Bachelor Thesis

Perceived sleep quality is related to subjective well-being, whereas sleep duration is not

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Abstract

Previous research indicates that there is a relationship between sleep and well-being. Yet, it remains unclear what exactly constitutes this relationship. The present study was conducted to examine the associations between sleep quality as well as sleep duration and subjective well-being. Based on the findings from previous studies it was hypothesised that good sleep quality and good composite sleep are each associated with increased subjective well-being including increased satisfaction with life as well as increased positive and decreased negative affect, whereas sleep duration is not associated with subjective well-being. Subjective well-being was measured using the Satisfaction with Life Scale (SWLS) and the adapted Scale of Positive and Negative Experience (SPANE), whereas both sleep duration and sleep quality were measured using the National Sleep Foundation's Sleep Health Index (SHI). A correlational design with multivariate multiple linear regression analysis with satisfaction with life scores, positive and negative affect scores as dependent variables and sleep duration, sleep quality and disordered sleep scores, or composite sleep scores, respectively, as independent variables was applied. As predicted, a statistically significant association between good sleep quality and increased subjective well-being including all three measures was found, whereas, again in line with expectations, no evidence was found for a relationship between sleep duration and subjective well-being. Moreover, as presumed, good composite sleep was significantly associated with increased subjective well-being, although the explanatory power was much smaller (15% explained variance) than that of sleep quality alone (26% or 27% explained variance). These results indicate that there is indeed a relationship between sleep and well-being and that sleep quality alone and not sleep duration is the single most important predictor in subjective well-being. Practically, this study pointed out that the sleep industry should focus on promoting sleep quality instead of sleep duration when aiming at improving their customers' well-being.

Key words: sleep, subjective well-being, multivariate, sleep health index

Introduction

Common sense already dictates that sleep is of major importance for our health and overall well-being. In fact, sleep is essential for optimal cognitive performance, the regulation of emotions, and quality of life (O'Leary, Small, Panaite, Bylsma, & Rottenberg, 2017) as well as an integral part of a healthy lifestyle (Becker, Santos Martins, De Neves Jesus, Chiodelli, & Rieber, 2018). Previous studies found a relationship between sleep and well-being in college students (Ridner, Newton, Staten, Crawford, & Hall, 2016); however, it remains unclear what exactly constitutes this relationship. Is it more about sleep quantity or sleep quality (Pilcher, Ginter, & Sadowski, 1996)? Finding out which of the two (or both) might be the largest contributor is important due to recent technical and societal developments: Living up to a healthy lifestyle by getting the most out of one's sleep is the latest lifestyle trend (e.g. NBC Universal, 2019). Promises are being made that by valuing, maximising, and optimising one's sleep, for example by means of the latest technology, people can easily feel better rested and improve their well-being and performance (e.g. Consumer Sleep Solutions LLC, 2019; Eight Sleep, 2019; Koninklijke Philips N.V., 2019). But do these promises really hold? Is there such a clear relationship between sleep and well-being? And do objective sleep measures such as sleep quantity supplied for example by sleep trackers even provide the most valuable information with regards to one's well-being? Or is there a more subjective component to sleep as for instance perceived sleep quality that matters most? Therefore, the aim of this study is to further clarify the relationship between sleep quality and sleep quantity and hedonic well-being comprising both a cognitive and an affective component.

Sleep health

Sleep is a basic physiological necessity for humans. Insufficient sleep quantity or quality is related to a number of severe negative health outcomes both mentally and physically: According to Sivertsen et al. (2014), insomnia is a significant risk factor for a range of conditions such as depression, anxiety, fibromyalgia, rheumatoid arthritis, whiplash, arthrosis, osteoporosis, headache, asthma, and myocardial infarction. Due to the enormous list of adverse consequences of lack of sleep, it is easily comprehensible that earlier studies mainly focused on sleep disorders and sleep deficiency. However, a new line of research is investigating what is called *sleep health*. According to Buysse (2014), "sleep health is a multidimensional pattern of sleep-wakefulness, adapted to individual, social, and

environmental demands, that promotes physical and mental well-being. Good sleep health is characterized by subjective satisfaction, appropriate timing, adequate duration, high efficiency, and sustained alertness during waking hours." The shift from sleeping problems to positive aspects and to a subjective perception of sleep offers new research perspectives by enabling the investigation of the current sleep status, trends over time, and intervention results in the general population (Buysse, 2014).

Although polysomnography, which consists of electroencephalography, electrooculography, electromyography, and electrocardiography, is still regarded as the gold standard for measuring sleep, questionnaires provide unique information beyond objective sleep data, namely a summarised self-perception of sleep quality which is essential for the purpose of this study. Contrary to the erroneous belief that subjective sleep measures are unreliable, several studies have shown that their sensitivity is between 73% and 97.7%, while specificity ranges between 50% and 96% (Ibáñez, Silva, & Cauli, 2018). As suggested by Matricciani et al. (2018), sleep as a multidimensional construct can be related to health outcomes in three different ways: the additive associations of sleep characteristics in linear regression models predicting health outcomes, a composite sleep score combining all sleep dimensions, and finally sleep profiles that identify groups of individuals within the population according to shared or similar attributes.

The construct of subjective well-being

As opposed to the distinct concept of sleep, the construct of well-being is rather abstract and there is an ongoing and vivid debate about its theoretical conceptualisation and measurement (Jayawickreme, Forgeard, & Seligman, 2012; Lent, 2004; Ryan & Deci, 2001). The current study focuses on the hedonic approach to well-being as this model and its method of measurement are well-established (Diener et al., 2009; Pavot & Diener, 2008) and previous studies mostly focused on hedonic aspects of well-being when investigating the sleep-well-being link. The hedonic approach conceptualises well-being primarily in the sense of pleasure and happiness (Ryan & Deci, 2001). According to Diener, Lucas and Oishi (2005), subjective well-being can be best described by a tripartite model consisting of satisfaction with life, the presence of positive affect, and the absence of negative affect. This hedonic approach understands well-being in terms of a combination of all three of these constructs, however, many researchers select life satisfaction alone when measuring well-being in the hedonic sense (Cooke et al., 2016). Subjective well-being offers the possibility to

let people evaluate their lives in accordance with their own standards of what they consider 'the good life' and to let them decide on their own which events and circumstances they evaluate as desirable (Diener, Oishi, & Tay, 2018).

Previous research on the relationship between sleep and well-being

When looking at the research already conducted on the relationship between diverse aspects of sleep and various concepts of well-being, a general finding suggests that sleep and well-being are indeed related to each other (e.g. Ridner et al., 2016), although the specific operationalisations of both the constructs of well-being and of sleep differ enormously among these studies which highlights the question what in fact constitutes this relationship. Several studies did not employ well-established scales or used single items for measuring the constructs which limits the generalisability of their findings (e.g. Lima, de Azevedo Barros, Ceolim, Zancanella, & de Oliveira Cardoso, 2018).

To enumerate the findings, a study by Pilcher et al. (1997) linked sleep quality rather than sleep quantity to subjective well-being, health, and sleepiness. In line with that, Stoica (2014) suggests that sleep measured in a subjective manner such as specific qualitative aspects is a predictor of mood unlike objective sleep measures such as sleep duration. Regarding sleep quality and its relationship with satisfaction with life as the first aspect of subjective well-being, a study by Shin and Kim (2018) suggests that good sleep quality is associated with increased life satisfaction. In line with that, Weinberg, Noble, and Hammond (2016) suggest that sleep quality partially mediates the relationship between stress and life satisfaction. With respect to sleep quality and its association with positive and negative affect as the second aspect of subjective well-being, a study by Bower, Bylsma, Morris, and Rottenberg (2010) suggests a particularly strong relationship between sleep quality and positive affect. A systematic review suggests that trait-like or general measures rather than state-like or short-term measures of positive affect and sleep provide the most consistent evidence of this association (Ong, Kim, Young, & Steptoe, 2017).

Support for a causal relationship between sleep quality and affect comes from a study by Bouwmans, Bos, Hoenders, Oldehinkel, and De Jonge (2017) who suggest that sleep quality predicts changes in positive and negative affect, but not vice versa, and that this relationship is mediated by fatigue. Further support for a causal relationship is provided by a study by Min, Sbarra, and Keim (2015) who suggest that poor sleep quality predicts prospective declines in self-reported wellness, whereas Lau, Hui, Cheung, and Lam (2015)

suggest that there is a bidirectional relationship between sleep quality and optimism with depressive mood as a mediator.

With respect to sleep duration instead of sleep quality, a study by Lima et al. (2018) suggests that there is a U-shaped association between sleep duration and life satisfaction with a higher chance of both long and short sleep in unhappy individuals. An actigraphy study by Lemola, Ledermann, and Friedman (2013) however suggests that the variability of sleep duration instead of average sleep duration is related to subjective well-being and that this relationship is partially mediated by subjective sleep quality. In line with that, another study suggests that healthy sleep patterns are linked to subjective well-being (Norlander, Johansson, & Bood, 2005).

The current study

Taken together, previous studies indicate that there is an urgent need to clarify the relationship between sleep and well-being (Lima et al., 2018; Ong et al. 2017; Shin & Kim, 2018). In line with the latest trend towards investigating sleep health rather than sleep problems, this study contributes to the understanding of the relationship between sleep and well-being by focussing on subjective perceptions of current sleep health in a non-clinical population (Knutson et al., 2017). In addition, the current study does not investigate certain aspects of well-being separately when modelling the sleep-well-being link. In contrast, satisfaction with life and positive as well as negative affect are combined according to Diener's tripartite model of subjective well-being in the hedonic sense in order to form one comprehensive measure of well-being (Diener et al., 2005).

Based on previous literature, it was hypothesised that (i) good sleep quality is associated with increased subjective well-being including increased satisfaction with life (Knutson et al., 2017; Lemola et al., 2013; Pilcher et al., 1997; Shin & Kim, 2018; Weinberg et al., 2016) as well as increased positive and decreased negative affect (Bouwmans et al., 2017; Bower et al., 2010; Lemola et al., 2013; Pilcher et al., 1997). Furthermore, it was hypothesised that (ii) sleep quantity is not associated with subjective well-being (Pilcher et al., 1997; Stoica, 2014). Lastly, it was hypothesised that (iii) good composite sleep is associated with increased subjective well-being (Matricciani, et al., 2018) including increased satisfaction with life as well as increased positive and decreased negative affect.

Method

Participants

141 students (23.4% males, 76.6% females) from the University of Twente (UT) and other universities/colleges were sampled to voluntarily take part in the study. Students from the UT who registered via the Behavioural, Management, and Social Sciences (BMS) Test Subject Pool System SONA received an incentive of 0.5 credits for their participation in the study (79.43%). Others, accessing the online survey directly via the Qualtrics website (Qualtrics, 2018), did not receive any incentive (20.57%). The age of the participants ranged from 18 to 36 (M = 21.39, SD = 2.61). 82.3% of the participants were German, 12.1% Dutch, and 5.7% hold another nationality. Eligibility was restricted to students above the age of 16 years who do not suffer from any diagnosed sleep disorder. All participants gave informed consent prior to filling in the online survey. The study was ethically approved by the BMS Ethics Committee of the UT.

Design

A cross-sectional, correlational design was applied with subjective well-being including both satisfaction with life scores and positive as well as negative affect scores as the dependent variables and sleep quality as well as sleep quantity scores as independent variables.

Materials

The online survey was created via the Qualtrics software (Qualtrics, 2018), an online questionnaire tool with a customised design for UT and comprised three standardised questionnaires for measuring subjective well-being and sleep next to the collection of demographic data.

Satisfaction with Life Scale

The Satisfaction with Life Scale (SWLS) is a self-report instrument that was developed by Diener, Emmons, Larsen, and Griffin (1985) for assessing satisfaction with life as one of three parts of the tripartite model of subjective well-being. The SWLS is a brief 5-item scale that was designed to measure global cognitive judgments of one's life satisfaction. Respondents need to indicate how much they (dis)agree with five statements using a 7-point Likert scale. A total score can be calculated by forming a sum score which ranges between 5 indicating low satisfaction with life and 35 representing high satisfaction with life.

Diener et al. (1985) showed desirable psychometric properties of the SWLS. They reported a two-month test-retest correlation coefficient of .82 and good internal consistency (coefficient alpha of .87). Factor analysis revealed a single factor accounting for 66% of the variance with factor loading ranging between .61 and .84. The scale was also cross-validated with other subjective well-being scales of that time (Diener et al., 1985). Further validations of the SWLS were reported in several studies (e.g. Pavot, Diener, Colvin, & Sandvik, 1991; Pavot & Diener, 1993; Pavot & Diener, 2008).

Scale of Positive and Negative Experience

The Scale of Positive and Negative Experience (SPANE) is also a brief self-report instrument that was developed by Diener et al. (2009) for the assessment of both positive affect and negative affect as the remaining two parts of the tripartite model of subjective well-being. The SPANE is a 12-item questionnaire with six items measuring positive feelings (positive, good, pleasant, happy, joyful, and contented) and six items assessing negative feelings (negative, bad, unpleasant, sad, afraid, and angry). Three items each are general (e.g. positive, negative) and three more specific (e.g. joyful, sad). Respondents have to indicate on a 5-point Likert scale how often they experienced the respective feeling during the past four weeks (ranging from 1 indicating 'very rarely or never' to 5 indicating 'very often or always'). For this study, the SPANE was slightly adapted in terms of changing the reference period to the past week only instead of the past four weeks in order to align with the reference period of the Sleep Health Index (Knutson et al., 2017). Total scores for positive feelings (SPANE-P) and negative feelings (SPANE-N) can be calculated by forming sum scores of the six positive items and of the six negative items, respectively. Both scores range from 6 (few positive/negative feelings) to 30 (a lot of positive/negative feelings). Moreover, an affect balance (SPANE-B) can be calculated by subtracting SPANE-N from SPANE-P resulting in a difference score ranging from -24 (unhappiest possible) to 24 (highest affect balance possible).

Diener et al. (2009) produced psychometric statistics for their scale. A principal axis factor analysis for positive and negative items separately was performed revealing one strong factor each which accounted for 61% (SPANE-P) and 53% (SPANE-N) of the variance in the scale items. Factor loadings ranged from .58 to .81 (SPANE-P) and from .49 to .78 (SPANE-N). Furthermore, the negative and positive scales correlated $r = -.60$ ($N = 682$, $p < .001$) with each other and they substantially correlated with the PANAS scales (Diener et al., 2009; Watson, Clark, & Tellegen, 1988). As a major advantage of the SPANE over other well-

established measures of feelings such as the PANAS, Diener et al. (2009) point out the inclusion of general feelings such as ‘positive’ and ‘negative’, thus encompassing a variety of positive and negative feelings and not just specific feelings that have different desirability and pleasantness for different people. Jovanović (2015) suggested that the SPANE subscales explained additional variance (ranging from 4% to 11% among young adults) in life satisfaction, depression, and general well-being beyond the PANAS subscales. Although SPANE and PANAS overlap substantially, they differ in the level of abstraction of feelings included in the scales and the response scales (SPANE uses frequency-based responses, while PANAS uses an intensity-based scale). The SPANE was further validated in other population samples (e.g. Du Plessis & Guse, 2017).

Sleep Health Index

The Sleep Health Index (SHI) is a self-report survey instrument that was developed by the National Sleep Foundation in order to measure sleep health in the general population (Knutson et al., 2017). The SHI is a 12-item tool based on 14 questions about participants’ sleep during the past week. The SHI provides insight into three subscales, namely ‘sleep quality’, ‘sleep duration’, and ‘disordered sleep’. ‘Sleep quality’ encompasses six items. First, an overall rating of respondents’ sleep quality measured on a 5-point Likert scale (ranging from excellent to poor). Second, five items measuring the number of days in the past seven days that respondents felt well-rested, had trouble falling asleep, had trouble staying asleep, were negatively impacted by lack of sleep, and dozed unintentionally. The subscale ‘sleep duration’ entails three items, namely a weekday sleep score (time in bed duration on weekdays calculated from the difference between ‘going to bed’ clock time and ‘waking up’ clock time), a sleep deficit score (difference between weekday sleep and amount of sleep respondents indicated they needed to feel their best), and sleep variability (difference between time in bed on weekdays and on weekends). The last subscale ‘disordered sleep’ comprises three items, namely sleep medication (number of days in the past seven days that respondents took sleep medication), sleep disorder diagnosed by a doctor (yes/no), and sleep problems discussed with a doctor (yes/no). Total scores ranging from 0 to 100 can be calculated based on a scoring algorithm provided by the National Sleep Foundation for the overall SHI and for each of the three subscales.

Knutson et al. (2017) showed that the SHI is a robust, valid measure of sleep health: Factor analysis provided a high internal consistency (Cronbach $\alpha = .75$ for the overall SHI score, $\alpha = .63$ for both the subscales ‘disordered sleep’ and ‘sleep duration’, and $\alpha = .77$ for

the subscale ‘sleep quality’) and factor loadings ranging from .26 to .70 for the ‘sleep quality’ subscale, from .42 to .75 for ‘sleep duration’ and from .35 to .85 for ‘disordered sleep’. Construct validity was shown through statistically significant correlations ($p < .001$) between the SHI and respondents’ ratings of their overall health ($r = .38$), stress ($r = -.37$), and life satisfaction ($r = .36$). Interestingly, those who were extremely or very satisfied with their lives scored significantly higher on the overall SHI score including all three subscale scores compared to those who were only a little or not at all satisfied with their lives. In line with that, regression analyses showed that life satisfaction positively predicted the SHI (Knutson et al., 2017).

For this study it was decided against the widely used Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds III, Monk, Berman, & Kupfer, 1988) and in favour of the SHI as the SHI was especially developed for the general population (which is in line with the university student sample in this study) unlike the PSQI which focuses primarily on sleep disturbances in clinical populations. Moreover, the SHI differs from the PSQI in that it pertains to a shorter recall period (seven days instead of one month) which improves accuracy due to less recall error as well as in that it distinguishes between weekdays and weekends and thus introduces a measure of sleep variability (Knutson et al., 2017).

Procedure

Participants accessed the online survey either via SONA or directly through the Qualtrics URL. They were briefly informed that the study was about sleep and its relation with well-being. They were instructed to carefully read the questions and to answer them in an honest and serious way. Moreover, they were kindly asked to refrain from doing other activities while filling in the online survey which was likely to take about ten minutes. At the beginning, participants were asked to provide their informed consent by selecting the (dis)agree option. Only when agreeing to the informed consent, participants continued with the online survey and were asked to provide demographic data including their student status (yes/no), their gender (male, female, other), their age (from 16 years upwards), and their nationality (German, Dutch, other).

First, participants filled in the questionnaires measuring the dependent variables: The first and content-wise most general questionnaire was the SWLS, followed by the time-wise more specific SPANE. Next, participants filled in the SHI measuring the independent variables split up into several subpages of the online survey. All questions of the online

survey forced participants' responses in order to prevent missing data. Finally, participants were thanked for taking part in the study and given contact details of the researcher in case of any questions or feedback.

Data Analysis

The data analysis was carried out using IBM SPSS Statistics 24 (IBM Corp., 2016) and R (Fox & Weisberg, 2019; R Core Team, 2018). As eligibility was restricted to students above the age of 16 years who do not suffer from any diagnosed sleep disorder, non-students as well as participants who indicated in the SHI that they have been told by a doctor that they have a sleep disorder were excluded. First, descriptive statistics were deduced from participants' demographic data and the scores of all participants were calculated for all questionnaires including the SWLS sum score, the SPANE-P score, the SPANE-N score, the total SHI score, the SHI sleep quality score, the SHI sleep duration score, and the SHI disordered sleep score.

In a next step, descriptive statistics including the mean, standard deviation, minimum and maximum were produced for each of the well-being and sleep scores and visualised by means of boxplots. A correlation matrix including the Pearson correlation coefficients was generated for all scores. Moreover, a principal component factor analysis with varimax rotation was performed for all questionnaires to ensure their respective construct validity. Next to that, the reliability of the scales was analysed by means of the internal consistency measure Cronbach's Alpha. In order to test the first and second hypothesis, a multivariate multiple linear regression analysis with 95% confidence intervals was performed (Bortz, 1999, p. 567f) to predict subjective well-being (SWLS sum score, SPANE-P and SPANE-N scores) based on sleep quality, sleep quantity, and disordered sleep (SHI scores for each subscale). The model assumptions for multivariate regression analysis were tested. Furthermore, based on large leverages (larger than three times the average leverage) outliers were identified (Field, Miles, & Field, 2012). For testing the third hypothesis, another multivariate linear regression analysis with 95% confidence intervals was performed to predict well-being based on a composite sleep score (total SHI score).

Results

In general, with regards to their well-being, students reported to be rather satisfied with their lives and to have experienced more positive than negative emotions during the past

week. Concerning their sleep, most of the students scored rather high on the SHI sleep duration subscale, although there were a few students that scored substantially lower. With respect to the SHI sleep quality subscale, scores varied much more along the whole scale. As eligibility was restricted to students that do not suffer from any diagnosed sleep disorder, the majority received the highest possible score on the SHI disordered sleep subscale. Figures 1, 2, and 3 provide an overview of the descriptive statistics by means of several boxplots for the scores on the well-being questionnaires (SWLS, SPANE-P, and SPANE-N) and the scores on the sleep questionnaire (SHI total, SHI sleep duration, and SHI sleep quality).

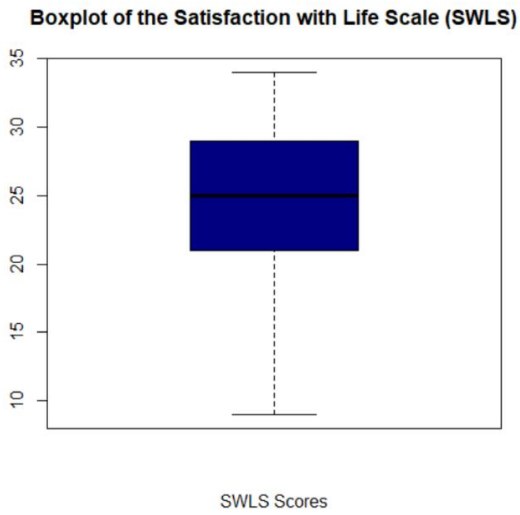

Figure 1. Boxplot of the scores of the Satisfaction with Life Scale (SWLS) ranging from 5 (low satisfaction) to 35 (high satisfaction).

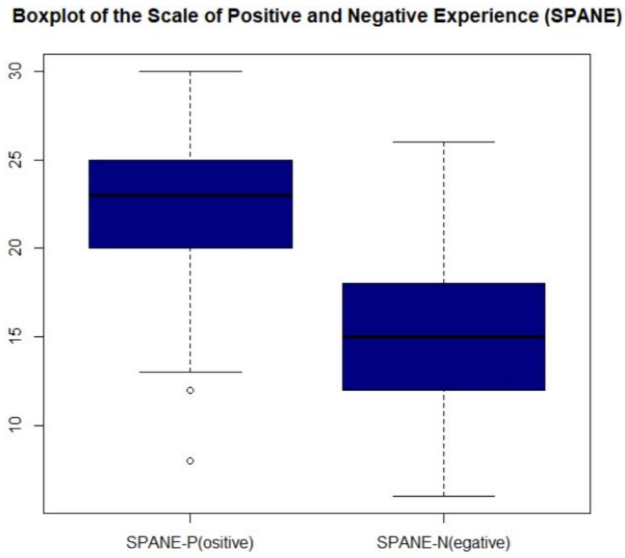

Figure 2. Boxplots of the scores of the Scale of Positive and Negative Experience (SPANE) ranging from 6 (few positive/negative feelings) to 30 (a lot of positive/negative feelings).

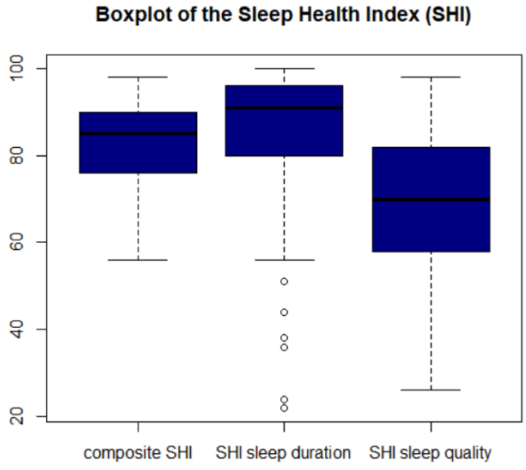

Figure 3. Boxplots of the sleep scores of the Sleep Health Index (SHI) ranging from 0 (poor sleep) to 100 (good sleep).

All well-being scores were significantly correlated with each other at the $p < .01$ level which suggests that the subsequent outcome of the multivariate regression analyses can be interpreted with confidence because the three well-being scores seem to represent one underlying construct, namely subjective well-being. With regards to the sleep scores, the SHI sleep duration and the SHI sleep quality significantly correlated with each other ($r = .23$) at the $p < .01$ level. When looking at the relationship between well-being and sleep, both the SHI sleep quality and the total SHI were significantly correlated with the well-being scores at the $p < .01$ level. While the SWLS and the SPANE-P were positively correlated with the two just mentioned SHI scores, the SPANE-N was negatively correlated with those scores. The SHI sleep duration score was not correlated with any of the well-being scores. Table 1 provides an overview of the Pearson correlation coefficients for all well-being and sleep scores.

Table 1
Pearson correlation coefficients

	Pearson correlation coefficients							
	SWLS	SPANE-P	SPANE-N	SPANE-B	SHI sleep duration	SHI sleep quality	SHI disordered sleep	total SHI
SWLS	1	.63**	-.50**	.63**	.00	.45**	.17*	.33**
SPANE-P		1	-.56**	.87**	.04	.39**	.09	.28**
SPANE-N			1	-.90**	-.03	-.46**	-.17*	-.35**
SPANE-B				1	.04	.48**	.15	.36**
SHI sleep duration					1	.23**	-.13	.62**
SHI sleep quality						1	.20*	.77**
SHI disordered sleep							1	.51**
total SHI								1

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

The principal component factor analysis showed acceptable results that were in line with expectations for both well-being questionnaires, indicating that the adaptation of the SPANE did not impair the construct validity of both positive and negative affect. Regarding the SHI, principal component factor analysis showed that there were three factors with an

Eigenvalue higher than 1. As expected, the three sleep duration measures (weekday sleep score, sleep deficit score, sleep variability score) loaded strongly on one factor (19% explained variance) with factor loadings ranging from .72 to .79. However, the remaining items did not load as expected on the two remaining factors. The cumulative variance explained by the three factors was 56%. Cronbach's alpha of all SHI items was $\alpha = .68$ (sleep duration items: $\alpha = .67$; sleep quality items: $\alpha = .74$; disordered sleep items: $\alpha = .24$).

Multivariate multiple linear regression analysis

To test the first and second hypothesis, a multivariate multiple linear regression analyses with all three well-being scores as the dependent variables and the additive scores of the SHI sleep duration, the SHI sleep quality, and the SHI disordered sleep as the independent variables was performed. This overall model was statistically significant ($F(9,329) = 5.58$, $p = .000$; *Wilks' Λ* = .71) indicating that there is a relationship between subjective well-being and sleep. The model assumptions of linear regression were tested, and no objections were found regarding the linearity, independence, normal distribution, and equal variance of residuals. Based on large leverages (larger than $hi > .09$), six outliers were detected which did not fit the regression model well. However, there exists no substantive information about those outliers that suggested removing them.

In accordance with the first hypothesis, the SHI sleep quality was a significant predictor in this model ($F(3,135) = 15.80$, $p = 000$; *Wilks' Λ* = .74; *partial* $\eta^2 = .26$) which indicates that sleep quality is significantly related to the three well-being scores taken as a whole with a large effect size of *partial* $\eta^2 = .26$. In addition to that, sleep quality was also significantly related to each well-being score seen individually (SWLS: $F(1,137) = 31.89$, $p = .000$, 95% CI [.11, .22], *partial* $\eta^2 = .19$; SPANE-P: $F(1,137) = 22.77$, $p = .000$, 95% CI [.06, .13], *partial* $\eta^2 = .14$; SPANE-N: $F(1,137) = 32.86$, $p = .000$, 95% CI [-.17, -.08], *partial* $\eta^2 = .19$).

In contrast to that, but in line with the second hypothesis, the SHI sleep duration was not a significant predictor in the multivariate multiple linear regression model ($F(3,135) = .48$, $p = .70$; *Wilks' Λ* = .989; *partial* $\eta^2 = .01$) which suggests that sleep duration is not significantly related to the three well-being scores taken as a whole. Neither was sleep duration related to any of the well-being scores seen individually (SWLS: $F(1,137) = 1.29$, $p = .26$, 95% CI [-.09, .02], *partial* $\eta^2 = .01$; SPANE-P: $F(1,137) = .39$, $p = .53$, 95% CI [-.06, .03], *partial* $\eta^2 = .00$; SPANE-N: $F(1,137) = .61$, $p = .44$, 95% CI [-.03, .06], *partial* $\eta^2 = .00$).

As this first model suggests that only sleep quality is significantly related to the well-being scores taken as a whole, it needs to be tested whether a simpler model with sleep quality as the only predictor reveals a larger effect size and thus explains even more of the variance of the well-being scores. For this purpose, another multivariate linear regression model again with the well-being scores as the dependent variables, but this time only with the SHI sleep quality scores as single independent variable was performed. This second model was again statistically significant ($F(3,137) = 17.20$, $p = .000$; *Wilks' Λ* = .73; *partial* η^2 = .27). Compared to the effect size of the SHI sleep quality in the previous model (*partial* η^2 = .26), the effect size of this second model is only slightly higher (*partial* η^2 = .27), though.

Figure 4 exemplarily illustrates that the SHI sleep quality scores were also significant predictors in the simple linear regressions for each well-being score seen individually (SWLS: $F(1,139) = 34.33$, $p = .000$, *partial* η^2 = .20; SPANE-P: $F(1,139) = 24.37$, $p = .000$, *partial* η^2 = .15; SPANE-N: $F(1,139) = 36.67$, $p = .000$, *partial* η^2 = .21). As opposed to that, figure 5 exemplifies that the SHI sleep duration scores were not significantly associated with the well-being scores. The remaining scatterplots for SPANE-P and SPANE-N can be found in the appendix.

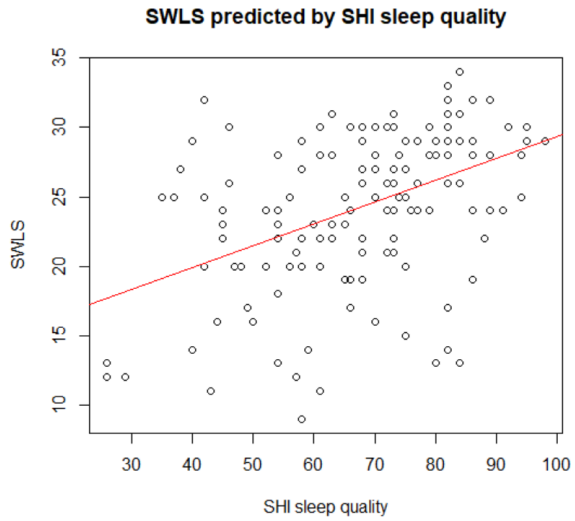

Figure 4. Scatterplot of the Satisfaction with Life Scale scores (SWLS) and the Sleep Health Index (SHI) sleep quality scores. The simple linear regression analysis with SWLS as dependent variable predicted by the SHI sleep quality scores as independent variable showed a significant linear relationship ($F(1,139) = 34.33$, $p = .000$, *partial* η^2 = .20).

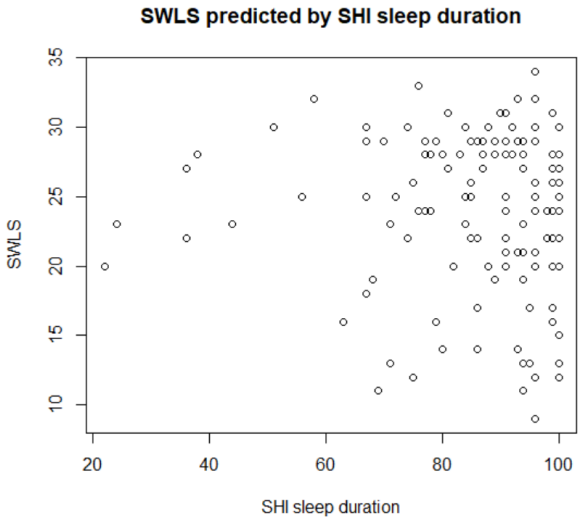

Figure 5. Scatterplot of the Satisfaction with Life Scale scores (SWLS) and the Sleep Health Index (SHI) sleep duration scores. No significant linear relationship between SWLS as dependent and SHI sleep duration as independent variable emerged.

On an exploratory basis, in order to further narrow down which specific sleep quality items were most strongly associated with subjective well-being, another multivariate multiple linear regression model again with the three well-being scores as the dependent variables, but this time with the six specific SHI sleep quality items as independent variables was performed. This model was again statistically significant ($F(6,134) = 3.69$, $p = .000$; *Wilks' Λ* = .63). Only two of the six items, namely SHI item 7 (number of days that the respondents had difficulties falling asleep) and SHI item 9 (number of days that poor or insufficient sleep impacted the respondents' daily activities), were significantly related to the three well-being scores taken as a whole (SHI item 7: $F(3,132) = 3.26$, $p = 024$; *Wilks' Λ* = .93; *partial* η^2 = .07; SHI item 9: $F(3,132) = 4.40$, $p = 006$; *Wilks' Λ* = .91; *partial* η^2 = .09). In terms of the effect size, this model (SHI item 7: *partial* η^2 = .07; SHI item 9: *partial* η^2 = .09) is inferior to the effect size of the overall SHI sleep quality score in the previous models (*partial* η^2 = .26 or *partial* η^2 = .27 respectively) which indicates that the overall SHI sleep quality scores explain more of the variance in the subjective well-being scores than the single SHI sleep quality items.

Additive versus composite sleep scores

Regarding the third hypothesis, another multivariate linear regression model again with three well-being scores as the dependent variables, but now with the total SHI score as the only independent variable was performed. This model was again statistically significant ($F(3,137) = 8.28$, $p = .000$; *Wilks' Λ* = .85; *partial* η^2 = .15). In addition to that, the total SHI was also significantly related to each well-being score seen individually (SWLS: $F(1,139) = 16.62$, $p = .000$, *partial* η^2 = .11; SPANE-P: $F(1,139) = 11.61$, $p = .000$, *partial* η^2 = .08; SPANE-N: $F(1,139) = 19.29$, $p = .000$, *partial* η^2 = .12). However, the effect size of the total SHI in this last model was considerably lower (*partial* η^2 = .15) compared to the effect sizes of the SHI sleep quality in the first (*partial* η^2 = .26) and the second simpler model (*partial* η^2 = .27). This indicates that composite sleep explains less of the variance in the subjective well-being scores than sleep quality.

Discussion

The aim of this study was to further clarify the relationship between both sleep quality and sleep quantity and Diener's subjective well-being (Diener et al., 2005) including satisfaction with life and positive as well as negative affect. For this purpose, students'

current sleep quality and sleep quantity were measured by means of the National Sleep Foundation's Sleep Health Index (Knutson et al., 2017), while their subjective well-being was measured by use of the Satisfaction with Life Scale (Diener et al., 1985) and the adapted Scale of Positive and Negative Experience (Diener et al., 2009). Overall, this study provided substantive evidence for a significant relationship between sleep quality and subjective well-being by means of several multivariate linear regression analyses.

With regards to the hypotheses, all three of them have been confirmed in this study: In line with the first hypothesis, good sleep quality was significantly associated with increased subjective well-being including both increased satisfaction with life and increased positive affect as well as decreased negative affect. In accordance with the second hypothesis, sleep duration was not associated with any of the subjective well-being scores. And lastly, good composite sleep was again significantly associated with increased subjective well-being. While sleep quality alone explained either 26% or 27% of the variance in subjective well-being scores depending on the underlying model being used, composite sleep explained only 15% of variance in subjective well-being scores, thus indicating that sleep quality alone is the single best predictor in subjective well-being scores. However, it must be kept in mind that this study was correlational, therefore no inferences about causality can be made.

These findings are consistent with previous studies that suggested, on the one hand, a relationship between sleep quality and satisfaction with life (Shin & Kim, 2018; Pilcher et al., 1997; Weinberg et al., 2016), and on the other hand, a relationship between sleep quality and positive as well as negative affect or affect balance (Bouwmans et al., 2017; Pilcher et al., 1997). However, none of the previous literature combined all three measures of Diener's tripartite model of subjective well-being (Diener et al., 2005) in one multivariate linear model which makes this study unique and provides the opportunity to investigate the sleep-well-being link in terms of one comprehensive construct of subjective well-being. Only Lemola et al. (2013) combined somewhat similar aspects, namely satisfaction with life, positive affect, and symptoms of distress when modelling subjective well-being in structural equation modelling.

Next, unlike Pilcher et al. (1997) who also suggested a moderate relationship between sleep quantity and subjective well-being, albeit significantly less strong than the relationship between sleep quality and subjective well-being, no such linear relationship between sleep duration and subjective well-being has been found in the current study. Also contrary to the

findings of the current study, Lemola et al. (2013) suggested a relationship between sleep variability and subjective well-being mediated by sleep quality. However, the results of the present study are in line with Stoica (2014) who did not find a significant relationship between objectively measured sleep duration and subjective well-being either.

Regarding the suggestion by Matricciani et al. (2018) to rethink the sleep-health link by means of different ways of integrating scores of the multidimensional construct of sleep which are then linked to health outcomes, this study examined two ways: On the one hand, this study used the additive scores of sleep quality and sleep duration and on the other hand, a composite sleep score was calculated. Although both variants significantly predicted well-being scores, they largely differed in the amount of explanatory power. In the additive model, sleep quality accounted for a much larger effect size than the composite sleep score in the composite model. Thus, this study confirms that it makes a tremendous difference in terms of explanatory power in which way the sleep-health link is modelled. These findings suggest that additive linear regression models should be preferred over composite scores when it is expected that only certain parts of the predicting construct (such as only sleep quality and not sleep duration in the present study) are responsible for the sleep-health link.

Differences in the measurement of sleep quality and of sleep duration

When comparing the results concerning sleep quality of the current study with previous literature (e.g. Bower et al., 2010; Pilcher et al., 1997; Shin & Kim, 2018; Weinberg et al., 2016), it must be noted, however, that nearly all previous studies employed the PSQI (Buysse et al., 1988) to measure sleep quality. As mentioned previously, the PSQI differs from the SHI in several ways. Thus, the findings are not completely comparable. Instead, the present study provides an important extension of previous findings to new aspects of sleep and its relationship with well-being by shifting the attention to positive qualities of momentary sleep health rather than underlying sleep problems or disordered sleep. Next to the differences mentioned previously, the SHI tries to separate measures of sleep quality from measures of sleep duration by forming specific subscales accordingly, whereas the PSQI combines various aspects of sleep quality, duration, and medication use in one global PSQI score that is put on an equal footing with sleep quality in previous studies. Thus, the global PSQI score seems to be more closely comparable with the composite SHI score rather than with the more specific SHI sleep quality score. The current study showed that the relationship between composite SHI and subjective well-being had a smaller effect size compared to the

SHI sleep quality score. This implies that by employing the global PSQI score instead of a measure of pure sleep quality previous studies might have actually underestimated the strength of the relationship between sleep quality and well-being.

With regards to sleep duration, an explanation for the different findings can possibly be ascribed to a different operationalisation of sleep quantity or duration in this study compared to Pilcher et al. (1997) who measured time in bed and time asleep or Lemola et al. (2013) who derived day-to-day sleep variability from polysomnography: In contrast to that, the SHI sleep duration combines a measure of weekday sleep duration, a measure of sleep variability, and a measure of sleep deficit (Knutson et al., 2017), so it is a combination of different aspects of sleep duration. In addition to that, the weekday sleep duration is inferred from respondents' time in bed and thus could be biased. Moreover, but rather positively, the SHI allows maximum scores only for optimal sleep durations between seven and nine hours as recommended by the National Sleep Foundation (Hirshkowitz et al., 2015), so it takes both too short and too long sleep durations into account while scoring.

Nevertheless, this could mean that the operationalisation of sleep duration might be one explanation of why this study did not find a significant relationship between sleep duration and subjective well-being rather than that this relationship does not exist at all. From a theoretical point of view, it seems likely that severe sleep deprivation has an influence on subjective well-being as it causes hallucinations right up to psychosis (Waters, Chiu, Atkinson, & Blom, 2018). But the focus of the current study was on sleep health in a non-clinical population and not sleep deprivation. In line with that, most participants scored rather high on the SHI sleep duration score with a few exceptions only. Thus, it can be deduced from the present study that, after a certain minimum of sleep duration is met (or nearly optimal sleep duration is reached), further variance of sleep duration seems not as relevant to subjective well-being anymore.

When further exploring the construct of pure sleep quality as measured by the SHI, the operationalisation of SHI sleep quality seems to lack coherence in this sample as suggested by the principal component factor analysis. Therefore, this study at least partly disagrees with the factor structure proposed by the SHI authors (Knutson et al., 2017). Furthermore, only two of the six specific SHI sleep quality items were significantly associated with the subjective well-being scores: the SHI item 7 (number of days that the respondents had difficulties falling asleep) and the SHI item 9 (number of days that poor or

insufficient sleep impacted the respondents' daily activities). This is partly in line with Bower et al. (2010) who found that next to a single item of subjective sleep quality, daytime dysfunction which is closely comparable to SHI item 9 was most consistently related to positive and negative affect. These findings suggest that when aiming to improve student's well-being, next to improving students' sleep quality, one should pay special attention to minimising the impact that poor sleep has on the student's daily activities, for example by offering lectures in the afternoon instead of the early morning.

Previous literature agrees in that subjective measures of sleep quality are better predictors of subjective well-being than objective measures (Evers, Hopp, Gross, Fischer, Manstead, & Mauss, 2014; Stoica, 2014) or more specifically that they mediate the relationship between objective measures of sleep and subjective well-being (Lemola et al., 2013). But still, what is subjective sleep quality? Krystal and Edinger (2008) put forward the possibility that sleep quality might reflect different aspects of sleep among different people. They also argue that the relationship between subjective sleep quality and non-sleep phenomena such as mood or anxiety (or subjective well-being in this study) might be more significant than objective sleep measures because it is exactly those extraneous mood states rather than actually poorer sleep that affect the subjective sleep quality appraisal process (Krystal & Edinger, 2008) which emphasises the question about the direction of causality.

Practical applicability of the findings

Finally, in terms of applicability of the results, interventions among college students focusing on improving the sleep quality rather than sleep quantity to promote subjective well-being (Ridner et al., 2016) are on the cards, although the direction of causality remains to be further examined first. Besides that, the finding that sleep quality instead of sleep quantity is closely connected to subjective well-being, is of interest for the sleep industry which is momentarily booming: Various digital products such as sleep trackers or smart mattresses are entering the market that aid in tracking one's sleep and that detect for example light sleep phases for a gentle wake-up call in the morning (e.g. Consumer Sleep Solutions LLC, 2019; Eight Sleep, 2019). Another technology goes even further by directly intervening in customers' sleep in order to improve their sleep quality: According to the producer (Koninklijke Philips N.V., 2019), slow-wave sleep is enhanced by playing specific sounds via headphones during deep sleep. But there are already some critical voices claiming that sleep tracking might eventually backfire and generate anxiety and self-diagnosed sleep

disturbances when the perfectionist expectation of ideal sleep is not met (Baron, Abbott, Jao, Manalo, & Mullen, 2017). Thus, the current study shows that the sleep industry would clearly benefit from focussing on qualitative aspects of sleep instead of more objective measures such as sleep duration when aiming at increasing their customers' well-being.

Suggestions for future research

As this study investigated the relationship between sleep and well-being in a correlational design which does not allow any inference about causality, future research should follow a longitudinal design. For this purpose, both sleep and subjective well-being could be measured on a weekly basis with the same instruments that have been used in the present study, so that it can be determined whether good SHI sleep quality in fact causes subjective well-being in the following week. However, a proper experimental design that manipulates participants' sleep quality and duration is needed to establish perfect causality by controlling for a possible third variable which might account for the relationship.

Moreover, the construct of subjective sleep quality is still under debate and this study could only add bits of information regarding this issue. Future research should therefore investigate whether further improvements to the SHI can be made in terms of its factor structure and the derivations of the composite score and the scores per subscale. This could for example be achieved by adapting certain items or by adjusting the scoring procedure. It might help to further concretise and specify the SHI sleep quality score which might then also be mirrored in the relationship between sleep quality and subjective well-being, e.g. by means of an even larger effect size.

Besides that, the current study relied exclusively on self-report measures. As suggested by Lemola et al. (2013), the relationship between objective measures of sleep such as sleep variability measured via polysomnography and subjective well-being is mediated by subjective sleep quality. Therefore, it would be interesting for future studies to extend the current study by adding objective measures of sleep such as polysomnography or wristbands that are capable of tracking participants' sleep. Then it could be tested whether the SHI sleep quality is indeed a mediator in the relationship of those objective measures and subjective well-being rather than a single independent predictor as suggested by the current study.

Lastly, the sample of this study was limited to university students. Future studies should expand their samples to the general population to see whether the current results can be replicated within the general population as well. Moreover, as the current study focused

exclusively on sleep health and thus excluded participants with any diagnosed sleep disorder, it would be of interest to test whether the sleep-well-being link found in this study still holds or whether sleep duration gains influence when including participants that suffer from any kind of sleep disorder.

Conclusion

In conclusion, this study found a statistically significant association between good sleep quality and increased subjective well-being including both increased satisfaction with life and increased positive affect as well as decreased negative affect. The effect size of this relationship was large (26% explained variance). No evidence was found for a relationship between sleep duration and subjective well-being. And finally, good composite sleep was significantly associated with increased subjective well-being as well, although the explanatory power was much smaller (15% explained variance) than that of sleep quality alone, indicating that the latter is the single most important predictor in subjective well-being in this study. Thus, when focussing on sleep health rather than sleep problems, this study showed that sleep quality and not sleep duration is accountable for the sleep-well-being link which is an important insight on the theoretical level. Practically, this study pointed out that the sleep industry should focus on promoting sleep quality instead of sleep duration when aiming at improving their customers' well-being.

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Appendix

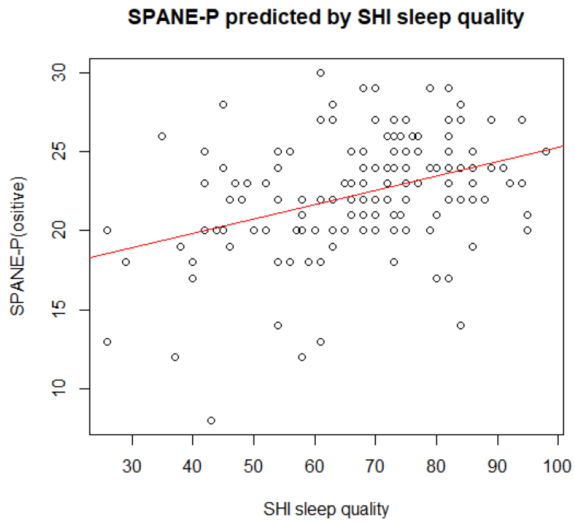

Figure 6. Scatterplot of the positive Scale of Positive and Negative Experience scores (SPANE-P) and the Sleep Health Index (SHI) sleep quality scores. The simple linear regression analysis with SPANE-P as dependent variable predicted by the SHI sleep quality scores as independent variable showed a significant linear relationship ($F(1,139) = 24.37$, $p = .000$, *partial* $\eta^2 = .15$).

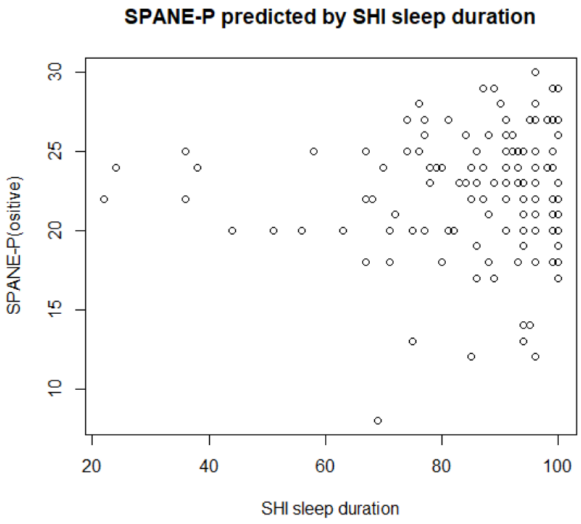

Figure 7. Scatterplot of the positive Scale of Positive and Negative Experience scores (SPANE-P) and the Sleep Health Index (SHI) sleep duration scores. No significant linear relationship between SPANE-P as dependent and SHI sleep duration as independent variable emerged.

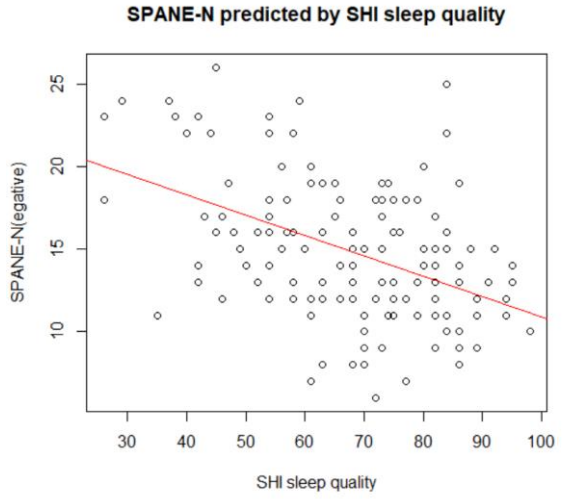

Figure 8. Scatterplot of the negative Scale of Positive and Negative Experience scores (SPANE-N) and the Sleep Health Index (SHI) sleep quality scores. The simple linear regression analysis with SPANE-N as dependent variable predicted by the SHI sleep quality scores as independent variable showed a significant linear relationship ($F(1,139) = 36.67$, $p = .000$, *partial* $\eta^2 = .21$).

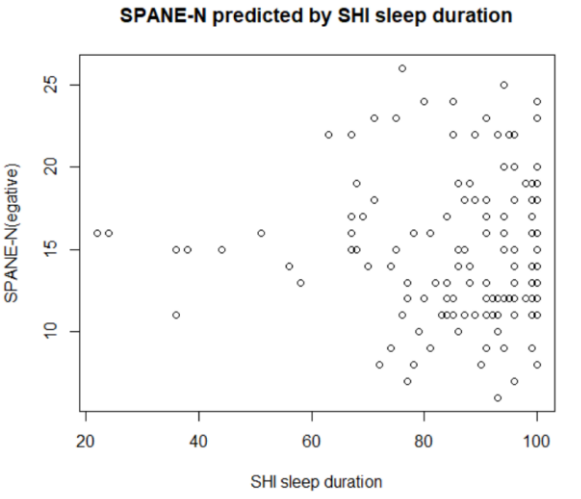

Figure 9. Scatterplot of the negative Scale of Positive and Negative Experience scores (SPANE-N) and the Sleep Health Index (SHI) sleep duration scores. No significant linear relationship between SPANE-N as dependent and SHI sleep duration as independent variable emerged.