Sleep and its effect on food related self-control

- Master Thesis -

by:

Name: Iris E. M. van Hooijdonk

Student-number: 3917517

E-mail: i.e.m.vanhooijdonk@students.uu.nl

Master: Toegepaste Cognitieve Psychologie/Applied Cognitive Psychology

Amount of ECTs: 27,5

Utrecht University

Faculty of Social Sciences

Psychology

In association with

Nutritional Neuroscience Laboratory

UMC

July 2016

Intern supervisor: *J. S. Benjamins*

Extern supervisor: *L. N. van der Laan*

First reviewer: *J. S. Benjamins*

Second reviewer: *J. H. A. Hogendoorn*

Abstract

During the last decades the obesity rate has grown dramatically. That is why a lot of research has been done on possible causes. One such plausible link has been found in sleep deprivation. Sleep deprivation has been linked to an impaired prefrontal cortex (PFC) and executive functioning, of which self-control is an important part. This is why the main purpose of this study was to investigate the effect of sleep on food-related self-control. The manipulation of sleep was controlled by the Munich Chronotype Questionnaire (MCTQ), online sleep diaries, by wearing an actigraph device and through performing the Psychomotor Vigilance Task (PVT). Food choices as well as self-control were measured using a choice task with simultaneous eye-tracking measurements. As expected, no deviations were found in sleep patterns between control and experimental weeks, but reaction times were significantly slower during the wake condition in the experimental week. However, participants chose healthy products more often and rated these also higher in both conditions. No significant effects were found in reaction times of the responses during the choice task between the sleep and wake condition. When dividing the group into restrained and non-restrained eaters, only the non-restrained eaters seemed to be affected by sleep deprivation. These contrasting results strengthen the fact that more research has to be done.

Introduction

When people in The Netherlands are asked about their eating habits, they rate their healthy eating behavior an average of 7,3 on a ten point scale. 84% of 1003 respondents were positive or very positive about the amount of healthy food they eat. One third of the respondents are or have been dieting even to gain a normal weight (Voedingscentrum, 2012). However, during the last decades the number of people with obesity has grown dramatically (Knutson, Spiegel, Penev & Van Cauter, 2007). The obesity rates in the Netherlands, for example, shifted from 5% of the adults in 1981 to 12% of the adults in 2012, in which the largest share was women (CBS StatLine, 2013). In these studies, a Body Mass Index (BMI) ($kg/m^{2)}$ of 25 and over is used to classify people as overweight and a BMI of 30.0 and over is often used to define obesity (Nguyen & El-Serag, 2010).

A major contribution to obesity is the enlarged intake of food which contains a large amount of fat and calories (Dalton, Blundell & Finlayson, 2012). This enlarged food intake in combination with the lack of exercise of overweight people often leads to several diseases or health issues. For instance; overweight people have a higher risk at diabetes, strokes and several kinds of cancer (Nguyen & El-Serag, 2010; Ogunbode, Fatiregun & Ogunbode, 2009). Furthermore, an association between obesity and a higher chance of death has been found. This chance is doubled in comparison with people of normal weight (Nguyen & El-Serag, 2010). Apart from the higher risks at diseases and even mortality, obesity also has a lot of psychological and social effects for the obese person him/herself (Puhl & Heuer, 2009). And at last, obesity puts the society and economy to large expenses, due to reduced productivity and higher rates of absenteeism (Narbo, et al., 1996).

Because of these severe consequences of overweight, there has been a lot of research on the possible causes and mechanisms of people becoming overeaters (Aronne & Segal, 2003; Bjorvatn et al., 2006; Doustmohammadian, Abdollahi, Bondarianzadeh, Houshiarrad, & Abtahi, 2012; Fliers, et. al., 2013;). One such plausible cause has been found in sleep deprivation. Research has shown that the average of people's sleep duration has declined during the last decades. At the same time, the amount of people with obesity has increased (Knutson, Spiegel, Penev & Van Cauter, 2007). Research on the association between sleep deprivation and the amount of ingested food shows that sleep deprivation will lead to an increase in BMI and obesity. This association between sleep deprivation during working weeks and BMI has a U-shape curve, with highest BMI scores in people with fewer than 6

hours or more than 9 hours of sleep (Bjorvatn et al., 2006). Note that, over 30 percent of the people have a sleep average of 6 hours per night (Knutson, et al., 2007).

Besides changes in lifestyle, societal changes in work behavior can be an explanation for the rising overweight by sleep deprivation in developed countries (World Health Organization, 2009). Currently, the society is changing into a 24-hours society, with its call upon working outside office hours. A 24-hours society contains, as a result, a lot of shift work. Having a job as a shift worker means working longer hours at varying time schedules during a day. This leads to interruptions in circadian rhythm and sleep restrictions (Atkinson, Fullick, Frindey & Maclaren, 2008), which can result in chronic sleep loss or sleep debt (Leonard, Fanning, Attwood & Buckley, 1998). Some studies show that chronic sleep loss and sleep debt can result in overweight among shift workers, because they are affecting the quality of healthiness, the quantity of the food intake as well as its distribution (Atkinson, et al., 2008; Reinberg et al., 1979).

People heighten their overall food intake with 22,5% due to sleep deprivation in comparison with a night of normal sleep (Brondel, Romer, Bougues, Touyarou and Dayenne, 2010). This significant effect of sleep deprivation on higher energy and fat intake has also been found in St-Onge et al. (2011). Besides a higher intake of foods containing high calories and fat, people also eat less fruit and vegetables after sleep deprivation, eat more fast food (Stamatakis & Brownson, 2008), eat during unconventional eating hours and prefer snacks over meals (Kim, DeRoo & Sandler, 2011; Reinberg, et al., 1979). The preference in snacks is mainly for sweet snacks (Heath, et al., 2012).

However, the exact mechanisms between sleep patterns and change in food choice and intake are not clear. Other physical or mental processes may be linked to it as well. For example, the overall increased intake of energy after sleep deprivation appears to be due to disturbance in the energy balance (Jung, et al., 2011). Possibly, people eat for homeostatic reasons, so they can get their energy levels stabilized and sustain their wakefulness (Markwald, et al., 2013). Hormones like leptin and ghrelin, which regulate the appetite, seem to be affected by sleep restriction. Studies show that leptin (reducer of appetite) decreases and ghrelin (stimulator of appetite) increases after a night with sleep restriction (Knutson, et al., 2007; Spiegal, Knutson, Leproult, Tasali & Van Cauter, 2005). Nevertheless, Markwald et al. (2013) showed that people eat more than can be explained by homeostatic reasons.

Another mechanism that could explain the over-eating process after sleep deprivation is the increased sensitivity of reward areas in the cognitive system to high caloric foods (Hogenkamp, et al., 2013). Alternatively, emotions can also play a major role in the

overeating process. Vgontzas, Lin and Papaliaga (2008) showed that sleep deprivation can result in emotional distress. Eating compensates emotional distress after a night with lack of sleep as it reduces your arousal levels, calms you down and makes you feel satisfied. The emotional difficulties after a sleep-deprived night may lead to overeating (Gibson, 2006).

Furthermore, there are more studies that associate these differences in food preference after sleep deprivation to impairments of the brain, which in turn cause behavioral changes (Desimone & Duncan, 1995; Jones & Harrison, 2001; Killgore, Balkin & Wesensten, 2006; Miller & Cohen, 2001; Muzur, Pace-Schott & Hobson, 2002). Sleep deprivation has been linked to an impaired prefrontal cortex (PFC) in several studies (Jones & Harrison, 2001; Killgore, Balkin & Wesensten, 2006; Muzur, Pace-Schott & Hobson, 2002). This brain region is important for top-down processes used by attention and executive functioning (Desimone & Duncan, 1995;Miller & Cohen, 2001). An important part of (impaired) executive functioning (by sleep deprivation) is self-control. Self-control is someone's capability to modify his or her state or responses (Baumeister, 2002). This mechanism of self-control is necessary when there are conflicting goals and desires (Baumeister & Vohs, 2007), in which a person wants to resist short-term pleasures by behaving in line with his/her long-term goals (Hofman, Friese & Strack, 2009). However, after a night of deprived sleep, people are often more impulsive and are not as good in making decisions. Their accuracy and time to react is also affected (Ratcliff & Van Dongen, 2009). This is the reason why research suggests that people with good sleeping habits have better self-control, because sufficient sleep is necessary to complement self-regulatory energy (Barber, Grawitch & Munz, 2013). However, Vohs, Glass, Maddox and Markman (2011) reported that sleep deprivation did not have a direct link to self-control after measuring responses during an aggressive videogame. Because of these contrasts in literature, further research that investigates the connections between sleep and self-control must be performed.

As stated before, self-control is needed when making decisions between conflicting goals and desires. Van der Laan, De Ridder, Charbonnier, Viergever and Smeets (2014) researched this topic. They investigated whether there is a self-control conflict in women with healthy long-term goals when they are confronted with choices between tasty high energy food (HE) and less tasty low energy food (LE). Contrary to the expectations, no conflict and no use of self-control was found in this condition in women. They chose as if they had no long-term goal, as if they were not weight-concerned. The absence of the conflict is curious, since the women in the experiment were tested on their long-term goals, which in turn should conflict with short-term pleasures. The absent use of self-control in the study from Van der

Laan, et al. (2014) may be explained by research of Vohs, et al. (2014). This research showed that making choices leads to a reduced self-control. People who made choices had poorer self-regulation than people who did not have to make a choice. This result was found in assigned choices as well as in spontaneous choices (Vohs, et al., 2014).

As is clear from the above, existing literature only discusses the links between sleep and choices, sleep and self-control or self-control and choices. Furthermore, within these studies the results are often contradictive to each other. For this reason, there have to be looked for a possible link between all three factors thoroughly: sleep, self-control and choices. Especially food-choices. These food-choices should be investigated in female students of healthy weight, as this gender constitutes the mayor part of people with obesity. Besides, women are more often weight concerned, so they make more use of their self-control (CBS StatLine, 2013; Hebl & Mannix, 2003). By exploring these subjects, the existing literature can possibly be expanded. The results of this study may also aid in the prevention of healthy women becoming overweight at a later age.

Because of the existing knowledge gap in contemporary literature as well as the social relevance, this research will attempt to answer the following question: What is the effect of sleep deprivation on food-related self-control? This results in a number of underlying questions: Firstly, is there a difference in food liking between a normal night of sleep and a sleep deprived night? This means that people may eat because of cognitive reasons; as their reward systems are more sensitive after sleep deprivation. Secondly, is there a change in food choice after sleep deprivation? Thirdly, can participants use their self-control to give successful answers in relation to their goals (choosing low energy products (LE) instead of high energy (HE) ones)?

All of these research questions will be tested using a food choice task with simultaneous eye-tracking measurements. Based on the literature, it is predicted that after sleep deprivation the average liking of HE products will be higher and the average liking of LE products will stay the same. Another expectation is that people will choose unhealthy high energy foods more often due to sleep deprivation. Besides that, more self-control will be needed from the participants in the trials with tasteful high-energy foods versus less tasteful low-energy foods in comparison to the other trial categories. It is expected that this self-control will work best after a normal night of sleep, which will make them choose the low energy products more often in this condition.

Method

Participants

A number of 14 female students volunteered to participate in this research. However 3 of them were excluded, because of withdrawal and technical issues. The eleven remaining participants were included for further analysis. The age range of this student population was from 18 to 27 (M=21, SD=2.49). All of the eleven women were tested on their weight concern (a score of 2.8 or higher on the Dutch Eating Behavior Questionnaire (DEBQ) was categorized as restrained) and on their BMI score (M=21.1, SD=1.38). Participants were included when they were women with a healthy weight (BMI: 18.5- 25), no heavy smokers, drinkers, drugs abusers, vegans, and did not have a food allergy or eating disorder. The participants were mainly collected within the University of Utrecht, within the department Psychology. They were recruited for this research using flyers at the University Utrecht (UU), by ads on Facebook as well as on the experiment site of the UU. Students could participate for 4 hours of participation credits.

Apparatus

Several kinds of questionnaires and programs have been used in this research. The participants started by filling in the Dutch Eating Behavior Questionnaire (DEBQ), some background questions as well as some questions about their goals to be and eat healthy (Appendix I). These questionnaires were emailed to them. When the participant fitted in the target audience they got an email with access to the online survey program containing the Munich Chronotype Questionnaire (MCTQ) as well as an online sleep diary (constructed in online platform LimeSurvey). A day before the first lab day they filled in an informed consent form and they received an actigraph device from GENEActiv, which they wore the next 24 hours. During both lab days (explained in procedure) the participants had to fill in a hunger/satiety test on paper, perform the Psychomotor Vigilance Task (PVT) and were presented a food choice task, programmed in MatLab® presented on a Windows XP computer fitted with a chinrest and an EasyGaze™ eye tracker to measure eye movements. At the end of the second lab session the participants were also presented with the Dutch version the Barrat Impulsiveness Scale (BIS-11)(Patton, et al., 1995) and of the Multidimensional Assessment of Interoceptive Awareness (MAIA) (Mehling, et al., 2012) on paper. The data of the MAIA test were obtained for a follow-up study, and therefore results will not be reported here. The lab sessions were held in a lab in the Langeveld building on the University campus.

Procedure

When women were included in the experiment, they received an email with explanation about the test (Appendix II) and access to their research account on online survey program called Limesurvey. Each participant started with filling in the MCTQ once and filled in an online sleep diary for one week before each lab day. These diaries and MCTQ were checked afterwards on deviations in sleep behavior. After a week of filling in these sleep diaries, the first lab day followed. In total there were two lab days, in which the participants performed the same tests. One lab day was after a night of 8 hours sleep (sleep condition). The other lab day was after a night of 4 hours sleep, which were the last hours of a normal 8 hours sleep (for brevity reasons we relabeled the 'sleep deprivation condition' as 'wake condition' in this research). For instance, if the participant went to bed at 24 o'clock in the sleep condition, she now went to sleep at 4 and got up at 8 o'clock in the morning. Hereby, the participants still had their REM sleep in which emotions are regulated. It was necessary that this emotion regulation stayed the same between the two lab days, because emotional distress has a major influence on overeating, which is not an influence we wanted to test.

An actigraph device was picked up by the participants at least a day before the first lab. To receive the actigraph device of GENEActiv the participant had to fill in the informed consent first (Appendix III). The next 24 hours the participant wore this actigraph device. Furthermore, the participants were prohibited to eat or drink after 22 o'clock before each lab day. They were only allowed to drink water, so they came fasted to the experiment. This is because we did not want the participants to compensate their lack of energy with food or stimulating drinks like coffee.

On each lab day the researcher started with giving an explanation about the tests. Next, a questionnaire about their hunger and thirst was filled in by the participant on paper. The participants could rate their hunger and thirst with a VAS scale, ranging from 0 (not hungry) to 100 (really hungry). The first real task the participants had to perform was rating 80 food stimuli, healthy (<150kcal/100g) and unhealthy products, on a computer with a scale from 1 (very untasty) to 9 (very tasty) to the question; how much do you want to eat a piece of this food now. These ratings were used in the food choice task, which was the last task. Based on the ratings of the food stimuli they liked (ratings > 5), stimulus pairs (LE vs HE) were created per individual. The created stimulus pairs belonged all to one of three categories. The three choice categories used in this experiment were: the healthy food is tastier than the unhealthy food (LE+ vs HE-), the healthy food is as tasty as the unhealthy food (LE+ vs HE+) and the healthy food is not as tasty as the unhealthy food (LE- vs. HE+). In the categories with a

difference in tastefulness between the healthy and unhealthy product, the difference was not more than 2 rating points. Furthermore, within each category a stimuli could only occur once. However, between the three categories the stimuli could occur more often, with a maximum of three.

The second task the participants had to perform was the Psychomotor Vigilance Task (PVT). This task was performed after the food rating task, because otherwise the fatigue of the PVT could have had an effect on the ratings of food. Vigilance and alertness were measured by the PVT task by taking the median reaction times and completed trials and by comparing the results of this test in the wake and sleep condition. During the trials in this task there was a red outlining of a rectangle continuously shown to the participant in which, within an interval of 2 to 5 seconds, a yellow counter appeared. When the participant noticed this yellow counter, they pressed the space bar as quickly as possible. The time between the trials was randomized and the maximum trials that could be completed was 48, otherwise the participants had a maximum of 3 minutes to perform the test.

After the PVT, all the stimuli pairs of the categories were loaded into the food choice program and participants were given an explanation about the choice task as well about usage of the eye-tracker. Calibration of the eyes of the participants was needed before the food choice task could be started. During the calibration and the test, the head of the participant was placed in a chinrest. When the calibration was completed, the experiment started. During the food choice task two stimuli, one plate with a high energy product and one with a low energy product, were shown next to each other onto a grey background on the computer screen. The location of the stimuli on the left or right side of the screen was randomized. The participant had to choose between the two stimuli by pressing the left or right arrow button. In total there could be a maximum of 60 trials with a maximum of 20 trials per category. Depending on how many trials could be created based on the rating task, the amount of trials differed per individual. After each arrow button press two new stimuli were presented, until all of the trials were done. After the computer food choice task the participants could choose between two real snacks to satisfy their hunger. They could choose between a banana (+LE) and a Dutch cookie called ‘stroopwafel’ (+HE).

During the second lab day two extra questionnaires were added to the normal test script. A Dutch version of the Barrat Impulsiveness Scale (BIS-11)(Patton et al., 1995) and the Multidimensional Assessment of Interoceptive Awareness (MAIA) (Mehling, et al., 2012) were filled in by the participant on paper. The participants also handed in the actigraph

device. Hereafter, the participants were finished with the experiment and they received their participation credits.

Design

The overall experiment was the same for all of the participants. The lab days were counterbalanced. Some participants started with the sleep condition and some with the wake condition. Furthermore, the amount of trials in the food choice task differed on account of the differences in rating of the tastefulness of the products. The overall design used within this research was a 2 (sleep vs. wake) x 3 (categories based on tastefulness and healthiness), within subjects. The three categories (shown with examples of participant 304) used in this design were:

1. +LE vs. – HE. The healthy product (Rating: 7) was more tasteful than the unhealthy product (Rating: 5). It is expected that there is no self- control needed in this category.
2. +LE vs. +HE. The tastefulness of both products was the same (Ratings: 6).
3. - LE vs. +HE. The tastefulness of the healthy product (Rating: 5) was not the same as the unhealthy product (Rating: 6). Self-control is needed in this trial when you are a restrained eater.

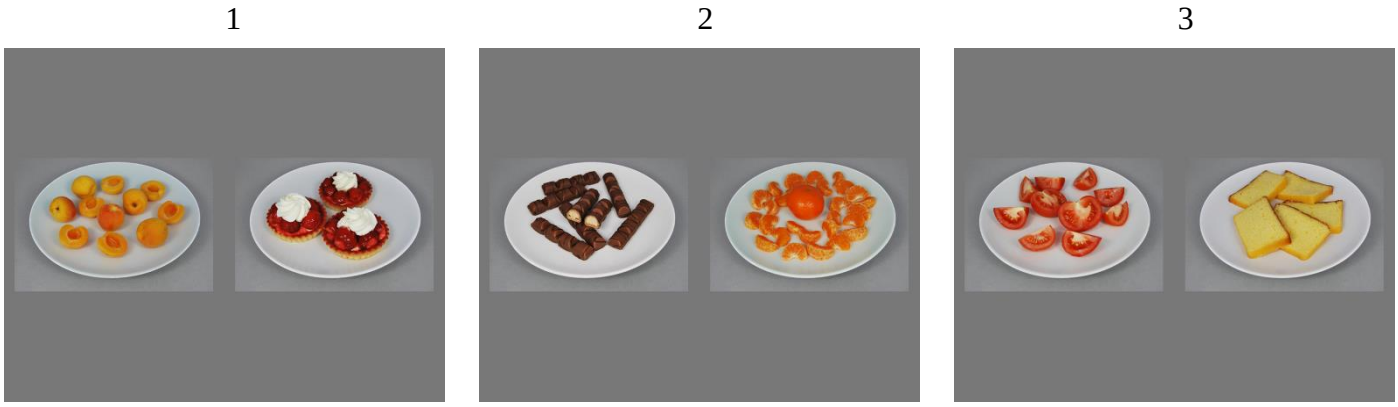


Figure 1. Examples of the three categories created for participant 304 in the sleep condition within this study.

Analysis

Within this research the sleep behavior of the participants was measured in three ways. Firstly, the data of the MCTQ was used to estimate the average midsleep of the participants as a control for divergent sleep patterns. Secondly, the data of the sleep diaries was used to control and compare the week before the first lab day with the week in between the two lab

days. The sleep duration and efficiency of these weeks will be analyzed by a paired samples t-test to test for changes due to the experimental manipulation. The data of the sleep deprivation night is excluded in this diary analysis. The results of the GENEActiv device will be used to compare the nights before each lab day. The actigraph data of the night before each lab day will be compared by visual observation in GENEActiv's own software. As a manipulation check, the effect of sleep deprivation will also be tested by the PVT. This PVT will show the participant's vigilance by measuring the median reaction time during both lab days. These median reaction times of both sleep conditions will be tested with a paired samples t-test.

The effect of sleep condition on the ratings of the healthy and unhealthy products will be tested by a one-way repeated measures ANOVA. The proportion of chosen healthy products and the reaction times within each choice category will be measured by a non-parametric Friedman two-way ANOVA. To measure self-control an eye-tracker is used. With the eye-tracker the dwell time of the eye movements on the healthy and unhealthy food can be shown. The data of the Easygaze^{TM} eye-tracker will also be analyzed with a Friedman two-way ANOVA.

Results

Participants

As indicated, eleven subjects participated in this research. All of the participants had to fill in the Dutch Eating Behavior Questionnaire (DEBQ) (M=2.91, SD= .71) in the beginning of the experiment. A score of 2.8 on the DEBQ is used to categorize someone as a restrained eater. When using this criterion, 6 participants (M= 3.37, SD= .58) were restrained eaters and 5 were not (M=2.36, SD=.38). Because of the limited amount of participants, we first had to focus on the group in total instead of categorizing them into two groups. The variable self-control can still be measured, even within the non-restrained eaters, as all of the participants had similar scores on the Dutch version of the Barrat Impulsiveness Scale (BIS-11)(Patton et al., 1995) on the self-control scale (M=11.00, SD= 1.34)(normality not violated). Because of this reason, the analysis of this study will start with the group in total. In the last paragraph the participants are divided into groups.

Sleep

Munich Chronotype Questionnaire – MCTQ

Each participant had to fill in the Munich Chronotype Questionnaire(MCTQ). This is a questionnaire, which contains questions about one's sleep behavior during work and free days. By filling in this questionnaire, an overview of possible deviant sleep patterns was obtained. The average midsleep (in minutes) of work days (*M*=290.45, *SD*=59.53) in comparison with free days (*M*=328.00, *SD*=61.91) is analysed by the non-parametric Wilcoxon Signed Rank test with an α of .05. This test was used, as it was concluded that the assumptions of normality and normality of difference scores of the average midsleep in work days were violated after visual inspection of the histograms and assessments with Shapiro-Wilk(*p*=.004). Transformation of the data would not help.

The Wilcoxon Signed Rank test indicated that the number of participants that reported that they have had later midsleep during work days was, *n*=1(*Sum of Ranks*=11.00). The number of participants that reported that they had later average midsleep (in minutes) during free days was , *n*=10 (*Sum of Ranks*=55.00). This Wilcoxon Signed Rank test showed no significant results, *T*=11.00, *z*=-1.96 (corrected for ties), *N*-Ties= 11, *p*=.05, two-tailed. This is a large effect, *r*=.06, suggesting no deviant sleep patterns.

Sleep Diaries

Online sleep diaries were filled in by the participants one week before each lab day. By filling in these diaries, information has been obtained on sleep behavior in both the control and experimental weeks with the two lab days. The median sleep duration was calculated in minutes for the control week (*M*= 461.82, *SD*= 48.02) and the experimental week (*M*= 482.05, *SD*= 48.51) to compare them afterwards by a paired samples t-test with an α of .05. The median sleep duration was also plotted into a histogram which showed that the assumptions of normality as well as the normality of difference scores were not violated. The results of the paired samples t-test showed that participants slept 20,23 minutes less in the week before the sleep condition in comparison with the week before the wake condition, 95% CI [-49.50, 9.04]. However, this difference was not statistically significant, *t*(10)= 1.54, *p*= .16, which means that both weeks did not differ in sleep behavior.

Psychomotor Vigilance Task – PVT

Again, a paired samples t-test with an α of .05 was used to compare the median reaction times for the sleep (*M*=.33, *SD*= .03) and wake condition (*M*= .34, *SD*=.03) (Figure 2). On average

the participants reacted .02 seconds, 95% CI [.03, .01], quicker in the PVT trials during the sleep condition in comparison with the wake condition. This difference was statistically significant, $t(10) = -3.57$, $p = .01$, and had a medium effect size of $d=.64$, suggesting that the sleep deprivation manipulation worked.

Furthermore, there were no violations of the assumptions of normality and normality of difference scores found after outputting and visually inspecting the relevant histograms.

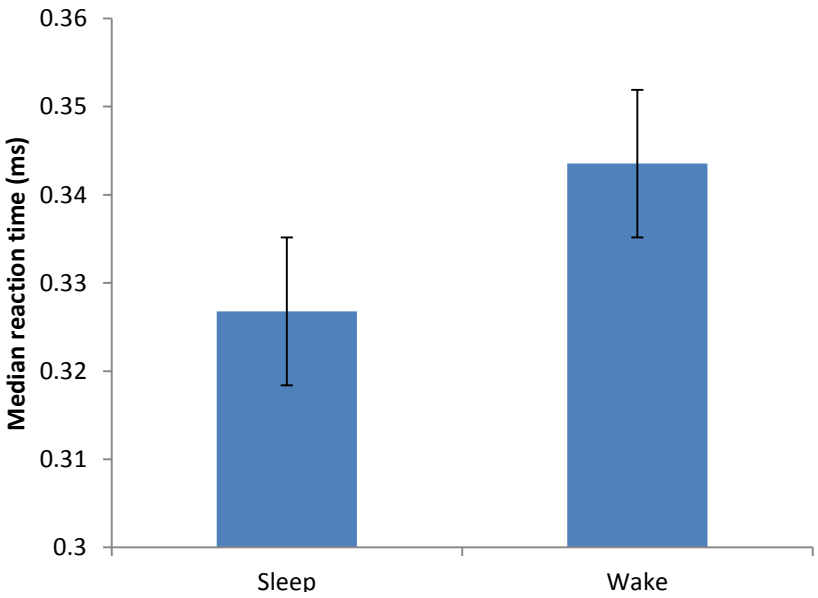


Figure 2. Median reaction time of the participants on the PVT during the sleep and wake condition with the SEM displayed.

Actigraph device GENEActiv

The actigraph device of GENEActiv was used to check the sleep behaviors of the participants the night before each lab day, to check whether participants indeed sleep deprived themselves. By visually inspecting the data of the nights using GENEActiv's software on light duration and X and Y movements, we could check if the participants really slept four hours during the night of the wake condition. All of the participants, except two, had less X and Y movements during the sleep condition in comparison with the wake condition and had a shorter night during the wake night. Two of the participants showed the same activity during the sleep and wake condition. However, given the data of the PVT, which was significant, and the sleep diary data, which showed that they had slept less during the wake condition, these participants were not excluded.

Food choice

Hunger scale

At the beginning of each lab session the participant had to rate their hunger with a VAS scale, ranging from 0 (not hungry) to 100 (really hungry). After checking the assumptions, a comparison of the scores in the sleep condition (*M*=54.72, *SD*=13,81) and wake condition (*M*= 67.71, *SD*= 22.16) was made by performing a paired samples t-test with an α of .05. During the wake condition the participants scored 12,99 points higher on the hunger VAS scale, 95% CI [-33.51, 7.53]. However, this difference was not significant, $t(10) = -1.41$, $p = .19$

Score rating task

An one-way repeated measures ANOVA (α=.05) was performed to compare the ratings of the HE and LE products in the sleep and wake condition. The statistics of Shapiro-Wilk showed that the conditions did not violate the assumptions of normality. The same can be concluded when looking at the boxplots which are roughly symmetrical as well as the statistics of Skewness and Kurtosis which did not exceed ±1.96 for all four groups. Besides that the data is practically normally distributed, the assumption of homogeneity has not been violated either (F_{max}= 2.43). The assumption of sphericity is met, because sphericity is always met for a two level repeated measures ANOVA (Field, 2013). Looking at the results of the repeated measures ANOVA for the HE products in the sleep condition (*M*=3.96, *SD*= 1.27), the LE products in the sleep condition (*M*=5.82, *SD*= 1.10), the HE products in the wake condition (*M*= 4.06, *SD*= .98) and the LE products in the wake condition (*M*=5.56, *SD*= .84), significant difference was found in ratings between HE and LE products, $F(1,10) = 16.55$, $p=.002$, $\eta^2 = .62$. The ratings of the HE products were, with a difference of -1.68, significantly lower than the LE products. No significant effect was found between the ratings between the sleep and wake condition, $F(1,10) = 1.81$, $p=.21$, $\eta^2=.15$. As the ratings did not differ between the two conditions, the amount of pairs created of the stimuli were also similar in the sleep (*M*=27.09, *SD*= 13,61) and wake condition (*M*= 26.91, *SD*= 7.18), $t(10) =.04$, $p= .97$.

Proportion healthy choices within the three categories

In this research the stimuli pairs were created within three choice categories: the unhealthy product was tastier than the healthy product (-LE vs. HE+), the healthy product was tastier than the unhealthy product (LE+ vs. HE-) and the two products were equal in taste (LE+ vs.

HE+). For this study the point of interest is, in which choice category the proportion of chosen healthy products is the biggest.

After checking the assumptions, it was concluded that the statistics of Shapiro-Wilk showed that the conditions did violate the assumptions of normality in the choice categories were the LE product is the tastiest (p= .02) and in the equal taste category (p=0.5), both within the wake condition. However, homogeneity has not been violated (F_{max}=3.42) as well as the assumption of sphericity (p=.05 , p=.51). For this reason, the non-parametric Friedman two-way ANOVA will be performed.

Looking at the results of this two-way ANOVA (α=.05) for the proportion healthy products in HE+ vs. LE- in the sleep condition (*M*= .33, *SD*= .29), in LE+ vs. HE- in the sleep condition (*M*= .76, *SD*= .20), in LE+ vs. HE+ in the sleep condition (*M*= .57, *SD*= .21), in LE- vs. HE+ in the wake condition (*M*= .38, *SD*= .25), in LE+ vs. HE- in the wake condition (*M*= .75, *SD*= .23) and in LE+ vs. HE+ in the wake condition (*M*= .56, *SD*= .15), significant results were found in the ranking of these choice categories, χ^2_F= 22.18 (corrected for ties), *df*=5, *N*-Ties=11, p<.001.

A follow-up pairwise comparisons with the Wilcoxon Signed Rank with a Bonferroni adjusted α of .017 was performed and showed that in the sleep condition within the choice category LE+ vs. HE- (*Mean Rank*= 5.09) significantly more healthy product were chosen than in the choice category LE- vs. HE+ (*Mean Rank*= 2.18), *T*=11.00, *z*=-2.81 (corrected for ties), *N*-Ties= 11.00, p=.005. This effect is considered as large, r= .89. The other comparisons were, despite of their large effects (r= .73 and .77), approaching significance (p=.03 and .02).

Results of the three choice categories in the wake condition also showed that not all of the categories differed significantly from each other. A significant difference was only found in the comparison of the categories LE+ vs. HE+ (*Mean Rank*= 3.41) and LE- vs. HE+ (*Mean Rank*= 2.36), whereby in the equal condition the proportion healthy products was significantly higher, *T*=11.00, *z*=-2.67 (corrected for ties), *N*-Ties= 11.00, p=.01, r= .81. The other choice categories did not differ significantly, despite of their large effects (r=.67 and .59). Also these comparisons were approaching significance (p= .03 and .05).

Comparisons of the three choice categories between the sleep and wake condition did not show any significant results, (p=.79, .72 and .89).

Real-life food choice task

At the end of each lab session the participant could choose between a ‘stroopwafel’ (HE+) and a banana (LE+). Most of the participants chose the banana (17 out of 22 lab sessions). In

some lab sessions the participant chose nothing (3 out of 22 lab sessions). There was only one participant that chose the 'stroopwafel' twice.

Self-control

Reaction times of the three categories

When checking the assumptions, it was indicated that the variable reaction time violated the assumptions; the statistics of Shapiro-Wilk showed that the conditions did violate the assumptions normality (p=.01 and .03). In both the sleep and wake condition the reaction times of the choice category LE- vs. HE+ were not normally distributed. F_{max} was 12.217, demonstrating that the homogeneity of variances was violated too. Because of the significance of the variables in the Mauchly's Test, the assumption of sphericity has also been violated (category*sleepwake p=.002 , category p=.118). Because of the violation of the assumptions, again a non-parametric Friedman two-way ANOVA (α=.05) was performed.

The test indicated that, when looking at the reaction times of the LE- vs. HE+ in the sleep condition (M= 1.91, SD=1.010), of the LE+ vs. HE- in the sleep condition (M= 1.40, SD=.441), of the LE+ vs. HE+ in the sleep condition (M=1.47, SD=.290), of the LE- vs. HE+ in the wake condition (M=1.57, SD=.517), of the LE+ vs. HE- in the wake condition (M=1.41, SD=.343) and of the LE+ vs. HE+ in the wake condition (M=1.70 , SD=.626) that the reaction times did not vary significantly between the choice categories (p=.55). These non-significant differences were also found between the sleep and wake condition (p=.15, .59 and .33) after performing a Wilcoxon Signed Rank test with a Bonferroni adjusted α=.017. The same can be said, when looking at the three choice categories between each condition. However, when looking into the reaction times of the sleep condition, there was one approaching significance. The effect of the difference between the reaction times of the LE+ vs. HE- (*Mean* Rank=2.73) and the HE+ vs. Le- (*Mean Rank*= 4.18) was large, but non-significant (p=.03, r= .64).

ROI analysis

The proportion dwell time on the Regions of Interest (ROI), the location of the food plates, has been determined, based on the raw eye-tracking data (horizontal and vertical positions on the screen), per trial per subject and averaged for the three different choice categories. Two ROI's were created, one of the HE product and one of the LE product. Three participants were excluded from this analysis since visual inspection clearly indicated a failure of

calibration.

After checking the assumptions, it was indicated that the proportion dwell time violated the assumption of normality. The statistics of Shapiro-Wilk showed that three out of twelve comparisons were not normally distributed (p=.03, .01 and .00). For that reason, a non-parametric Friedman two-way ANOVA (α=.05) was performed.

The test indicated that the mean proportions dwell time varied significantly, χ^2_F= 27.90 (corrected for ties), df=11, N-Ties=8, p=.00. A follow-up pairwise comparisons with the Wilcoxon Signed Rank test with a Bonferroni adjusted alpha (α= .0083 or .017) was performed afterwards.

Within each condition and each choice category no significant effects were found between the proportion dwell time at the HE or LE product (p=from .02 to .89). Within each choice category, the proportion dwell time on the HE or LE product did not differ between the sleep and wake condition either (p= from .09 to .78). The same can be said, when looking at the proportion dwell time on the HE product within each choice category in the sleep condition (p= .48, .40 and .67), the LE product within each choice category in the sleep condition (p=.67, .89 and .58), the HE product within each choice category in the wake condition (p=.58, .05 and .05) and LE product within each choice category in the wake condition (p=.67, 04 and .12).

Group difference

The group of participants can, at last, be divided into two groups based on the DEBQ. Based on a score of 2.8 or higher on the DEBQ, one group could be categorized as restrained eaters and one group as non-restrained eaters. After checking the assumptions of the split files of the hunger scale, results showed that non-restrained eaters were significantly hungrier during the wake condition (M=75.81, SD=15.86), in comparison with the sleep condition (M=48.38, SD=14.62), $t(4) = -4.03$, $p = .02$, and large d=1.79. This difference was not found within the restrained group (p=.95)(Figure 3).

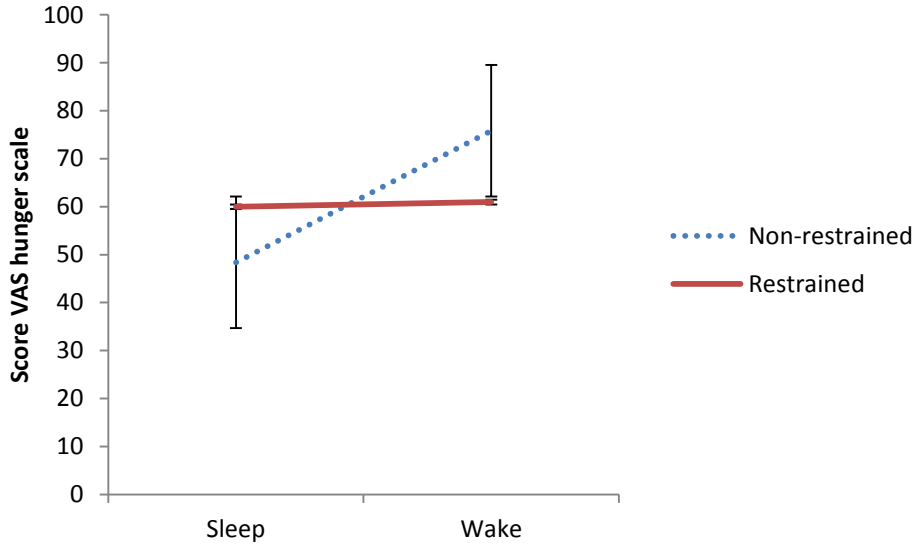


Figure 3. Scores on the hunger VAS scale during the wake and sleep condition divided into groups, with SEM displayed.

When dividing the group in two, the results showed that during the PVT non-restrained participants were significantly slower during the wake condition (*M*=.36, *SD*=.03) in comparison with the sleep condition (*M*=.34, *SD*=.03), *t*(4) = -3.33, *p* = .03, and medium *d*=.66. This result was not found for the restrained group (*p*=.11)(Figure 4).

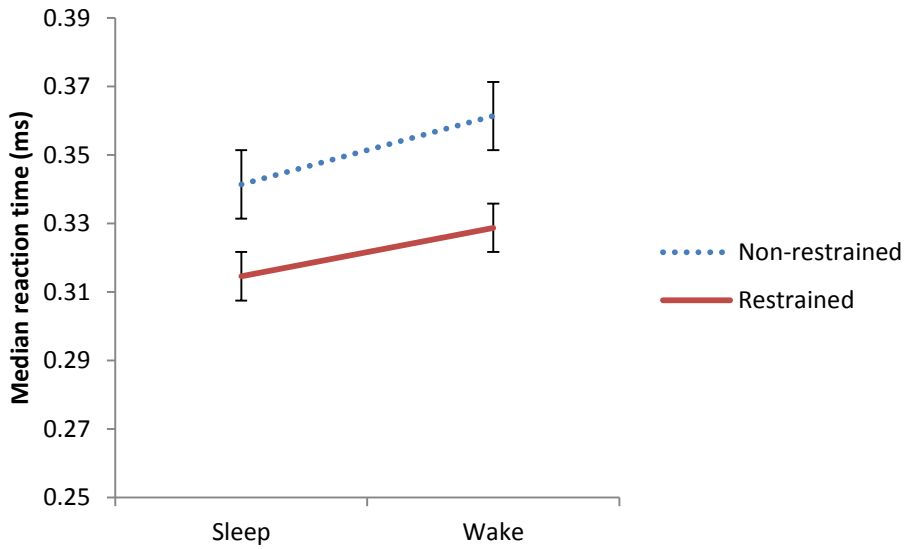


Figure 4. Median reaction time of the participants on the PVT during the sleep and wake condition divided into groups, with the SEM displayed.

After checking the assumptions of the split files, a one-way repeated measures ANOVA could be performed to analyse the differences in ratings of food between these groups. However, no significant difference was found between the rating of the two groups in each condition (p=.07). However this non-significance can be seen as a trend towards significance (Bangalore & Messerli, 2006). The ratings of each group did not change between the sleep and wake condition either (p=.80).

The proportion of healthy products chosen, the reaction times of the responses and the proportion dwell time on the HE or LE product of the three choice categories, could not be tested between the two groups, because the normality was violated.

Discussion

The main purpose of this research was to investigate the effect of sleep on food-related self-control. Underlying questions that were to be answered were: is there a difference in food liking (1) and choice (2) between the sleep and wake condition? And can participants use their self-control to give a successful answer in relation to their goals (choosing low energy products (LE) instead of high energy (HE) ones)(3)? These research questions were tested on healthy women using a food choice task with simultaneous eye-tracking measurements. The factors that were manipulated were sleep and choice category. Within the choice category three manipulations were made. The healthy product had a different score on tastiness (LE- vs. HE+ or LE+ vs. HE-) or was equal in taste (LE+ vs. HE+) to the healthy product. The responses to these categories were tested after a night of eight or a night of four hours of sleep.

Several measurements were performed to control the sleep manipulation and to guarantee that there were no deviations in sleep behavior of the participants. The general sleep patterns were measured by use of the Munich Chronotype Questionnaire (MCTQ), the sleep behavior of the week before every lab day through sleep diaries, the manipulation of sleep deprivation by wearing a GENEActiv actigraph device and the effect of sleep deprivation on the vigilance and alertness of the participant using the Psychomotor Vigilance Task (PVT).

No extreme results were found by the MCTQ. The average midsleep is the same within working days and free days. This means that sleep patterns could not have influenced the vigilance of the participant even when they were tested in the beginning or at the end of the week. The sleep diaries showed no significant effect between the weeks before each lab day either. The participants had similar median sleep duration during the control and

experimental week. This non-significant difference between these weeks is necessary to exclude fatigue effects other than the manipulation. Visual inspection of the actigraph device showed that almost all of the participants followed the instructions to sleep only the last 4 hours. Furthermore, the PVT results showed that the manipulation of sleep deprivation has worked, because the participants were significantly slower during the wake condition in comparison with the sleep condition.

In spite of the effect of the manipulation of sleep deprivation, no significant differences were found in the hunger feelings scored on a VAS scale. This result contradicts findings in existing literature, which shows that people who sleep less have an increased appetite caused by changes in leptin and ghrelin (Knutson, et al., 2007; Spiegal, Knutson, Leproult, Tasali & Van Cauter, 2005). The ratings of the healthy (LE) and unhealthy (HE) products did not change either. Possibly, this is because of similar hunger feelings in the sleep and wake condition. However, in each sleep condition a significant effect was found; the ratings of the HE products were significantly lower than the LE products in both sleep conditions. These results are partially in contrast with the first hypothesis and previous literature (Hogenkamp, et al., 2013; Stamatakis & Brownson, 2008). In previous studies the participants preferred foods containing high calories and fat over fruits and vegetables after sleep deprivation. Studies show that this occurs due to an increased sensitivity of the reward areas in the cognitive system to high caloric foods (Hogenkamp, et al., 2013). This means that there should have been a difference in preferring HE products between the sleep and wake condition. However, this was not found in this study. The expectation that the LE rating stayed the same was confirmed within this research**.**

To answer the second underlying research question, the proportion of chosen healthy products within the three choice categories had to be investigated. The statistical analysis showed that in the sleep condition within the choice category LE+ vs. He- significantly more healthy products were chosen than in the choice category LE- vs. HE+. This means that participants chose the healthy product more frequently when the healthy product was the tastiest option, instead of when the unhealthy product was the tastiest. The other comparisons between choice categories were not significant. Within the wake condition the categories LE+ vs. HE+ and LE- vs. HE+ were different, in which the proportion of chosen healthy products was significantly higher in the equal condition. Again, the choice category LE- vs. HE+ was the hardest one to choose a healthy product in. Comparisons of the three choice categories between the sleep and wake condition did not show any significant results either. Overall, can be concluded that the LE product was chosen the most in the easier choice categories and the

amount of chosen HE products stayed the same in both conditions. These results are again contradictive to the hypothesis of this study. The HE products were expected to be chosen more often in the wake condition, however the proportions stayed the same.

The third hypothesis is focused on the aspect of self-control, which should be used during the choice task when the unhealthy product is the tastiest. As stated before, the least amount of healthy products was chosen in the choice category LE- vs. HE+, indicating that this choice category is indeed the hardest one. However, there was no statistical difference in this choice category between the sleep and wake condition. The participants were not able to use their self-control to answer successfully and to choose the same amount of healthy product in both conditions as in the other two easier choice categories. Additionally, as the amount of chosen healthy products did not decline in the hardest choice category in the wake condition, it can be concluded that sleep deprivation did not affect their self-control. The findings of the current study match the results of the study from Van der Laan, et al. (2014), both studies show that the participants did chose the unhealthy product more often in this category.

The results of the reaction times during the choice categories also indicated that the third hypothesis must be rejected. No differences in reaction times were found between the three choice categories or between the sleep and wake condition. This outcome is in contrast with previous literature that claims that sleep deprivation effects the time to react (Ratcliff & Van Dongen, 2009). However, when looking into the reaction times of the sleep condition, one result approaching significance was found; the reaction times of the choice category LE- vs. HE+ were longer than those of LE+ vs. HE-. Despite the non-significance, it could be seen as a trend towards significance. This means that the participant had to think longer (self-control conflict) in the sleep condition before answering in the hardest choice category in comparison to an easier choice category. Note, however, that the longer reaction time in the sleep condition did not make the participant choose significantly more healthy products.

Taking the proportion dwell time on the HE or LE product into account, no difference was found between the three choice categories and between the sleep and wake condition either. This may mean that the difficulty of the three choice categories was the same to the participants, as they did not hesitate more in one of the categories. Furthermore, this could mean that the self-control conflict was not experienced and self-control was not affected in the wake condition.

Given that, self-control will be used mainly when someone has strong long-term goals, the group of participants was divided into two groups, the restrained eaters and the non-

restrained eaters. When looking at the scores on the VAS hunger scale, a significant effect was found between the sleep and wake condition within the non-restrained eaters. This was not found in restrained eaters. It can be concluded that after sleep deprivation only people with no long-term diet goals are affected and are hungrier. Analysing the data of the PVT, there was, again, only an effect in the non-restrained group. Only, they were significantly slower in the wake condition. These two results would indicate that the restrained group is not affected by the sleep deprivation at all.

Having healthy goals, it was expected that the restrained group would have different ratings of the HE and LE products between the two conditions, as a result of effected self-control (Ratcliff & Van Dongen, 2009). The non-restrained group was expected not to change their ratings in the wake condition, since they do not have to look at the healthiness of the products. The restrained group, however, had the same ratings during the sleep and wake condition (no heightened ratings of HE). The same can be said about the non-restrained eaters. Both groups rated the LE products higher than the HE. Therefore, no significant differences were found between the groups and between the sleep and wake condition. The results of the non-restrained eaters match our hypothesis. However, the results of the restrained group did not. The results did, however, match the results of Vohs, Glass, Maddox and Markman (2011), who showed that sleep deprivation did not have a direct link to self-control. However, the PVT results indicated that the restrained eaters were not even affected by the sleep deprivation, which would imply that the results match the contrasting literature, stating that having good sleep habits also means having better self-control (Barber, Grawitch & Munz, 2013). Thus, the self-control of the participants may not have been affected, as their sleep was not affected.

When taking a general look at the contrasting results, there may have been some limitations that could have influenced the outcomes of the current experiment.

Firstly, the participants were all tested between 8 and 11 o'clock in the morning. This time schedule was chosen because the participants had to come fasted to the experiment and we did not want to give the participants the opportunity to take a nap before the experiment started. However, testing in the morning could have had an effect on the hunger and cravings, because the drive for eating may be stronger in a wake condition in the afternoon (Hanlon, et al., 2015). Moreover, research suggests that there is a relation between later timing of food intake and becoming overweight or obese (Arble, Bass, Laposky, Vitaterna & Turek, 2009; Garaulet & Gomez-Abellan, 2014). People who eat 33% of their daily intake in the evening are twice more likely to become obese in comparison to people who eat in the morning

(Wang, Patterson, Ang, Emond, Shetty & Arab, 2013). When testing in the afternoon, the ratings of hunger as well as of products could possibly be higher, which can result in more trials and different outcomes.

Secondly, there is a lack of controllability of certain aspects in this study. The eating and drinking behavior of the participants, for instance, could not be controlled. The participants were not allowed to drink (except water) or eat after 22 o'clock until after the experiment. However, we did not check if they respected these limitations. If participants had been eating or drinking prior to the lab day, this could have had an effect on the tests within the wake condition. When participants were less tired because of energy intake, they could have rated the products lower and chosen the unhealthy product less often then when they were genuinely sleep deprived. This energy intake counter acts the sleep deprivation manipulation, which could explain the small non-significant differences in comparison to the sleep condition.

Thirdly, all participants received a verbal instruction at the start of every test during the lab days. However, this instruction was not completely standardized, which could have led to different understandings of the participants. This notion is important, especially for a proper understanding of the rating task, which impacted the entire choice task. A misunderstanding of this task could have led to different outcomes of the ratings and of the amount of pairs that could be made, which are now low in some cases giving a poor estimate of a participant's real choice. Misunderstandings of the rating task in this research, may have resulted in lower scores (mainly of the unhealthy food), created pairs that were not persuading enough (because the difference in rating was often 1) and in a lack of choice category LE- vs. HE+. When the understanding of the rating task was correct, the ratings of the HE products probably would have been higher and the self-control would be tested more often, which could have led to different outcomes of the current study.

Fourthly, the design of the study possibly reveals the goal of the research too much. By sending out questionnaires about healthy eating goals to the participants (especially psychology students), it was clear that it had something to do with food choices. Furthermore, the two lab days were similar to each other, except two additional questionnaires at the end of lab day two, which made it clear that the food choices were checked after the sleep manipulation. As the aim of this study was fairly clear, participants could be expected to give socially desirable answers. Participants were rating the LE products the highest and choosing this product the most, despite the fact that some of the participants did not have long-term health goals. This may have been caused by the fact that the observer was in the room with

the participants. Furthermore, the social desirableness was visible by the fact that everybody, except one, chose the banana (LE+) during the real-life choice task. In future research, the lab days should not be that similar and should include more tests that have nothing to do with the subject.

Fifthly, calibration of the eye-tracker was done for every participant, but not always successfully. The non-successful calibration could have had an effect on the amount of data that was available to analyse. If more data had been available, there would have been more data per choice category. This could have had an effect on the preciseness of the average dwell times on the ROI's in the hardest choice category in comparison with the other two. This means that there may have been an effect between these choice comparisons when the data was more precisely.

Finally, the number of participants in this research was too low (N=11). Based on a power analysis, a sample size of 40 participants is necessary to gain enough power and to decrease the chance of a Type II error. By adding more participants, the generalization of the restrained and non-restrained eaters would be more plausible to the whole population and could possibly lead to different outcomes. The limited amount of participants was mostly caused by the fact that experiment time was limited, the amount of time invested by the participants was extensive (2 weeks) and only participation credits were available as a reward.

Taking these limitations into account, some suggestions can be made for future research. First of all, using the GENEActiv achtigraph device, seemed to control the manipulation of sleep very well. Participant felt monitored and thus obliged to adhere to instructions of not sleeping. The sleep diaries can be interchanged for more objective measurements, as the preciseness of the answers could not be guaranteed. The choices made after sleep manipulation should be tested in a different manner either. The lab days were too similar in this study, making the main purpose of the study too obvious. It would be better to add other tests with different goals to obscure the true purpose of the experiment. Furthermore, the participants should be more persuaded with more tasty unhealthy food, or, in other words, be presented with a stronger conflict. When, for instance, the test design will be changed into a virtual grocery-shopping trip, you can place banners with very tasty unhealthy food in the trials. This may lead to more self-control conflicts in the restrained group. In addition, the DEBQ must be interchanged with another health goal measurement, or the criterion score must be heightened. In this study participants that did not have clear health goals were possibly included in the restrained eaters group, which could have influenced the data.

In conclusion, this study seems to be a good expansion of research on the topic of sleep deprivation and over-eating. In this study adding the variable self-control has broadened this topic. The found results both reject and support conclusions of previous studies. This study replicates the non-existence of the self-control conflict observed by Van der Laan, et al. (2014). However, the three hypotheses, which were based upon previous research, had to be (partially) rejected. Overall, it can be concluded that the sleep manipulation worked for the non-restrained eaters and that it made them hungrier. However, this hunger did not mean more craving for unhealthy food. Furthermore, it is suggested that sleep deprivation does not have a direct link with self-control for women with long-term health goals, as they answered the same in the sleep as wake condition. The differences between the results of this research and previous literature, as well as the discussed suggestions for future studies clearly indicate that there is ample room for future research on this topic.

References

Arble, D. M., Bass, J., Laposky, A. D., Vitaterna, M. H., & Turek, F. W. (2009). Circadian timing of food intake contributes to weight gain. *Obesity, 17,* 2100-2102.

Aronne, L. J., & Segal, K. R. (2003). Weight gain in the treatment of mood disorders. *The Journal of Clinical Psychiatry, 64,* 22-29.

Atkinson, G., Fullick, S., Grindey, C., & Maclaren, D. (2008). Exercise, energy balance and the shift worker. *Sports Medicine, 38,* 671–685.

Bangalore, S., & Messerli, F. H. (2006). Of statistical significance: "Trends" toward significance and optimism bias. *Journal of the American College of Cardiology, 48,* 1471-1471.

Barber, L. K., Grawitch, M. J., & Munz, D. C. (2013). Are better sleepers more engaged workers? A self-regulatory approach to sleep hygiene and work engagement. *Stress and Health: journal of the International Society for the Investigation of Stress, 29,* 307–316.

Baumeister, R. F. (2002). Self-control failure, impulsive purchasing, ad consumer behavior. *The Journal of Consumer Research, 28,* 670-676.

Baumeister, R. F., & Vohs, K. D. (2007). Self-regulation, ego depletion and motivation. *Social and Personality Psychology Compass, 1,* 115–128.

Bjorvatn, B., Sagen, I. N. A., Øyane, N., Waage, S., Fetveit, A., Pallesen, S., & Ursin, R. (2007). The association between sleep duration, body mass index and metabolic measures in the Hordaland Health Study. *Journal of Sleep Research, 16,* 66-76.

Brondel, L., Romer, M. A., Bougues, P. M., Touyarou, P., & Dayenne, D. (2010). Acute partial sleep deprivation increases food intake in healthy men. *The American journal of clinical nutrition, 91,* 1550-9.

CBS StatLine, (2013). Trend overgewicht volwassenen. Retreived from https://www.volksgezondheidenzorg.info/onderwerp/overgewicht/cijfers-context/trends#bronverantwoording

Dalton, M., Blundell, J., & Finlayson, G. (2012). Effect of BMI and binge eating on food reward and energy intake: further evidence for a binge eating subtype of obesity. *Obesity facts, 6,* 348-359.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18,* 193 – 222.

Doustmohammadian, A., Abdollahi, M., Bondarianzadeh, D., Houshiarrad, A., & Abtahi, M. (2012).Parental determinants of overweight and obesity in Iranian adolescents: a national study. *Iranian Journal of Pediatrics,22,* 35-42.

Field, A. P. (2013). *Discovering statistics using SPSS.* London, England: SAGE.

Fliers, E. A., Buitelaar, J. K., Maras, A., Bul, K., Höhle, E., Faraone, S. V, Franke, B., & Rommelse, N. N. (2013). ADHD is a risk factor for overweight and obesity in children. *Journal of Developmental and Behavioral Pediatrics, 34,* 1-15.

Garaulet, M., & Gómez-Abellán, P. (2014). Timing of food intake and obesity: a novel association. *Physiology & behavior, 134,* 44-50.

Gibson, E. L. (2006). Emotional influences on food choice: Sensory, physiological and psychological pathways. *Physiology & Behavior, 89,* 53–61.

Hanlon, E. C., Tasali, E., Leproult, R., Stuhr, K. L., Doncheck, E., de Wit, H.,Hillard, C. J.,& Van Cauter, E. (2015). Sleep Restriction Enhances the Daily Rhythm of Circulating Levels of Endocannabinoid 2-Arachidonoylglycerol. *Sleep*, *39*(3), 653-664.

Heath, G., Roach, G. D., Dorrian, J., Ferguson, S. A., Darwent, D., & Sargent, C. (2012). The effect of sleep restriction on snacking behaviour during a week of simulated shiftwork. *Accident Analysis & Prevention, 45,* 62-67.

Hebl, M. R., & Mannix, L. M. (2003). The weight of obesity in evaluating others: A mere proximity effect. *Personality and Social Psychology Bulletin, 29,* 28-38.

Hofmann, W., Friese, M., & Strack, F. (2009). Impulse and self-control from a dual-systems perspective. *Perspectives on. Psychological Science, 4,* 162–176.

Hogenkamp, P. S., Nilsson, E., Nilsson, V. C. Chapman, C. D., Vogel, H., Lundberg, L. S., Zarei, S., Cedernaes, J., Rangtell, F. H., Broman, J-E., Dickson, S. L., Brunstrom, J. M., Bededict, C., & Schiöth, H. B. (2013). Acute sleep deprivation increases portion size and affects food choice in young men. *Psychoneuroendocrinology, 38*, 1668-1674.

Jones, K., & Harrison, Y. (2001). Frontal lobe function, sleep loss and fragmented sleep. *Sleep medicine reviews, 5,* 463-475.

Jung, C. M., Melanson, E. L., Frydendall, E. J., Perreault, L., Eckel, R. H., & Wright, K. P. (2011). Energy expenditure during sleep, sleep deprivation and sleep following sleep deprivation in adult humans. *The Journal of physiology,589,* 235-244.

Killgore, W. D., Balkin, T. J., & Wesensten, N. J. (2006). Impaired decision making following 49 h of sleep deprivation. *Journal of sleep research, 15,* 7-13.

Kim, S., DeRoo, L. A., & Sandler, D. P. (2011). Eating patterns and nutritional characteristics associated with sleep duration. *Public health nutrition, 14,* 889-895.

Knutson, K. L., Spiegel, K., Penev, P., & Van Cauter, E. (2007). The metabolic consequences of sleep deprivation. *Sleep Medicine Reviews, 11,* 163-178.

Leonard, C., Fanning, N., Attwood, J., & Buckley, M. (1998). The effect of fatigue, sleep deprivation and onerous working hours on the physical and mental wellbeing of pre-registration house officers. *Irish journal of medical science, 167,* 22-25.

Markwald, R. R., Melanson, E. L., Smith, M. R., Higgins, J., Perreault, L., Eckel, R. H., & Wright, K. P. (2013). Impact of insufficient sleep on total daily energy expenditure, food intake, and weight gain. *Proceedings of the National Academy of Sciences, 110,* 5695-5700.

Mehling, W. E., Price, C., Daubenmier, J. J., Acree, M., Bartmess, E., & Stewart, A. (2012). The multidimensional assessment of interoceptive awareness (MAIA). *PLoS One, 7,* 421.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual review of neuroscience, 24,* 167-202.

Muzur, A., Pace-Schott, E. F., & Hobson, J. A. (2002). The prefrontal cortex in sleep. *Trends in cognitive sciences, 6,* 475-481.

Narbro, K., Jonsson, E., Larsson, B., Waaler, J., Wedel, H., Sjostrom, L. (1996). Economic consequences of sick leave and early retirement in obese Swedish women. *International Journal of Obesity Related Metabolic Disorders, 20*, 895–903.

Nguyen, D. M., & El-Serag, H. B. (2010). The epidemiology of obesity. *Gastroenterology Clinics of North America, 39,* 1-7.

Ogunbode, A. M., Fatiregun, A. A., & Ogunbode, O. O. (2009). Health risks of obesity. *Annals of Ibadan Postgraduate Medicine, 7,* 22-25.

Patton, J. H., & Stanford, M. S. (1995). Factor structure of the Barratt impulsiveness scale. *Journal of clinical psychology, 51,* 768-774.

Puhl, R. M., & Heuer, C. A. (2009). The stigma of obesity: a review and update. *Obesity, 17,* 941-964.

Ratcliff, R., & Van Dongen, H. P. (2009). Sleep deprivation affects multiple distinct cognitive processes. *Psychonomic Bulletin & Review, 16,* 742-751.

Reinberg, A., Migraine, C., Apfelbaum, M., Brigant, L., Ghata, J., Vieux, N., & Laporte, A. (1979). Circadian and ultradian rhythms in the feeding behaviour and nutrient intakes of oil refinery operators with shift-work every 3--4 days. *Diabete & Metabolisme, 5*, 33-41.

Spiegal, K., Knutson, K., Leproult, R., Tasali, E., & Van Cauter, E. (2005). Sleep loss: a novel risk factor for insulin resistance and Type 2 diabetes. *Journal of Applied Physiology, 99,* 2008–2019.

Stamatakis, K. A., & Brownson, R. C. (2008). Sleep duration and obesity-related risk factors in the rural Midwest. *Preventive medicine, 46,* 439-444.

St-Onge, M-P., Roberts, A. L., Chen, J., Kelleman, M., O'Keeffe, M., Roy, Choudhury, A. R., & Jones, P. J. H. (2011). Short sleep duration increases energy intakes but does not change energy expenditure in normal-weight individuals. *The American Journal of Clinical Nutrition, 94,* 410-416.

Van der Laan, L. N., De Ridder, D. T. D., Charbonnier, L., Viergever, M. A., & Smeets, P. A. M. (2014). Sweet lies: neural, visual, and behavioral measures reveal a lack of self-control conflict during food choice in weight-concerned women. *Frontiers in Behavioral Neuroscience, 8,* 184.

Vgontzas, A. N., Lin, H. M., Papaliaga, M., Calhoun, S., Vela-Bueno, A., Chrousos, G. P., & Bixler, E. O. (2008). Short sleep duration and obesity: the role of emotional stress and sleep disturbances. *International Journal of Obesity, 32,* 801-809.

Voedingscentrum, (2012). *Wat weten consumenten over voeding en gewicht?* Retreived from http://www.voedingscentrum.nl/Assets/Uploads/Documents/Rapportage%20Feiten%20en%20Fabels_Deel%20Voeding%20%20Gewicht.pdf

Vohs, K. D., Baumeister, R. F., Schmeichel, B. J., Twenge, J. M., Nelson, N. M., & Tice, D. M. (2014). Making choices impairs subsequent self-control: a limited-resource account of decision making, self-regulation, and active initiative. *Journal of Personality and Social Psychology, 5,* 883-898.

Vohs, K. D., Glass, B. D., Maddox, W. T., & Markman, A. B. (2011). Ego depletion is not just fatigue: evidence from a total sleep deprivation experiment. *Social Psychological and Personality Science*, 2, 166-173.

Wang, J. B., Patterson, R. E., Ang, A., Emond, J. A., Shetty, N., & Arab, L. (2014). Timing of energy intake during the day is associated with the risk of obesity in adults. *Journal of Human Nutrition and Dietetics, 27,* 255-262.

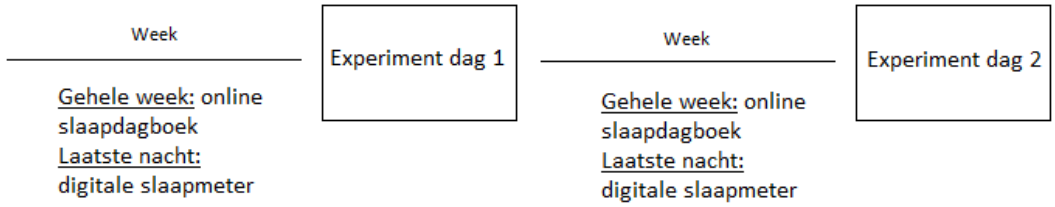
World Health Organisation, 2009. *Global Strategy on Diet, Physical Activity and Health.*Retrieved from http://www.who.int/mediacentre/factsheets/fs312/en/index.html

Appendix I – Questionnaires and short explanation research (Dutch)

Beste Participant,

Wanneer u dit leest, heeft u aangegeven mee te willen doen aan onderstaand onderzoek. Door volledige deelname aan dit onderzoek kunt u in totaal 4 proefpersoon uren verdienen. Dit onderzoek zal gaan over de effecten van slaap en slaap deprivatie op keuzes. Hierbij zal u twee keer getest worden in het Langeveld op de Uithof. Eén test is na een nacht van 8 uur slaap en de andere test is na een nacht van 4 uur slaap. Tussen beide experimenten zal precies 1 week zitten en elk experiment zal maximaal 1 uur duren. Voorafgaand aan elk experiment zal u een week lang een online slaapdagboek bijhouden (duurt enkele minuten per dag) en de nachten voor het experiment draagt u een digitale slaapmeter (moeiteloos). Voorbeeld: wanneer u op dinsdagen getest wordt, zal u beide maandag op dinsdag nachten de digitale slaapmeter dragen. Hieronder een schematische weergave van het onderzoek.

Overzicht van het onderzoek



Voor dit onderzoek is een bepaalde doelgroep binnen de vrouwen populatie nodig. Vandaar dat wanneer u deel wilt nemen aan het onderzoek, u eerst enkele korte vragenlijsten zal moeten invullen. Deze vragenlijsten nemen hooguit 5 minuten van uw tijd in. Wanneer u hierna geselecteerd wordt, zal u uitgenodigd worden de digitale slaapmeter op te komen halen, als ook een mondelinge uitleg van het experiment te krijgen.

Tot één vragenlijst over uw algemene slaap zal u online toegang krijgen. De toegangscodes en link staan genoteerd in de mail van deze bijlage. De andere vragenlijsten zijn te vinden verder in dit Word document. Als u deze formulieren gezamenlijk terugstuurt, kan ik vervolgens beslissen of u geschikt bent en krijgt u meteen een reactie terug. Hierna zullen wij samen de data inplannen.

Heeft u nog enige vragen over het onderzoek of over de vragenlijsten, mail mij dan gerust!

Alvast hartelijk dank voor uw deelname!

Met vriendelijke groet,

Iris van Hooijdonk; slaaponderzoekiris@gmail.com

Vragenlijsten

Geeft u alstublieft eerlijk antwoord op de volgende vragen:

	Vraag	**Antwoord**
1.	Wat is uw naam?	
2.	Wat is uw leeftijd?	
3.	Wat is uw lengte (in cm)?	
4.	Wat is uw gewicht (in kg)?	
5.	Heeft u een eetstoornis?	
6.	Bent u gewoonlijk een goede slaper?	
7.	Bent u vegetariër of veganist?	
8.	Volgt u een dieet om medische redenen?	
9.	Heeft u voedselallergieën?	
10.	Bent u een roker?	
11.	Bent u een hevige drinker (rond de 14 glazen per week)	
12.	Gebruikt u vaak stimulerende middelen?	
13.	Doet u mee aan dit onderzoek voor proefpersoon uren (studie psychologie)?	
14.	Zo ja, wat is uw studentennummer?	

Invulinstructies

Hieronder vindt u vragen over eetgewoontes.
Lees elke vraag goed door en zet een kruisje in het hokje van het antwoord dat het beste bij u past.
Kruist u per vraag maximaal één antwoord aan **en sla geen vragen over**.
Uw eerste indruk is meestal de beste; sta dus niet te lang stil bij elke vraag.
Elk antwoord dat u geeft is goed.

		Nooit	Zelden	Soms	Vaak	Zeer vaak
15.	Als u wat zwaarder bent geworden, eet u dan daarna wat minder dan u gewend bent?					
16.	Hoe vaak slaat u aangeboden eten en drinken af omdat u aan uw gewicht wilt denken?					
17.	Komt het voor dat u tijdens de maaltijden minder probeert te eten dan u wel zou lusten?					
18.	Let u er precies op hoeveel u eet?					
19.	Eet u met opzet dingen die goed zijn voor de lijn?					

20.	Als u teveel hebt gegeten, eet u dan de dag daarna minder dan u gewend bent?					
21.	Eet u om niet dikker te worden met opzet wat minder?					
22.	Hoe vaak probeert u tussen de maaltijden door niets te eten omdat u aan de lijn doet?					
23.	Hoe vaak probeert u in de loop van de avond niets te eten omdat u aan de lijn doet?					
24.	Houdt u met eten rekening met uw gewicht?					

Geef bij onderstaande vragen een antwoord door middel van een cijfer. Het cijfer kan lopen van 1=helemaal niet tot 9=heel erg. Geef per vraag maximaal één antwoord (cijfer) aan **en sla geen vragen over**.
Uw eerste indruk is meestal de beste; sta dus niet te lang stil bij elke vraag.
Elk antwoord dat u geeft is goed.

	Vraag	**Antwoord (1 = helemaal niet 9 = heel erg)**
25.	In hoeverre ben je bezig met je gewicht	
26.	In hoeverre ben je bezig met slank zijn?	
27.	In hoeverre lukt het je om op gewicht te blijven?	
28.	In hoeverre lukt het je om gewicht te verliezen?	
29.	In hoeverre vind je het moeilijk om op gewicht te blijven?	

Appendix II – Example explanation research 4h-8h condition (Dutch)

Beste Participant,
U bent geselecteerd voor het onderzoek, aangezien u goed past binnen de doelgroep van het onderzoek! Bij deelname aan het volledige onderzoek verdient u 4 Proefpersoon uren. Dit onderzoek zal gaan over de effecten van slaap en slaap deprivatie op keuzes. Hierbij zal u twee keer getest worden in het Langeveld op de Uithof. Als u vijf minuten voor de afgesproken test tijden aanwezig bent bij de wachtruimte op verdieping H.0. zal u daar opgehaald worden door de observator.

Uw onderzoek zal er als volgt uit zien:Een week voor de eerste testdag, begint u met dagelijks in de morgen het online dagboek in te vullen en dit zal u twee weken lang doen. Dit kost elke dag hooguit 2 minuten (Elke dag zal u via de mail een reminder ontvangen van dit dagboek). De eerste testsessie vindt plaats na een nacht van 4 uur slaap. De tweede testsessie (een week later) vindt plaats na een normale nacht slaap (van 8 uur). De 4 uur slaap zullen de laatste 4 uur van uw normale slaap zijn. Wanneer u bijvoorbeeld altijd om 24 uur gaat slapen en opstaat om 8 uur, gaat u voorafgaand aan de tweede test dag dus om 4 uur slapen en staat u op om 8 uur. Bij beide nachten voorafgaand aan de testdagen draagt u een digitale slaapmeter. Deze kunt u voorafgaand aan de eerste testdag ophalen in het Langeveld en neemt u mee terug tijdens de tweede testdag.

Schematisch overzicht van uw onderzoek

Belangrijk bij beide voorgaande nachten aan de testdagen is dat u na 22:00 niks meer eet en drinkt. Alleen water is nog toegestaan (dus geen thee/koffie of andere stimulerende producten). U zult daarbij geen ontbijt nuttigen voorafgaand aan het onderzoek. De testen zullen echter in de ochtend worden afgenomen, zodat u daarna meteen uw ontbijt kunt eten. De testen zullen tevens niet langer dan maximaal 45 minuten duren en achteraf aan de testen krijgt u een snack om uw honger te stillen. Het is tevens belangrijk voor het eye-tracking gedeelte dat u geen make-up op heeft rondom de ogen tijdens de tests.

Hopelijk geeft dit bestand genoeg informatie over het onderzoek waar u aan meedoet! Heeft u toch nog vragen voorafgaand of tijdens het onderzoek, mail mij dan gerust!

Met vriendelijke groet, Iris van Hooijdonk. slaaponderzoekiris@gmail.com

Appendix III - Informed consent (Dutch)

Korte toelichting voor de proefpersoon op het onderzoek:
Je gaat mee doen aan een onderzoek naar de invloed van slaapdeprivatie op keuzegedrag. Dit onderzoek houdt in dat je al een aantal vragenlijsten hebt ingevuld om na te gaan of je binnen de doelgroep van het experiment behoort en dat je vervolgens vanaf een week voorafgaand aan de eerste testdag twee weken lang een online slaapdagboek gaat bijhouden. Je krijgt iedere ochtend een email met hierin een link naar het slaapdagboek. Er word van je verwacht dat je dit in de ochtend invult, bij voorkeur één half uur nadat je bent opgestaan. Het invullen van het slaapdagboek neemt iedere ochtend niet meer dan 5 minuten in beslag. Je zal binnen de twee weken twee maal getest worden. Eén keer na een nacht van 8 uur en één maal na een nacht van 4 uur. Tijdens de testen krijg je een computer keuze taak, waarbij je oogbewegingen gevolgd zullen worden door middel van een eye-tracker. Elk test moment duurt niet langer dan 45 minuten. Je slaap zal tevens gemeten worden de nachten voorafgaand aan de testen door middel van een digitale slaapmeter. Deze krijg je na het invullen van deze verklaring mee. Voor deelname aan dit onderzoek ontvang je in totaal 4 Proefpersoon uren.

Het is van belang om te weten dat deelname aan dit onderzoek volledig vrijwillig is en dat je op elk moment tijdens het onderzoek kan stoppen. Hiervoor heb je geen geldige reden nodig. De resultaten die verkregen zullen worden door middel van uw deelname, zullen uitsluitend gebruikt worden voor dit thesis onderzoek. Uw persoonlijke gegevens zullen vol vertrouwen gebruikt worden en niet verder verspreidt worden aan derden. Daarnaast zullen de persoonlijke gegevens geheel anoniem blijven en zullen er geen persoonlijke gegevens in het onderzoek gepubliceerd worden.

Verklaring
Ik heb de informatie voor de proefpersoon gelezen. Ik heb de mogelijkheid gekregen om aanvullende vragen stellen. Mijn vragen zijn genoeg beantwoord. Ik heb genoeg tijd gehad om te beslissen of ik meedoe.
Ik weet dat meedoen helemaal vrijwillig is. Ik weet dat ik op ieder moment kan beslissen om toch niet mee te doen. Daarvoor hoef ik geen reden te geven.
Ik geef toestemming om mijn gegevens te gebruiken, voor de doelen die in de toelichting staan. Ik ben er van op de hoogte dat mijn gegevens vertrouwelijk behandeld worden.
Ik ga akkoord met deelname aan het onderzoek.
Ik ben er van op de hoogte dat ik aan het eind van mijn tweede testdag de digitale slaap meter weer inlever, aangezien het eigendom is van de Universiteit van Utrecht.

Naam proefpersoon:

Handtekening: Datum : / /

Ik verklaar hierbij dat ik deze proefpersoon voldoende heb geïnformeerd over het genoemde onderzoek.
Als er tijdens het onderzoek informatie bekend wordt die de toestemming van de proefpersoon zou kunnen beïnvloeden, dan breng ik hem/haar daarvan tijdig op de hoogte.

Naam onderzoeker:
Handtekening: Datum: / /
