic cost for the whole society. It is calculated that five OECD countries (US, Japan, UK, Canada and Germany), lose each year

up to $680 billion due to insufficient sleep (Hafner et al., 2017). In the 2016–2017 financial year, Australia had a cost of $45.2 billion, being 3.91% of Australian gross domestic product (GDP) in 2016, due to sleep disorder. This cost is divided as financial cost, with the amount of $17.88 billion, representing 1.55 per cent of Australian GDP in 2016 and the non-financial cost, which provides a value for loss of life quality, of $27.33 billion representing 4.6 per cent of the total Australian burden of disease for the same year (Hillman et al. 2018). In another essay to estimate the cost of sleep deprivation, Daley et al. (2009) calculated the annual cost of insomnia in the province of Quebec in 2009 to be $6.6 billion dollars (Cdn$). In this calculus it included costs for health care, transportation, work-related injuries, private motor vehicle accidents and other direct and indirect costs.

2.3 Behavior Economics strategies to improve sleep quality

A widely accepted strategy to improve sleep quality is sleep hygiene (SH), that is a set of recommendations for the promotion of healthy sleep that includes behavioural and environmental components. There is no consensus of all the measures that are included in the SH strategies, but accepted ones are limited daily nap time, avoid caffeine, alcohol and nicotine, frequent physical exercises, limited use of luminated screens before sleeping and a relaxing sleep environment (Mead and Irish, 2020). Even though SH strategies are well known, it is still not clear how it helps people to sleep better. Peach, Gaultney and Ruggiero (2018), in their study about sleep quality knowledge and improvement in quality sleeping, found that the knowledge about SH was not enough for people to change their behavior.

Sleep Hygiene Education (SHE) has shown inconsistent results and it is still not clear if SHE interventions lead to improved sleep quality (Irish, Kline, Gunn, Buysse, & Hall, 2015). Despite this lack of consensus, some studies have shown promising results, Hershner and O'brien (2018) were successful in using SH to improve sleep quality, they made an experiment that showed an increase in sleep quality for people that participated in an intervention with an online app that takes personal information and makes personalized advice for the users. Those pieces of advice were about SH and bad consequences of sleep deprivation. Blunden et al. (2012) argue that the biggest limitations of the studies based on SH Education is that they do not incorporate principles of behavior changes, they are based on the knowledge transfer from the provider to the patient.

The utilization of BE has been proven to be successful for behavioural changes in different fields. According to a study by Thaler and Sunstein (2008), the use of BE principles into public policy can result in more favourable outcomes, such as heightened savings and enhanced energy efficiency. Similarly, the study by Cialdini et al. (1990) has demonstrated that the employment of persuasion and social influence strategies can lead to changes in behavior in areas such as recycling and water conservation. These findings were important for the growing application of BE in different fields such as public health (Thorgeirsson & Kawachi , 2013; Shuval et al., 2017), marketing (Ariely, 2008), and education (Mullainathan & Shafir, 2013).

Based on the success of BE in behavioural changes and the lack of study of BE concepts to help sleep deprivation, Stevens (2017) suggests the use of six Behavior Economics concepts to increase the adherence of sleep interventions. One of these concepts is Salience, which refers to the degree of prominence or visibility of a particular piece of information or action (Thaler & Sunstein, 2008). In the context of promoting safe infant sleep practices, increasing the salience of the dangers associated with certain sleep practices, such as placing the infant on their stomach, can lead to changes in behavior (Stevens & Kelleher, 2017).

Another concept, Choice Overload, refers to the phenomenon of individuals experiencing anxiety or confusion when presented with too many options (Iyengar & Lepper, 2000). By providing clear and concise recommendations for safe sleep practices, the chance of choice overload can be reduced, thereby promoting the adoption of these practices (Stevens & Kelleher, 2017).

Loss Aversion, which refers to the tendency of individuals to prefer avoiding losses over acquiring gains (Kahneman & Tversky, 1979), can be used to promote safe sleep practices by highlighting the potential losses (e.g. death, injury) associated with unsafe sleep practices (Stevens & Kelleher, 2017).

Social Norms is defined as the unwritten rules and expectations that regulate behaviour within a particular group or society (Cialdini, 2003). Receiving feedback on how one's behaviour compares to a relevant group of peers through the influence of social norms can lead to changes in future actions and can be leveraged to encourage the adoption of safe sleep practices by highlighting the prevalence of these practices within a particular community (Stevens & Kelleher, 2017).

Framing, which refers to the way in which information is presented and can impact an individual's decision-making process (Tversky & Kahneman, 1981), can be used to promote safe sleep practices by presenting these practices as the norm or standard (Stevens & Kelleher, 2017).

Finally, the Identifiable Victim Effect, which refers to the tendency of individuals to be more emotionally impacted by a single identifiable individual than by a statistic or group (Slovic, 2000), can be leveraged to promote safe sleep practices by highlighting real-life cases of infants who have been injured or died as a result of unsafe sleep practices (Stevens & Kelleher, 2017).

Moreover, the utilization of BE strategies has been linked to health issues across various domains. In the field of addiction recovery, Monterosso and Ainslie (2007) have established that willpower alone is not sufficient in overcoming addiction. Instead, they propose that comprehending the underlying psychological and economic factors that contribute to addiction can lead to more efficacious treatment plans. Similarly, Thorgeirsson and Kawachi (2013) have applied BE to the promotion of healthy lifestyles, contending that interventions that take into account the psychological and economic factors that shape behavior can be more successful in increasing healthy behaviours. Shuval et al. (2017) demonstrated that the approach of BE can be applied in primary care in order to increase physical activity counselling. Roberto and Kawachi (2014) also showed the potential of BE to promote healthy eating. Lastly, Stevens and Berlan (2014) have applied BE to promote the use of long-acting reversible contraceptive methods, which suggests that understanding the underlying psychological and economic factors can lead to more effective interventions.

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3. Methodology

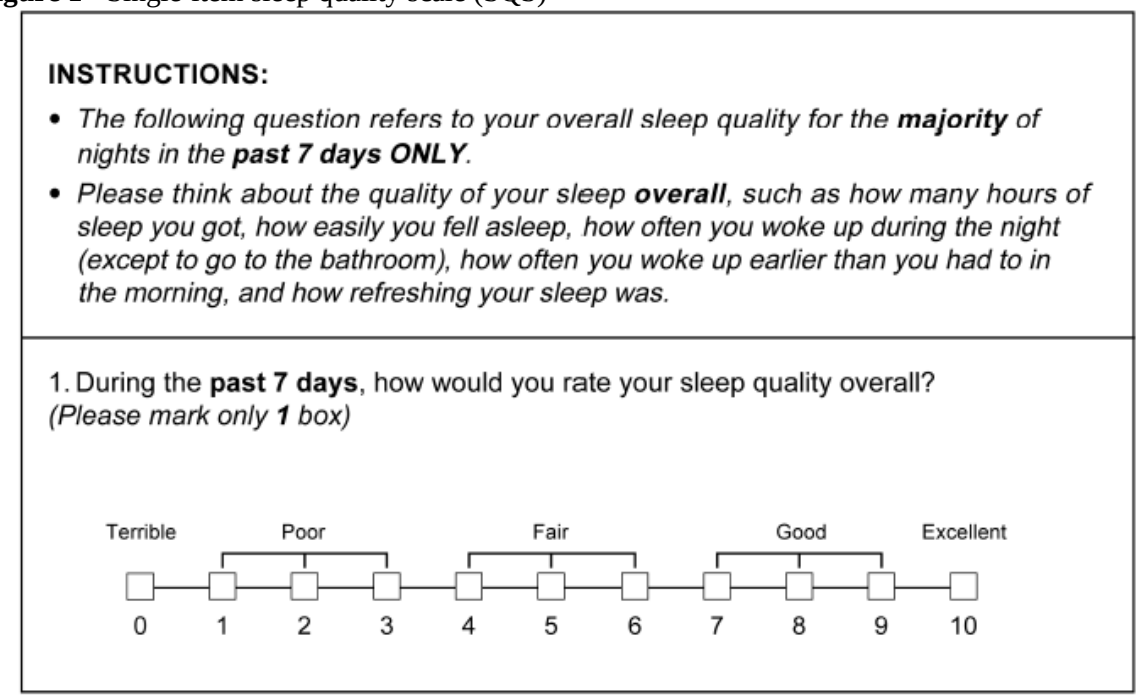
This study was divided into two phases: 1) survey and 2) intervention. The survey part aimed to identify the key habits that enhance sleep quality in the studied population. In the second part of the study, an BE based intervention was employed.

3.1 Description of the survey phase

For the first part of the study, one questionnaire with two questions was used. The questionnaires were distributed to colleagues, friends and family members.

The first question was the single-item sleep quality scale (SQS), which measures the quality of sleep. This scale has a high correlation with the Pittsburgh Sleep Quality, that is the most used one to measure sleep quality (Snyder et al., 2018). The choice for the single-item SQS instead of the Pittsburgh index was due to its simplicity and for taking into account the previous week of the surveillance instead of the past 31 days. Figure 1 illustrates the question.

Figure 1 - Single-item sleep quality scale (SQS)



Note. From Snyder, E., Cai, B., DeMuro, C., Morrison, M. F., & Ball, W. (2018). A new single-item sleep quality scale: results of psychometric evaluation in patients with chronic primary insomnia and depression. *Journal of Clinical Sleep Medicine*, *14*(11), 1849-1857.

The second part of the questionnaire was the SH Index (SHI), a 13-item self-report measure designed to assess SH behaviour. To be consistent with the SQS, the participants were asked

to consider the same last 7 days. Each item was scored from 0 (never) to 4 (always) on a five-point scale. The total score ranges from 0 to 52, with a high score indicating poor sleep hygiene. SHI shows good reliability and validity data (Mastin et al. 2006).

The 13 items were:

1. I take daytime naps lasting two or more hours.

2. I go to bed at different times from day to day.

3. I get out of bed at different times from day to day.

4. I exercise to the point of sweating within 1 h of going to bed.

5. I stay in bed longer than I should two or three times a week.

6. I use alcohol, tobacco, or caffeine within 4 h of going to bed or after going to bed.

7. I do something that may wake me up before bedtime (for example: play video games, use the internet, or clean).

8. I go to bed feeling stressed, angry, upset, or nervous.

9. I use my bed for things other than sleeping or sex (for example: watch television, read, eat, or study).

10. I sleep on an uncomfortable bed (for example: poor mattress or pillow, too much or not enough blankets).

11. I sleep in an uncomfortable bedroom (for example: too bright, too stuffy, too hot, too cold, or too noisy).

12. I do important work before bedtime (for example: pay bills, schedule, or study).

13. I think, plan, or worry when I am in bed.

3.2 Statistical analysis of the survey phase

With the data from the questionnaires, an Ordinary Least Squares regression (OLS) was used to check and classify the items that affect the SQS. Other control variables were used to help with the analysis, such as gender, age, educational level, marital status, country/region, employment status.

Before the OLS regression, a Power test was done to find out the minimum sample size needed for this regression. For that, the effect size chosen was 0.15, the alpha level was 0.05 and the desired power 0.8. The result of the Power test was that the study needed 153 respondents. So the study exceeded this number by having a total of 221.

The OLS used the single-item sleep quality as a depend variable and used the thirteen self-report measures from the SH Index as explanatory variables. Further, the control variables, such as gender, age, educational level, marital status, country/region, employment status were added. This regression was used to calculate the effect of each of the measures and to check which of the measures have a real effect in the single-item sleep quality.

All the explanatory variables were treated as dummy variables because all those variables were in ordered categorical value or categorical value. The variables in ordered categorical value and in categorical value were treated as dummy variables because regression models assume that the input of the variables are continuous. But those variables are not continuous. Due to this limitation, a set of dummy variables were created to represent the categories of the original variables. By treating these variables as a set of dummy variables, it was possible to assess the impact of each category on the dependent variable.

For the 13 measures of SHI, the comparison was made for the responses *sometimes*, *about half of the time*, *most of the time*, and *always* in comparison with *never* for each of them.

Since all 13 measures of SHI were in ordered categorical values and treated as dummy variables, we performed a Wald test, for each of them, to check the joint significance of all the scores: *never*, *sometimes*, *about half of the time*, *most of the time*, and *always* for each of the measures. This step checked if each of the 13 measures in the SHI was statistically significant in the SQS. This test helped to understand if the set of all the dummies for each of the measures were jointly significant. If the test rejects the null hypothesis, it suggests that the variables have incremental value to the model. If the test could not reject the null hypothesis, it suggests that the variables do not have incremental value to the model.

To check if omitted variables were not causing some misspecifications in the regression, a Ramsey Regression Equation Specification Error Test (RESET) test was also done. The hypothesis of the test was:

H0: Model has no omitted variables.

H1: Model has omitted variables.

3.3. Intervention phase:

From the data collected in this first part of the study, we designed an specific treatment, using the BE strategies *Social Norm* and *Choice Overload*.

By email, the control and the treatment group were contacted (see Appendix B for details). Both groups were informed that they were selected because they had answered that their sleep quality was neither good nor excellent and in a period of 10 days, they would receive another email.

The message for the treatment group also included the following information:

"*According to the data from this survey two items from the survey showed a bigger impact in the sleep quality than the others. Those two habits were: "I go to bed feeling stressed, angry, upset, or nervous" and "I think, plan, or worry when I am in bed". Those two habits have shown signs of reducing the quality of sleep of those who are used to them.*

Going to bed feeling stressed, angry, upset, or nervous can have an influence of a decrease of up to 3 points[1] *on the sleep quality scale. Thinking, planning, or worrying when in bed can also have an influence of a decrease of up to 2.8 points*[2] *in the sleep quality scale*."

The purpose of this interventional text was to encourage the participants to change their behaviour and strive for better sleep quality by highlighting the negative effects of these habits. To increase the effectiveness of the strategy of *Social Norm* (highlighting the negative effects of these habits), we used *Choice Overload* as well. Instead of presenting all the measures of the SHI, we only used the two ones with biggest impact in the study.

After ten days from this communication, another survey was sent to all the respondents with a questionnaire with the same single-item sleep quality scale. The impact of the interventional text was analysed by a Mann-Whitney U test, to compare the changing of the sleep quality between the control and treatment group. The Mann-Whitney U test is a nonparametric test to detect whether two independent samples come from the same population. The two samples are compared to each other, and not to a theoretical benchmark. In this test the null hypothesis is

[1] Although both regressions did not show any significant difference between groups, the coefficients showed a small difference. The first regression showed an influence of up to 3 points, while the final regression showed of 4.35 points.

[2] In this case the difference was smaller than 2.8 points in the first regression and 2.54 in the regression.

that samples are equal, so if we can reject the null hypothesis, the two samples are different. If we fail to reject the null hypothesis, we cannot confirm that there is a real difference between the samples.

Before the Mann-Whitney U test, a Power test was done to find out the minimum sample size needed for this test. To do the power test, the effect size chosen was 0.5, the alpha level was 0.05, the desired power 0.8 and the allocation ratio was 1. The result of this Power test gave the minimum necessary sample size is 78. However, for this experiment the sample collected was 32, indicating that the power of this test was not the ideal.

4. Data

The number of respondents in the survey was over 280, however when importing the data, some of the data had important missing values and those with missing value were disregarded. At the end, the total number of valid responses were 221. The subjects used for the intervention were only those with SQS considered fair or worst.

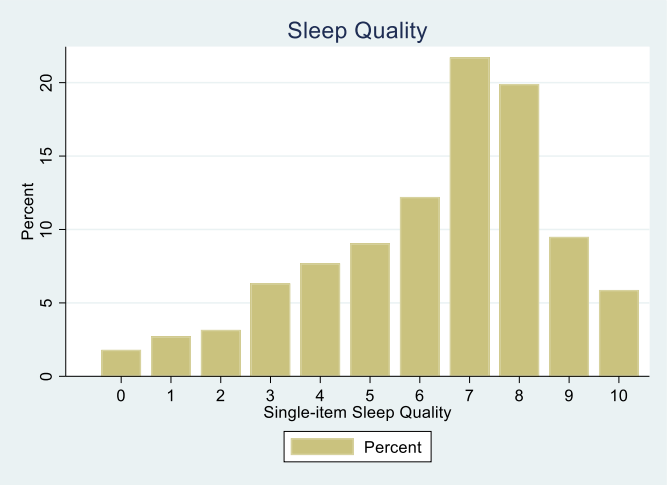
Table 1 Descriptive Statistics

Variable	Category	Frequency	Percentage	Cumulative Percentage
Gender	Male	82	37.10	37.10
	Female	139	62.90	100.00
Employment	Full time	145	65.61	65.61
	Part time	36	16.29	81.90
	Unemployed looking for work	4	1.81	83.71
	Unemployed not looking for work	2	0.90	84.62
	Retired	14	6.33	90.95
	Student	19	8.60	99.55
	Disabled	1	0.45	100.00
Nationality	Dutch	3	1.36	1.36
	Brazilian	210	95.02	96.38
	Other	8	3.62	100.00
Age	18-24	11	4.98	4.98
	25-34	49	22.17	27.15
	35-44	40	18.10	45.25
	45-54	63	28.51	73.76
	55-64	44	19.91	93.67
	65-74	13	5.88	99.55
	75-85	1	0.45	100.00
Marital Status	Married	116	52.49	52.49
	Widowed	6	2.71	55.20
	Divorced	24	10.86	66.06
	Separated	4	1.81	67.87
	Never married	71	32.13	100.00
Education	High school	14	6.33	6.33
	Bachelor's degree	71	32.13	38.46
	Master's degree	80	36.20	74.66
	PhD	49	22.17	96.83
	Other	7	3.17	100.00
Sleep Quality	0	4	1.81	1.81
	1	6	2.71	4.52
	2	7	3.17	7.69
Sleep Quality	3	14	6.33	14.03
	4	17	7.69	21.72

Variable	Category	Frequency	Percentage	Cumulative Percentage
	5	20	9.05	30.77
	6	27	12.22	42.99
	7	48	21.72	64.71
	8	44	19.91	84.62
	9	21	9.50	94.12
	10	13	5.88	100.00

For gender, all the respondents answered that they were either male or female. This survey had higher than expected females, corresponding to 63% of the total and 139 answers from the total 221. For employment, most of the subjects answered that they were full time employed with 65.6% of the total and part time, retired and students completing almost all the other answers. Most of the subjects were Brazilians with 95% and 210 out of the 221 responses. Others and Dutch corresponded for the other 5%. For age the distribution is not very concentrated, being people from 45-54 years the biggest group, corresponding to almost 30% of the sample. For marital status, 52% were married, 32% never married and 11% divorced. All the other categories had few answers. (Table 2)

Figure 2 Sleep quality distribution of the subjects



For the single item sleep quality scale, 57% of the subjects declared they had good or excellent sleep. That means that 43% declared that they did not have good sleep quality, but only 14% declared they had bad or terrible sleep quality.

Data for the treatment

For the second phase of the experiment all the respondents that declared they had a fair or worst sleep quality were contacted. They were randomly divided into two groups: control and

treatment. However only 32 of the 95 respondents answered all the questions. Inside the group of the 32 respondents, 16 were in the control group and the other 16 respondents were in the treatment group.

5. Results

5.1 OLS regression

The OLS regression aimed to identify the measures of the SHI that have the biggest influence on the Single-item sleep quality scale. The results of this OLS regression are summarized in Table 2:

Table 2 OLS Regression Results

Variables	Coefficient
I think, plan, or worry when I am in bed.	
sometimes (versus never)	0.51 (0.9)
about half of the time (versus never)	0.08 (0.98)
most of the time (versus never)	-1.19 (0.96)
always (versus never)	-2.54** (1.13)
I do important work before bedtime.	
sometimes (versus never)	-0.06 (0.46)
about half of the time (versus never)	0.24 (0.67)
most of the time (versus never)	0.14 (0.6)
always (versus never)	2.07*** (0.68)
I sleep in an uncomfortable bedroom.	
sometimes (versus never)	-0.67 (0.46)
about half of the time (versus never)	-0.66 (1.78)
most of the time (versus never)	-0.44 (0.97)
always (versus never)	-3.05 (1.88)
I sleep on an uncomfortable bed.	
sometimes (versus never)	-0.43 (0.42)
about half of the time (versus never)	-1.75* (1.04)
most of the time (versus never)	0.65 (1.14)
always (versus never)	1.86 (1.95)
I use my bed for things other than sleeping or sex.	
sometimes (versus never)	0.11 (0.45)
about half of the time (versus never)	0.32 (0.6)
most of the time (versus never)	-0.38 (0.63)
always (versus never)	0.68 (0.64)
I go to bed feeling stressed, angry, upset, or nervous.	
sometimes (versus never)	-0.63 (0.45)
about half of the time (versus never)	-1.75** (0.71)
most of the time (versus never)	-2.13*** (0.73)
always (versus never)	-4.35*** (1.25)

I do something that may wake me up before bedtime.	
sometimes (versus never)	-0.17 (0.67)
about half of the time (versus never)	0.32 (0.64)
most of the time (versus never)	0.25 (0.63)
always (versus never)	0.52 (0.68)
I use alcohol, tobacco, or caffeine within 4 h of going to bed or after going to bed.	
sometimes (versus never)	0.41 (0.32)
about half of the time (versus never)	-1.02 (0.68)
most of the time (versus never)	0.97 (0.68)
always (versus never)	0.51 (1.06)
I stay in bed longer than I should two or three times a week.	
sometimes (versus never)	0.57 (0.36)
about half of the time (versus never)	-0.2 (0.53)
most of the time (versus never)	0.7 (0.85)
always (versus never)	-2.26** (0.93)
I exercise to the point of sweating within 1 h of going to bed.	
sometimes (versus never)	0.43 (0.43)
about half of the time (versus never)	1.9*** (0.66)
most of the time (versus never)	-0.53 (0.91)
always (versus never)	0.98 (0.94)
I get out of bed at different times from day to day.	
sometimes (versus never)	-0.08 (0.42)
about half of the time (versus never)	-0.23 (0.66)
most of the time (versus never)	-0.87 (0.72)
always (versus never)	-0.84 (1.19)
I go to bed at different times from day to day.	
sometimes (versus never)	-0.35 (0.7)
about half of the time (versus never)	0.15 (0.91)
most of the time (versus never)	-0.44 (0.82)
always (versus never)	0.31 (0.98)
I take daytime naps lasting two or more hours.	
sometimes (versus never)	-0.54 (0.35)
about half of the time (versus never)	-1.2 (1.06)
most of the time (versus never)	0.33 (1.41)
always (versus never)	-0.11 (0.94)
Gender	
female (versus male)	-0.18 (0.31)
Employment	

part time (versus fulltime)	0.98** (0.43)
unemployed looking for work (versus fulltime)	1 (1.19)
unemployed not looking for work (versus fulltime)	3.12*** (1.1)
retired (versus fulltime)	0.55 (0.75)
student (versus fulltime)	0.88 (0.67)
disabled (versus fulltime)	-1.83 (1.48)
Nationality	
Brazilian (versus Dutch)	1.3 (1.24)
Other (versus Dutch)	0.41 (1.34)
Age	
25-34 (versus 18-24)	-1.09 (0.92)
35-44 (versus 18-24)	-0.68 (1.13)
45-54 (versus 18-24)	-1.33 (1.15)
55-64 (versus 18-24)	-0.92 (1.25)
65-74 (versus 18-24)	-1.49 (1.41)
75-85 (versus 18-24)	2.64 (1.87)
Marital Status	
widowed (versus married)	1.57** (0.71)
divorced (versus married)	-0.78 (0.58)
separated (versus married)	0.58 (0.58)
never married (versus married)	0.93* (0.5)
Education	
bachelor's degree (versus high school)	2.15** (0.87)
master's degree (versus high school)	2.15** (0.89)
phd (versus high school)	2.7*** (0.93)
other (versus high school)	3.46*** (0.97)
Constant	5.37** (2.56)

Note: OLS coefficient. Standard errors in parentheses. Significance levels: *: 10%, **: 5%, ***: 1%.

The results of the RESET test shows that we cannot reject the hypothesis that the model has no omitted variables with 1% significant level. (Table 3)

Table 3 RESET Test Results

Test	F-value	Df	Probability
Ramsey RESET	1.53	3, 142	0.2089

In the table, the "F-value" and "Probability" columns represent the results of the RESET test. The "df" column stands for degrees of freedom, which is a measure of the number of independent pieces of information in the test. The "Omitted" row indicates the variables that were left out of the model. The "H0" row states the null hypothesis, which in this case is that the model has no omitted variables.

The Wald test to check the joint significance for each of the measures of the SH Index have shown that 5 measures were statistically significant, with two statistically significant at 1% level. (Table 4)

Table 4 Joint Test Results

Variable	F-value	Df	Probability
I think, plan, or worry when I am in bed.	7.07	4, 145	0.0000***
I do important work before bedtime.	2.98	4, 145	0.0213**
I sleep in an uncomfortable bedroom.	1.25	4, 145	0.2908
I sleep on an uncomfortable bed.	1.60	4, 145	0.1782
I use my bed for things other than sleeping or sex.	0.87	4, 145	0.4857
I go to bed feeling stressed, angry, upset, or nervous.	4.25	4, 145	0.0028***
I do something that may wake me up before bedtime.	0.49	4, 145	0.7457
I use alcohol, tobacco, or caffeine within 4 h of going to bed or after going to bed.	1.48	4, 145	0.2105
I stay in bed longer than I should two or three times a week.	2.46	4, 145	0.0481**
I exercise to the point of sweating within 1 h of going to bed.	2.69	4, 145	0.0336**
I get out of bed at different times from day to day.	0.57	4, 145	0.6850
I go to bed at different times from day to day.	0.52	4, 145	0.7199
I take daytime naps lasting two or more hours.	1.38	4, 145	0.2449

In the table, the "F-value" and "Probability" columns represent the results of the joint test for each variable. The "df" column stands for degrees of freedom, which is a measure of the number of independent pieces of information in the test. Significance levels: *: 10%, **: 5%, ***: 1%.

The results of the OLS show that, on average, a person that always goes to bed feeling stressed, angry, upset, or nervous have a negative effect of 4.35 points in the single-item sleep quality scale, when compared to a person that never goes to bed feeling stressed, angry, upset, or nervous, ceteris paribus. This effect can be the difference between a person that has poor sleep quality and a good sleep quality, showing the huge effect that this measure has on the quality of sleep in a person.

Thinking, planning, and worrying when in bed has also a considerable impact in the sleep quality of the subjects. On average, a person that always think, plan, or worry when in bed have a negative effect of 2.54 points in the single-item sleep quality scale, when compared to a person that never think, plan, or worry when in bed, ceteris paribus.

The item *I stay in bed longer than I should two or three times a week*, have also shown a negative impact in their sleep quality. On average, a person that always stays in bed longer than it should two or three times a week have a negative impact of 2.26 points in the single-item

sleep quality scale, when compared to a person that never stays in bed longer than it should two or three times a week, ceteris paribus.

An interesting result occurred in the other two items in the SH Index: item *I exercise to the point of sweating within 1 h of going to bed* and item *I do important work before bedtime* shows that they have shown a positive impact in the single-item sleep quality scale. This result is not coherent with what is expected by the SH Index, where the more a person do one of the items, the worst the sleep quality should be.

The item *I exercise to the point of sweating within 1h of going to bed* shows that on average, a person that always exercise to the point of seating within 1h of going to bed have a positive impact of 0.98 point in the single-item sleep quality, when compared to a person that never exercise to the point of seating within 1h of going to bed, ceteris paribus.

The item *I do important work before bedtime* shows that on average, a person that always do important work before bedtime have a positive impact of 2.07 points in the single-item sleep quality, when compared toa a person that never do important work before bedtime. This impact is even bigger than the item *I exercise to the point of sweating within 1 h of going to bed*. This item having such a big impact on the sleep quality and being statistically significant is big outlier inside the SH Index.

5.2 Treatment

Table 5 Descriptive Statistics of Participants in the Control Group

Variable	Category	Frequency	Percentage	Cumulative Percentage
Sleep Quality before treatment	0	1	6.25	6.25
	1	1	6.25	12.5
	2	2	12.5	25
	3	1	6.25	31.25
	4	2	12.5	43.75
	5	4	25	68.75
	6	5	31.25	100
Average SQ before treatment	5.13			
Sleep Quality after treatment	0	1	6.25	6.25
	1	1	6.25	12.5
	2	0	0	12.5
	3	2	12.5	25
	4	2	12.5	37
	5	2	12.5	50

	6	3	18.75	68.75
	7	4	25	93.75
	8	1	6.25	100
	9	0	0	100
	10	0	0	100
Average SQ after treatment	5.94			

Table 6 Descriptive Statistics of Participants in the Treatment Group

Variable	**Category**	**Frequency**	**Percentage**	**Cumulative Percentage**
Sleep Quality before treatment	0	1	6.25	6.25
	1	0	0	6.25
	2	1	6.25	12.5
	3	2	12.5	25
	4	5	31.25	56.25
	5	3	18.75	75
	6	4	25	100
Average Sleep Quality before treatment	5.19			
Sleep Quality after treatment	0	0	0	0
	1	1	6.25	6.25
	2	0	0	6.25
	3	1	6.25	12.5
	4	3	18.75	31.25
	5	1	6.25	37.5
	6	6	37.5	75
	7	1	6.25	81.25
	8	1	6.25	87.5
	9	0	0	87.5
	10	2	12.5	100
Average Sleep Quality after treatment	6.75			

For the second part of the experiment, a total of 32 responses were gathered, being 16 from the control group and 16 from the treatment group. The data presented in tables 6 and 7 indicate that the sleep quality of both the control and treatment groups showed improvement during the study. Prior to the treatment, the average sleep quality of the control group was 5.13 and the treatment group had an average sleep quality of 5.19, which were relatively similar. However, following the treatment, the average sleep quality for the control group rose to 5.94, and the treatment group's average increased to 6.75. The larger gap between the two groups is an indication that the treatment had some effectiveness in increasing the sleep quality of the

subjects. However, with only the descriptive statistics of the two groups we cannot prove that the success of the treatment.

Table 7 Mann-Whitney U Test Results

Group	Observations	Rank Sum	Expected Rank Sum
Control	16	248	264
Treated	16	280	264
Combined	32	528	528

Statistic	Value	Probability	Exact Probability
Z	-0.613	0.5401	0.5520

In the table, the "Observations" column indicates the number of observations in each group, and the "Rank Sum" column shows the sum of the ranks in each group. The "Expected Rank Sum" column shows the expected rank sum for each group based on the null hypothesis. The "Value" column in the second table shows the value of the test statistic, and the "Probability" column shows the p-value of the test. The "Exact Probability" column shows the exact probability of the test.

The Mann-Whitney test fails to reject the null hypothesis, showing that the difference between the two groups is not statistically different. This means that the treatment in this experiment was not sufficient to increase the sleep quality in the treated subjects.

6. Discussion

One of the goals of this study was to investigate the most impactful measures of the Sleep Hygiene Index (SHI) on sleep quality. Results indicate that the measures from the SHI that had the greatest impact on sleep quality were "*I think, plan, or worry when I am in bed*" and "*I go to bed feeling stressed, angry, upset, or nervous*." Other important measures identified included "*I do important work before bedtime*," "*I stay in bed longer than I should two or three times a week*," and "*I exercise to the point of sweating within 1 h of going to bed.*"

However, it is worth noting that "*I do important work before bedtime*" and "*I exercise to the point of sweating within 1 h of going to bed*" showed inconsistent results compared to what the SHI implies. These measures were found to have a positive impact on sleep quality, whereas the SHI suggests that these habits would lead to poorer sleep quality. This highlights the need for further research to better understand the complex relationship between SH and sleep quality.

The other goal of this study was to use the information gathered from the previous regression and create an intervention, using some BE strategies to try to improve the sleep quality of the subjects. The two measures from the SHI were the two that showed the biggest importance the quality of sleep and they were "*I think, plan, or worry when I am in bed*" and "*I go to bed feeling stressed, angry, upset, or nervous*" and the two BE strategies chosen for the intervention were "*social norm*" and "*choice overload*". For the intervention only the participants that had the single item sleep quality scale (SQS) equal or under 6 were tested, and a randomized sample of these subjects were in the control group and in the treated group.

The outcome of the intervention failed to reveal any statistical significance variation between the control and treatment groups. But, when examining the average SQS scores, the treatment group recorded an average of 6.75, while the control group registered an average of 5.94. It's important to note that prior to the intervention, the average SQS scores for both groups were 5.19 and 5.13, respectively. These results imply that BE techniques may enhance sleep quality. However, further research is necessary to draw a definite conclusion.

The sample used in this studied was composed majorly from Brazilians with a high level of education, with more than 60% having at least a Master's degree. This may introduce a potential bias in the education level, as access to higher education and English language in Brazil is not as widespread as in other countries. A study by (Li, et al., 2019) found that individuals with

higher levels of education reported better sleep quality compared to those with lower levels of education. The study found that individuals with a college degree or higher had better sleep efficiency, less insomnia symptoms and wake up feeling more refreshed than those with less than a college degree.

Another characteristic of the sample is that more than 85% of the sample have at least "*fair*" sleep quality. Despite cutting off subjects with reported sleep quality of "*good*" or better, the majority of the sample for the intervention had a sleep quality that was close to "*good*". This suggests that there may be a need for further research that focuses specifically on individuals with poor or very poor sleep quality. Such a study could help to identify more effective interventions for those who are struggling the most with sleep problems and potentially provide more tailored treatment options. Additionally, it would be beneficial to investigate whether the results of the current study would be generalizable to those with severe sleep disturbances, as the current sample primarily consisted of individuals with moderate to mild sleep difficulties.

The Sleep Hygiene Index created by Mastin et al. (2006) is not specific about the time to consider for the responses of the questionnaire. Due to this lack of transparency about the time to consider, this study uses the prior 7 days of the response as the time to consider. The 7 days prior to the survey is consistent with the single-item sleep quality scale that uses this specific amount of time.

The intervention did not show any real improvement in the sleep quality of the subjects, and this could be due to some limitations in the experiment. One possibility is that the intervention was not implemented consistently or was not delivered with sufficient intensity. Behavior changing interventions often require consistent implementation and reinforcement in order to be effective. A lot of people do not read their emails very often and they receive a lot of spam messages, so the intervention email can be easily disregarded by the subjects. The announcement in the questionnaire of a future approach by email is a manner to try to minimize this limitation, however it is not clear how effective this was. A possibility to tackle this problem may be to do the treatment in manner that the subjects is more likely to respond, which can be done by some compensation for the subject to respond all the answers or to even have a lottery with a higher compensation for those that answered all the questions.

It is also worth noting that the sample size for the intervention of this study was relatively small, which may have limited the power of the Mann-Whitney U test done in this study to

detect significant differences between the intervention and control groups. A larger sample size may have yielded different results.

Additionally, other factors that were not accounted for in the study, such as underlying medical conditions or work or family demands, may have had a stronger influence on the participants' sleep quality. These variables could have masked any potential benefits of the behavior economics intervention.

Despite the lack of a significant effect in the intervention of this study, it is still possible that a BE intervention could be useful in addressing sleep deprivation in other contexts or with a different population, these treatments have shown positive returns inside health economics in other areas (Schwartz, 2004; Stevens, 2017). Further research is needed to determine the effectiveness of this type of intervention in different settings and to identify potential factors that may influence its success.

7. Conclusion

In this study, consisting mostly of Brazilian well educated participants, evidenced a good sleep quality and the two most impactful SH habits were a) *going to bed feeling angry, upset, or nervous* and b) *thinking, planning,* and *worrying when in bed*.

Another interesting finding is that the two habits *I exercise to the point of sweating within 1 h of going to bed* and *item I do important work before bedtime* have shown a positive impact on sleep quality, which is contrary to the belief of sleep hygiene.

The result of the intervention that utilized *social norm* and *choice overload* as BE principles showed indication of an improvement in sleep quality among the subjects, however it did not present a statistically significant effect on sleep quality.

Overall, this study highlights the complexity of addressing sleep deprivation and the need for further research to understand the most effective interventions for improving sleep outcomes. While behavior economics principles such as *social norm* and *choice overload* may have potential as tools for improving sleep habits, this study suggests that further research is still needed to prove the effectiveness of behavior economics principles in improving sleep quality.

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9. Appendix

Appendix A

First Survey

Consent form

Survey master thesis Frederico Brant.

This survey is part of my master thesis in Behavioural Economics at the Erasmus University Rotterdam.

The survey will collect information about sleep quality and habits associated with it. All data retrieved will be handled confidentially and will not be shared with anybody else. You will be asked to share an email address, because we could need to contact you for a follow up study. The email address will be excluded from our data as soon as all the results needed are gathered. Some demographic questions are used to understand the main traits of the population and not to identify the single participants.

If you agree to take part in this survey you can continue.

Thank you for participating.

Personal questions

*What gender do you identify as?

- ◯ Male
- ◯ Female
- ◯ Non-binary / third gender
- ◯ Prefer not to say

*What is your employment status?

- ◯ Employed full time
- ◯ Employed part time
- ◯ Unemployed looking for work
- ◯ Unemployed not looking for work
- ◯ Retired
- ◯ Student
- ◯ Disabled

*Email

*What nationality are you?

- ◯ Dutch
- ◯ Brazilian
- ◯ Other

*Age group

- ◯ Under 18
- ◯ 18 - 24
- ◯ 25 - 34
- ◯ 35 - 44
- ◯ 45 - 54
- ◯ 55 - 64
- ◯ 65 - 74
- ◯ 75 - 84
- ◯ 85 or older

*Marital status

- ◯ Married
- ◯ Widowed
- ◯ Divorced
- ◯ Separated
- ◯ Never married

*What is your highest level of education? If currently enrolled, highest degree received.

- ◯ Less than High School
- ◯ High school
- ◯ Bachelor's Degree
- ◯ Master's Degree
- ◯ PhD
- ◯ Other

Sleep habits

In this block of the questionnaire you will find a list of statements. Please rate how true each statement is, according to their frequency in the past 7 days.

*I take daytime naps lasting two or more hours.

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I go to bed at different times from day to day.

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I get out of bed at different times from day to day.

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I exercise to the point of sweating within 1 h of going to bed.

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I stay in bed longer than I should two or three times a week.

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I use alcohol, tobacco, or caffeine within 4 h of going to bed or after going to bed.

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I do something that may wake me up before bedtime (for example: play video games, use the internet, or clean).

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I go to bed feeling stressed, angry, upset, or nervous.

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I use my bed for things other than sleeping or sex (for example: watch television, read, eat, or study).

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I sleep on an uncomfortable bed (for example: poor mattress or pillow, too much or not enough blankets).

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I sleep in an uncomfortable bedroom (for example: too bright, too stuffy, too hot, too cold, or too noisy).

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I do important work before bedtime (for example: pay bills, schedule, or study).

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

*I think, plan, or worry when I am in bed.

- ◯ Never
- ◯ Sometimes
- ◯ About half the time
- ◯ Most of the time
- ◯ Always

Single-item Sleep Quality

INSTRUCTIONS:

- The following question refers to your overall sleep quality for the **majority** of nights in the **past 7 days ONLY.**
- Please think about the quality of your sleep **overall**, such as how many hours of sleep you got, how easily you fell asleep, how often you woke up during the night (except to go to the bathroom), how often you woke up earlier than you had to in the morning, and how refreshing your sleep was.

*During the **past 7 days**, how would you rate your sleep quality overall. According to the following five categories:

- 0 = terrible
- 1–3 = poor
- 4–6 = fair
- 7–9 = good
- 10 = excellent

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10

Appendix B

Emails

Email intervention example

Control group:

"Hello!

This is Frederico Eloi Brant and I am getting in touch for the follow up of the survey for my master thesis. You are receiving this email because you answered that your sleep quality was neither good nor excellent. In ten days, you are going to receive a new email with a link for the second part of the survey, which will take you no more than 3 minutes and ask you further questions on your sleep quality.

Thank you very much for responding to the survey and have a nice day!"

Treatment group:

"Hello!

This is Frederico Eloi Brant and I am getting in touch for the follow up of the survey for my master thesis. You are receiving this email because you answered that your sleep quality was neither good nor excellent.

According to the data from this survey, two items from the survey showed a bigger impact in the sleep quality than the others. Those two habits were: "I go to bed feeling stressed, angry, upset, or nervous" and "I think, plan, or worry when I am in bed". Those two habits have shown signs of reducing the quality of sleep of those who are used to them.

Going to bed feeling stressed, angry, upset, or nervous can have an influence of a decrease of up to 3 points on the sleep quality scale. Thinking, planning, or worrying when in bed can also have an influence of a decrease of up to 2.8 points in the sleep quality scale.

In ten days, you are going to receive a new email with a link to the second part of the survey, which will take you no more than 3 minutes and ask you further questions on your sleep quality.

Thank you very much for responding to the survey and have a nice day!”

Follow up email for the last results:

Last email:

Dear volunteer

Hello!

This is Frederico Eloi Brant and I am getting in touch again for the final phase of my master study. Now it is just one more question about your sleep quality. Your answer is very important to complete the understanding of the results.

Please find the form using this link.

https://erasmusuniversity.eu.qualtrics.com/jfe/form/SV_6eXWnJv6SifDP1A

Thank you very much for collaborating with this study and have a nice day!

Second try last email:

Dear collaborator

I am writing to tell you that although we received most of the answers necessary to finish our work, some still remained unanswered, including yours.

Since we need to complete this investigation, I kindly ask you again to answer this very last question.

https://erasmusuniversity.eu.qualtrics.com/jfe/form/SV_6eXWnJv6SifDP1A

Sorry for the inconvenience but your answer is really very important.

Sincerely,

Frederico Eloi Brant

Appendix C

Second Survey

Consent

Survey master thesis Frederico Brant.

This survey is part of my master thesis in Behavioural Economics at the Erasmus University Rotterdam.

The survey will collect information about sleep quality and habits associated with it. All data retrieved will be handled confidentially and will not be shared with anybody else. You will be asked to share an email address, because we could need to contact you for a follow up study. The email address will be excluded from our data as soon as all the results needed are gathered.

Thank you for participating.

Email

*Email

Single-item Sleep Quality

INSTRUCTIONS:

- The following question refers to your overall sleep quality for the **majority** of nights in the **past 7 days ONLY.**
- Please think about the quality of your sleep **overall**, such as how many hours of sleep you got, how easily you fell asleep, how often you woke up during the night (except to go to the bathroom), how often you woke up earlier than you had to in the morning, and how refreshing your sleep was.

*During the **past 7 days**, how would you rate your sleep quality overall. According to the following five categories:

- 0 = terrible
- 1–3 = poor
- 4–6 = fair
- 7–9 = good
- 10 = excellent

- ◯ 0
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10