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The effect of anticipatory stress and openness and engagement on subsequently perceived
sleep quality - an Experience Sampling Method Study

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Conflict of Interest

All authors declare that they have no competing interests.

Author Contributions

Author A. T. G. conceived and designed the study. Authors V. J. B. and A. T. G. drafted the manuscript. Authors V. J. B. and A. H. M. conducted the statistical analysis. All authors had access to and critically revised the manuscript. All authors read and approved the final manuscript.

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Summary

High stress levels can influence sleep quality negatively. If this also applies to *anticipatory* stress is poorly documented, however. Across insomnia severity levels, this study examined participants' evening levels of a) anticipatory stress and b) their skills hypothesized to downregulate the impact of stress, namely openness to internal experiences and continuous engagement in meaningful activities (openness & engagement) and their association with the quality of the subsequent night's sleep. The moderating role of insomnia severity was also tested. We used a quasi-experimental longitudinal design with Experience Sampling Method (ESM) using smartphones over the course of one week (3976 assessments; 93.2% of prompted queries). Participants recorded their sleep quality, anticipatory stress, and openness and engagement within their daily context. Participants included in the study were diagnosed with Major Depressive Disorder (MDD; $n = 118$), Social Phobia (SP; $n = 47$), or belonged to the control group (CG; $n = 119$). Both anticipatory stress and openness and engagement predicted subsequent sleep quality. Diagnostic group was associated with overall sleep quality, but did not interact with the predictors. These findings were invariant across levels of self-reported insomnia severity. Furthermore, openness and engagement and anticipatory stress did not interact in their effect on sleep quality. The results suggest that both stress reduction and increased openness and engagement are associated with improved subjective sleep quality on a day to day basis, regardless of insomnia severity. Targeting these variables may help improve sleep quality. Future research should disentangle the effects of openness and engagement on anticipatory stress.

Keywords: sleep, stress, daily life, repeated measures, smartphone, ecological momentary assessment

Introduction

One in four people in Europe suffer from sleep disturbances (van de Straat & Bracke, 2015), meaning they experience difficulties in falling asleep, maintaining sleep, and/or they suffer from early awakening (Franzen & Buysse, 2008). Sleep disturbances are associated with a broad range of psychopathological symptoms, including mood and anxiety. As psychopathology and sleep are intertwined, sleep disturbances may be understood not only a cause but also as consequence of mental disorders in etiopathogenetic models (Harvey, 2008). Sleep disturbances have been implicated in both anxiety and mood disorders (Alvaro, Roberts, & Harris, 2013). For Major Depressive Disorder (MDD), sleep disturbances occur in a majority of patients, but at varying levels of severity, and studies find that sleep disturbances are an important risk factor for the subsequent development of MDD (Rumble, White, & Benca, 2015). Social Phobia (SP) has been associated with decreased sleep quality in some studies, but findings are inconclusive (Moutier & Stein, 2001). Therefore, the degree to which sleep disturbances are a characteristic of diagnostic categories is nuanced. Therefore, in order to more fully understand sleep disturbances, it is important to consider a range of diagnoses as well as the general population.

Similar to sleep disturbances, stress is generally associated with negative effects on mental health. Stress is the ability to mobilize reserves of strength and energy to react appropriately to dangerously perceived situations (Chrousos, 2009). The presence of stress can negatively affect sleep by decreasing sleep quality during the night and, due to lack of rest, consequently increase sleepiness during the day (Åkerstedt, Hallvig, & Kecklund, 2017), impair cognitive functioning (Durmer & Dinges, 2005), and disrupt functional emotion encoding (Tempesta, Socci, De Gennaro, & Ferrara, 2018). Several biological pathways have been implicated in this process. For example, evidence suggests that the 5-HTT gene variation moderates the relationship of chronic stress of caregivers on sleep quality (Brummett

et al., 2007). Stress can also elevate cortisol levels and increase restlessness (Dahlgren, Kecklund, & Åkerstedt, 2005; Morgenthaler et al., 2007), and alter the heart-rate variability, leading to heightened arousal during sleep with more sleep disruptions (Hall et al., 2004). To cope with stress, emotion regulation behaviors such as worrying and ruminating have been observed (Irish, Kline, Gunn, Buysse, & Hall, 2015). Overall, evidence points towards dysfunctional emotional responding both biologically and behaviorally, especially when sleep is chronically disturbed (Goldstein & Walker, 2014).

In order to mitigate the negative impact of stress on sleep, it is necessary to theorize and examine the relationship between these two variables in a temporally sensitive manner. That is, in what way does stress that occurs before sleep impact temporally subsequent sleep. Towards this end, cross-sectional research is inadequate. Needed are theories that explicate the temporal sequence and longitudinal studies. One example of such a temporal description is the observation that stress impacts sleep by increasing restlessness, which in turn is believed to increase the risk to develop insomnia (Léger, Poursain, Neubauer, & Uchiyama, 2008). Still, little is known about the effect of anticipatory stress – stress that is expected to only manifest itself later – and how it relates to sleep, as this specific type of stress regarding future events has not been studied in depth.

How stress has been investigated also differs widely from analyzing life-event stress to measuring accumulated daily work-stress. Most studies that assess the effect of stress on sleep use laboratory or cross-sectional study designs, making the findings dependent on a single measurement point (Nelson, McGorry, Wichers, Wigman, & Hartmann, 2017).

Anticipatory stress, a form of stress concerning the future but manifesting itself in the present, may be an important link to better understanding how stress impacts sleep quality. To our knowledge, there are no studies yet investigating the stress people expect to have the next day (i.e. anticipatory stress) and its temporal association with subsequent sleep quality,

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as research has focused on past or present stress. It stands to reason that anticipatory stress could be problematic if it includes increased worry about the next day. Based on cross-sectional studies, worry (or concerns about ambiguous future-oriented stressors) has been associated with sleep (McGowan, Behar, & Luhmann, 2016). The only study specifically examining the influence of anticipatory stress on sleep used a laboratory paradigm and found that induced anticipatory stress before a scheduled nap negatively impacted sleep onset in the next hour (Gross & Borkovec, 1982).

In addition to specifying temporal relationships, the active mechanisms that contribute to sleep disturbances can be further explained by examining how individuals react to stress. This is particularly important given that it is not the objective quality of the situation alone (e.g. a given workload) that defines the stress reaction. How an individual reacts to a given stressor largely depends on how the individual perceives the situation and his or her capability to cope with the implicated challenges (Chrousos, 2009). People can respond to stress rigidly and in ways that magnify its impact or flexibly and in ways that mitigate its impact. That is, the degree to which someone can be open to their experiences including the thoughts and feelings that elicit stress and continue to engage in the things they wish (openness and engagement) may help mitigate the impact of stress and increase the quality of sleep. Indeed, openness and engagement are parts of the larger construct of psychological flexibility, which has been found to decrease suffering and increase well-being across numerous disorders and problem areas. Psychological flexibility, a compound of dynamic psychological processes has been found to be a fundamental factor in mental health (Kashdan & Rottenberg, 2010). Within its definition, openness and engagement can be described as “distancing from, and letting go of, unhelpful thoughts, beliefs, and memories”, “making room for painful feelings, urges, and sensations, and allowing them to come and go without a struggle”, and “engaging fully with you’re here-and-now experience, with an attitude of

openness and curiosity” (Ciarrochi, Kashdan, & Harris, 2013, p.3). This includes how individuals relate to stress (Wersebe, Lieb, Meyer, Hofer, & Gloster, 2018). Lower levels of openness and engagement have been associated with higher levels of stress (Hofer et al., 2018) and are implicated as a moderator in the processing of stress (Gloster, Meyer, & Lieb, 2017). A previous study also found, that an increase in openness and engagement could predict increases in functioning for patients suffering from anxiety and burnout (Benoy et al., 2019), both complaints that are linked to stress. The lack of openness and engagement skills, however, can lead to experiential avoidance when dealing with stressful situations, even increasing a person’s sensitivity to distress (Bardeen & Fergus, 2016), which could have implications for sleep.

The association between skills of openness and engagement and sleep quality has been investigated only three times to our knowledge within the broader concept of psychological flexibility (Daly-Eichenhardt, Scott, Howard-Jones, Nicolaou, & McCracken, 2016; Langrial, Oinas-Kukkonen, Lappalainen, & Lappalainen, 2018; McCracken, Williams, & Tang, 2011). The first study, using a cross-sectional cohort design, found a significant association of sleep parameters and psychological flexibility for patients with chronic pain, such that sleep disturbances were more severe in those with lower psychological flexibility (McCracken et al., 2011). The second study indirectly measured the effect of training psychological flexibility for pain management on sleep disturbances, reporting remission from clinical insomnia for 15% of the sample after a four-week intervention (Daly-Eichenhardt et al., 2016). Finally, a recently published study reported on a web-based intervention aimed at increasing psychological flexibility resulting in improved sleep management for 32.7% of participants (Langrial et al., 2018). However, the role played by stress and the skills of openness and engagement with regards to insomnia or its severity in other clinical samples remains unclear.

Ong and Manber (2013) propose a metacognitive model of insomnia, in which key aspects of psychological flexibility, namely mindfulness, acceptance and perspective-taking, are implicated as pathways through which sleep disturbances can be affected. The impaired ability to flexibly deal with emotions can be described as a process commonplace in people suffering from psychopathology (Kashdan & Rottenberg, 2010) and one aspect - regulating one's emotions - has been shown to impact sleep (Fairholme & Manber, 2015). Furthermore, poor sleep has been associated with difficulties in emotion regulation, a process that can be influenced by engaging in adaptive behaviors such as using openness and acceptance, even when controlling for stress (Mauss, Troy, & LeBourgeois, 2013). In order to examine the processes of sleep with temporal fidelity, it is important to collect data using ESM. ESM also has the advantage of limiting the Memory Experience GAP (Rinner et al., 2019), a phenomenon that describes increasingly skewed memories, the longer ago the experience or the broader the timespan in question is (Miron-Shatz, Stone, & Kahneman, 2009). It stands to reason to use state-of-the-art methodology that circumvents this gap, especially if one is interested in the daily influence of variables in a real-life setting (i.e. of the participant during his daily routine). Ambulatory assessment enables researchers to obtain data close to the participant and several times per day (Wilhelm & Grossman, 2010) therefore measuring variables with greater ecological validity. Only few studies have measured stress with an ambulatory assessment paradigm, where stress is measured multiple times daily and sleep is measured in a natural setting. Smyth et al. (1998) for example, used ESM to show that cortisol levels increase in concordance with number of stressors experienced at a given time point. Prospective studies looking at how sleep quality and stress interact have found that better sleep quality, when occurring with higher levels of positive affect, can buffer against subsequent stress (Blaxton, Bergeman, Whitehead, Braun, & Payne, 2015). Furthermore, Åkerstedt et al. (2012) could show in a prospective study using repeated stress measurements

across a six-week period that self-reported stress at bedtime was able to predict subjective sleep quality, but that for this relationship, only the rating right before bedtime was predictive. It has been recommended to use smartphones to use ESM to gather data close to the participants experience (Gloster et al., 2008), which are widely available. Still, there is a lack of studies investigating the temporal effects of stress on sleep on a daily basis using modern experience sampling methods, investigating the natural dynamics of anticipatory stress, openness and engagement, and sleep quality. Even if stress levels were measured several times per day, data was often averaged across time, foregoing time-sensitive analyses.

However, subjective sleep quality and possible psychological moderators, such as openness and engagement, have not been examined. In addition, it remains important to test factors that potentially impact sleep within the participants' natural environment. The Experience Sampling Method is ideal to study future (i.e. subsequent) stress, but to our knowledge, this method has not yet been employed to study the association between anticipatory stress, openness and engagement, and sleep quality.

To address this gap, the aim of this study was to explore whether anticipatory stress and state openness and engagement affected subsequent sleep quality over the course of a week. Furthermore, to examine the moderating role of openness and engagement on the relationship between stress and sleep for a sample comprising of both clinical and non-clinical participants using Experience Sampling Method. We hypothesized the following: First, using all participants, we hypothesized that across all diagnostic groups and across time, anticipatory stress negatively and openness and engagement positively affect subsequent subjective sleep quality. Second, that the Insomnia Severity Index score moderates the temporal association of anticipatory stress and openness and engagement with subjective sleep quality. Third, that a higher level of openness and engagement negatively moderates the relationship between anticipatory stress and subjective sleep quality. Fourth,

that the results of the first three hypothesis are replicable for the nonclinical subsample (control group, CG) and the clinical subsample (MDD and SP).

Methods

Design

The study used a quasi-experimental longitudinal design with an Experience Sampling Method (ESM) paradigm that allowed daily variations in sleep, stress, and openness and engagement to be assessed. Participants also completed three diagnostic assessments in the laboratory on Day 1 (T1), Day 8 (T2), and Day 15 (T3). They were given a smartphone between assessment T2 and T3 to answer questionnaires six times per day, from 08:00 to 23:00 in three-hour intervals. Using scheduled repeated measures helped to minimize recall bias, as the participants were asked to answer the questions about their experiences in the last interval. Data was collected between May 2014 and August 2016 in Switzerland and Germany. The study received ethical approval of the local ethics committee (EKBB, Study 236/12) and all participants signed an informed consent form. This study used questionnaire data from T2 and ESM data from the morning and evening questionnaires. A detailed description of the study procedure has been published elsewhere (Gloster, Miché, et al., 2017).

Sample

Participants were recruited through treatment centers and online advertisements in Switzerland and Germany. Participants were evaluated with a standard clinical assessment (SKID-I, Wittchen, Wunderlich, Gruschwitz, & Zaudig, 1997) and divided into three quasi-experimental groups: Major Depressive Disorder (MDD), Social Phobia Disorder (SP), and a group with neither MDD nor SP. Exclusion criteria were as follows: age below 18 or above

65, suicidal intent, substance dependence, lack of comprehending German, and any disability that hindered a person from following the procedures of the study.

Of the 290 people who took part in the study, 6 were excluded due to an ESM participation rate of less than 50%. Data from the remaining participants was used for analysis. The groups were matched for age and sex and consisted of 118 MDD patients, 47 SP patients, and 119 control participants. Table 1 gives an overview of the sample characteristics.

----- Insert Table 1 here -----

Procedure

Participants underwent a demographic and a semi-structured interview, and diagnostic-specific and trans-diagnostic questionnaires, including the Insomnia Severity Index (ISI). One week later (T2, Day 8), participants filled out the same questionnaires again. They then received a smartphone for one week, which prompted them six times daily. The participants returned the phone when they came in for the last laboratory assessment (T3, Day 15).

Measures

Experience Sampling Method.

Experience Sampling Method (ESM) is an ambulatory assessment method with high ecological validity, as data is collected during the participant's daily life. ESM has shown to be a feasible method for gathering data from psychiatric populations with generally good retention rates (Menon, Rajan, & Sarkar, 2017). The temporal nearness of data collection to the investigated event helps to diminish recall bias (Rinner et al., 2019). To take advantage of this, participants answered questions about the last three-hour interval six times a day. In

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order to assess multiple constructs yet prevent participant burden, some constructs were operationalized with single items to ensure participants do not lose motivation.

Sleep quality

The morning questionnaire consisted of seven items covering different aspects of sleep. To measure sleep quality, it used a dimensional item (0 = very bad to 100 = very good) worded “How do you rate your sleep quality?” and participants rated their sleep experience on a visual analogue scale. Assessing sleep using subjective items provides data on personal interpretation of behavior and captures a unique aspect of sleep (Krystal & Edinger, 2008).

Anticipatory Stress

Anticipatory stress levels were assessed during the evening questionnaire with the item “I am expecting a stressful day tomorrow”, scaled from 0 (not at all stressful) to 100 (very stressful). Collecting data on stress with one item using a subjective rating scale is an efficient method when collecting repeated measurements (Minkel et al., 2012).

Openness and Engagement:

Openness and engagement was measured with three items belonging to the Open and Engagement State Questionnaire (OESQ, Benoy et al., 2018). The Open and Engagement State Questionnaire is a context- sensitive questionnaire aimed at measuring the current openness and engagement with the participant’s experience. The original version consists of four items regarding the past seven days. For this paper, we used and adapted three items for short-interval repeated measurement with ESM. One item aiming at a longer timespan was omitted instead of adapted. The three items used in this study were: “How much percent of the time since last interval were you upset and concerned about your feelings & emotions (e.g., anxiety, depression, stress, etc.)?”, “How much percent of the time did you put effort into trying to make your feelings and emotions (e.g. anxiety, depression, stress, etc.) or thoughts disappear (e.g. suppress them, distract yourself or seeking courage/reassurance from

someone else)?”, and “How much percent of the time since last interval did the way you deal with your feelings and emotions (e.g., anxiety, depression, stress, etc.) keep you from doing something that is really important to you?”. Items were rated on a scale from 0 (at no point during this time) to 100 (the whole time). The internal consistency of these three items was high ($r=.86$) within this data set. The participants filled out these items during the day and in the evening, always referring to the three-hour time interval that had passed since the last ESM prompt. For this study only the data from the evening questionnaire was used, as it was the timepoint closest to sleep.

Insomnia Severity Index.

The ISI (Rosch, 1994) is a widely used screening instrument for insomnia symptom severity. It shows high internal consistency both in community ($\alpha=0.90$) and clinical samples ($\alpha=0.91$) (Morin, Belleville, Blanger, & Ivers, 2011). The questionnaire consists of seven items that are rated on a 5-point Likert scale (0-4) and has patients rate their symptoms of the last two weeks. The sum can be interpreted using the following categories: 0-7 = absence of insomnia; 8-14 = sub-threshold insomnia; 15-21 = moderate insomnia; and 22-28 = severe insomnia. Patients filled out the ISI at T2 and T3 of the study. This study used the scores from T2, so there is no overlap in time of rating sleep quality.

Data Analysis

The data has a 2-level hierarchical structure with days nested within individuals. Multi-level random effect models (MLM) were used for the analysis. No random slope was added, as this did not improve the fit. A within-group correlation structure of the form auto-regressive of order 1 was used, as the measurements happened on consecutive days and the residuals were therefore expected to depend on each other, with decreasing dependency within increasing time lag. The data was transposed to long format with seven morning-evening pairs per participant. Openness and engagement items were reversed, so

that higher scores represent higher levels of openness and engagement. In each model, subjective sleep quality was the outcome variable. To test the first hypothesis, anticipatory stress and openness and engagement were included as predictors. For the second hypothesis, both anticipatory stress and openness and engagement were included as predictors, and insomnia severity, as measured with the ISI was included as moderator, which interacted with both predictors. For the third hypothesis, anticipatory stress was included as a predictor and openness and engagement as a moderator. The sample was then divided into a subsample of the CG and a clinical group (combining MDD and SP). The hypotheses were tested for each subsample to compare if the factors predicted the outcome differently depending on clinical status. The two time-varying variables anticipatory stress and openness and engagement were both person-mean-centered, i.e. from the scores of each of these variables we subtracted the mean value of the respective person.

For all analyses, an alpha level of 5% for statistical significance was assumed.

Results

In total, 284 participants received 1988 prompts in the morning and 1988 prompts in the evening. Overall, for 3704 (93.16%) of these prompts, questionnaires were completed and used for the subsequent analyses.

Mean scores of the Insomnia Severity Index, subjective sleep quality, and anticipatory stress levels can be found in Table 1. As categorized by ISI cut-off scores, from the 1878 cases with questionnaire data available, 623 (33.17%) stemmed from participants scoring in the subthreshold range of insomnia, 344 (18.32%) in the moderate range of insomnia and 56 (3.98%) in the severe range of insomnia on the ISI. Only 855 (45.52%) stemmed from participants reporting no sleep disturbances. Two hundred and eighty-eight (72%) of the moderate and severe insomnia cases were from participants with MDD, 63 (15.75%) from

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participants with SP, and 49 (12.25%) from the control group. When comparing group means, insomnia status had a significant effect on sleep quality levels, $F(3, 1587) = 98.02, p < .001$.

Is anticipatory stress and openness and engagement associated with subjective sleep quality? (Hypothesis 1)

The association of anticipatory stress and openness and engagement with subsequent subjective sleep quality was tested. Anticipatory stress negatively predicted sleep quality, $b = -0.07, t(1685) = -3.30, p = .001$, while openness and engagement positively predicted sleep quality, $b = 0.08, t(1685) = 2.37, p < .018$. There was no temporal trend for sleep quality across the week, (effect of time: $b = 0.22, t(1685) = 1.04, p = .30$), but sleep quality differed among the diagnostic groups, $b = -8.46, t(1685) = -5.90, p < .001$, with subjects belonging to the MDD or SP group reporting lower sleep quality levels.

Does insomnia severity moderate these associations? (Hypothesis 2)

Insomnia severity neither moderated the association between anticipatory stress and subjective sleep quality ($b = -0.002, t(1677) = -0.47, p = .637$) nor the association between openness and engagement and subjective sleep quality, $b = -0.0002, t(1677) = -0.07, p = .942$.

Does openness and engagement act as a moderator of the association of anticipatory stress and sleep quality? (Hypothesis 3)

There was no indication for a moderating effect of openness and engagement on the association between anticipatory stress and sleep ($b = 0.001, t(1685) = 0.51, p = .611$).

Is the association of anticipatory stress and openness and engagement with subjective sleep quality different for the clinical group than for the non-clinical group? (Hypothesis 1 tested for subgroups)

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In order to test the results of the first hypothesis for subgroups, the same model was run for both only the clinical group (MDD, $n=118$ and SP, $n=47$) and for the control group (CG, $n=119$). The model was calculated across time.

For the clinical subgroup (MDD and SP) there were 1158 (MDD=828, SP=330) night-day observations of which 989 were used for the analysis. For patients suffering from MDD or SP, anticipatory stress did not predict subsequent sleep quality, $b = -0.02$, $t(822) = -0.56$, $p < .001$, but openness and engagement positively predicted subsequent sleep quality, $b = 0.10$, $t(822) = 2.39$, $p = .017$. Over the course of one week, the results were not influenced by time, $b = -0.01$, $t(822) = -0.02$, $p = .982$.

For the CG there were 833 night-day observations of which 750 were used for the analysis. Anticipatory stress negatively predicted subsequent sleep quality, $b = -0.15$, $t(629) = -3.62$, $p < .001$, but openness and engagement did not predict subsequent sleep quality in the model, $b = -0.085$, $t(629) = -0.69$, $p = .488$. There was no temporal influence on subjective sleep quality over the course of one week, $b = 0.34$, $t(629) = 1.13$, $p = .258$.

*Does insomnia severity moderate these associations for either the clinical group or the CG?
(Hypothesis 2 tested for subgroups)*

The second hypothesis was run for the clinical group (MDD and SP) and for the CG separately. Again, the model was calculated across time.

In the clinical group (MDD and SP), there neither was a significant moderation effect of insomnia severity on the association between anticipatory stress and subjective sleep quality ($b = -0.008$, $t(627) = -1.18$, $p = .237$) nor of insomnia severity on the association between openness and engagement and subjective sleep quality ($b = -0.020$, $t(627) = -1.67$, $p = .096$).

Running the analysis for the CG, there also was neither a moderation effect of insomnia severity on the association between anticipatory stress and subjective sleep quality

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($b = -0.004$, $t(814) = -0.69$, $p = .491$) nor on the association of openness and engagement and subjective sleep quality ($b = -0.005$, $t(814) = -0.72$, $p = .471$). Therefore, the results were the same as when we ran the model for the whole group.

Does Openness and Engagement moderate the relationship between Anticipatory Stress and Subjective Sleep Quality in either the clinical group (MDD and SP) or the CG? (Hypothesis 3 tested for subgroups)

The third hypothesis was rerun for both the clinical group (MDD and SP) and for the CG separately, calculating the model across time.

For patients in the clinical group (MDD and SP), there was no indication of a moderation effect of openness and engagement on the association of anticipatory stress and subjective sleep quality, $b = -0.001$, $t(821) = 0.78$, $p = .434$.

For the CG there was also no indication of a moderation effect of openness and engagement on the association of anticipatory stress and subjective sleep quality, $b = 0.005$, $t(628) = 1.35$, $p = .179$. This also mirrors the results found when using both groups to calculate the model.

Discussion

This was the first study to examine the association of daily anticipatory stress and openness and engagement with sleep quality and whether insomnia severity or openness and engagement moderated the association of anticipatory stress and sleep quality. Results indicated that on nights when participants anticipated stress the next day they subsequently reported poorer sleep. In contrast, on nights when participants reported higher values in openness and engagement, they subsequently reported better sleep quality. Contrary to our hypothesis, openness and engagement did not moderate the association between anticipatory stress and sleep quality.

Overall, higher anticipatory stress in the evening resulted in a negative association with subjective sleep quality appraisals the following morning, but upon analyzing the subgroups, this was only replicated for the CG. A large enough anticipatory stressor can have a measurable impact on the “good night’s sleep” needed to prepare emotion regulation and memory processes for the next day (Walker & van der Helm, 2009). The analysis of the clinical group (MDD and SP) did not show anticipatory stress as an influence. Even though the clinical group reported higher overall stress levels, maybe the experience of having a stressful day tomorrow was too common for them and thus a type of ceiling effect.

With respect to overall openness and engagement, when an individual experienced lower openness and engagement, they also rated their sleep quality lower the next morning. Upon analyzing the subgroups, this result was found only for the clinical group (MDD and SP) but not for the CG. For the CG, it seemed that mean openness and engagement was already very high, once again a potential ceiling effect, leaving only anticipatory stress to have an influence on sleep quality.

As anticipatory stress is associated with sleep quality, it could also dampen the ability to deal with stressors the next day as reappraisal of negative emotional stimuli is impaired. Our findings suggest that anticipatory stress – a form of stress that conceptually bridges one’s sleep and extends into the next day’s activities – is negatively associated with sleep quality. Logically, when a person is thinking about tomorrow’s anticipatory stress, it is done from the present moment and this also creates a stressful experience in the present. Acute stress has been identified to contribute to physiological changes that disrupt or hamper sleep (Drake, Richardson, Roehrs, Scofield, & Roth, 2004). The experience of stress often coincides with physiological arousal and increased sleep onset latency, both of which reduce sleep quality (Drake et al., 2004). This mechanism might explain the link between anticipatory stress and sleep quality. If activating openness and engagement would facilitate relaxation, perceived

sleep quality could increase. This has been demonstrated in a study where women who were more relaxed in the evening were able to fall asleep faster (Kalmbach, Pillai, Roth, & Drake, 2014).

This study examined the effect of a person's nightly openness and engagement level on subsequent sleep for the first time. The higher an individual appraised their openness and engagement in the evening, the better they rated their sleep quality the next morning. In a subgroup analysis this was only found for the clinical group (MDD and SP). This result is therefore of particular clinical value, as it can offer patients a trainable set of skills that may be used to impact sleep. Individuals that struggle with behaviors detrimental to openness and engagement such as continuously worrying and ruminating (Irish et al., 2015) may profit from training to help them flexibly choose to accept negative emotions instead of pushing them away, and focus on the process of falling asleep, in turn possibly improving their sleep quality by compensating the negative effects of anticipatory stress on sleep.

As seen in Table 1, nights from people in the MDD and SP group showed an overall lower sleep quality than nights from people in the CG. MDD and SP groups also showed lower levels of openness and engagement and higher levels of anticipatory stress throughout the week. In a clinical context, this can mean that MDD or SP patients seeking treatment will likely report sleep disturbances when queried. As sleep is important for functioning, interventions increasing experienced sleep quality on a daily basis might be important. Furthermore, interventions aimed at decreasing levels of anticipatory stress or increasing openness and engagement in the evening could benefit patients' sleep quality. It is notable, that future stressors might not be preventable or may be hard to influence, as it often requires changes in the patient's environment. Openness and engagement is trainable however (Gloster, Klotsche, et al., 2017), even alone if proper instruction is received (Hofer et al., 2018) and has shown to also increase a person's ability to deal with stressors (Bardeen &

Fergus, 2016). In particular the ability to accept negative emotions, which is one core element of psychological flexibility and part of openness and engagement, is associated with better sleep, since it can result in functional reappraisal (Bothelius, Jernelöv, Fredrikson, McCracken, & Kaldö, 2015) to choose to willingly experience falling asleep even though there are negative emotions. Therefore, the results of this study could be used as a basis to design further research aimed at identifying possible interventions targeting these goals. Using ESM to gather data on the daily-life implications of interventions aimed at anticipatory stress and openness and engagement skills would help to identify mechanisms of change.

Another plus is the trans-situational applicability of openness and engagement. Increases in openness and engagement correlate with better subjective sleep quality, and have been associated with well-being (Gloster, Klotzsch, et al., 2017; Gloster, Meyer, et al., 2017). Therefore, it can be argued that openness and engagement may impact how sleep quality is experienced and if emotions are constructively processed, sleep quality can be increased despite anticipatory stress. It is therefore a variable that can be directly influenced by the patient and should prove a logical leverage point when wanting to increase a patient's subjective sleep quality.

No moderating role of openness and engagement on the influence of anticipatory stress on sleep quality was found. Both anticipatory stress and openness and engagement seem to be predictors, but do not interact. This was an unexpected finding, since previous literature identified the skills defined within psychological flexibility as a moderator for various outcomes, such as physical health, mental health, and wellbeing (Gloster, Meyer, et al., 2017), and we expected openness and engagement, as part of psychological flexibility, to therefore also act as a moderator for sleep quality. Anticipatory stress seems to be a robust influence on the subjective sleep quality where openness and engagement – contrary to other findings in other contexts – does not act as a moderator. From an evolutionary perspective,

anticipatory stress could be interpreted as a survival strategy (Chrousos, 2009), especially for the CG that reports high openness and engagement scores.

Analysis also showed a significant effect of insomnia status, but again not an interaction. Sleep disturbances that are perceived to be persistent can be expected to have a robust effect on sleep quality evaluation. A patient's beliefs about their own agency, which has been shown to be linked to mental health outcomes, such as higher stress levels (De Castella, Platow, Tamir, & Gross, 2018), could play a role. Appraisals, influenced by the individual's agency beliefs, may cause attribution of lower sleep quality to anticipated negative emotional experiences in addition to an expectation of continuous bad sleep. It could be argued that because MDD and SP patients evaluate their openness and engagement skills lower and perceive a larger amount of anticipatory stress than the control group, this could be seen as a contributing factor to their mental illness in the first place. Hence, since sleep quality was robustly linked to their openness and engagement but not to their anticipatory stress, agency beliefs warrant further investigation.

This study must be considered within the context of several limitations. First, the appraisal of openness and engagement always preceded the item about anticipatory stress, possibly leading to an order-effect. This may have happened especially in the CG, who reported very high levels of openness and engagement. The anticipatory stress ratings could be dependent on how well equipped a person felt to deal with emotions and thoughts at the moment. Second, we did not ask the participants about the valence of their anticipatory stress. It cannot be ascertained if the anticipatory stress level is connected to positive or negative emotions. Shonkoff, Boyce, and McEwen (2009) conceptualized stress in three different forms: positive, tolerable, and toxic. As the association of anticipatory stress with sleep quality was always negative in our analysis, we assume a majority of negative valence in participants' ratings. Since continuous bad sleep leads to increased experience of negative

emotions (Minkel & Phillips, 2015), it could intensify the experience of not being able to deal with stress in the future, corresponding to toxic stress. Future studies should therefore assess positive and negative affect and consider the influence of affectivity on anticipatory stress and in various patient populations, and whether patients think of anticipatory stressors in positive, tolerable or toxic terms. Third, anticipatory stress and sleep quality were only measured with one item and openness and engagement was measured with a subset of items from a questionnaire. Even though the repeated measure design leads to a rich dataset, this needs to be kept in mind when interpreting the results. Other studies, however, have operationalized a construct with only one item (Beil & Hanes, 2013; Minkel et al., 2012). Fourth, we assess insomnia with a questionnaire only. Future studies specifically examining participants above the diagnostic threshold should replicate our findings. That said, the dimensional approach is consistent with recent calls to more fully investigate dimensions of human behavior (i.e., Research Domain Criteria (RDoC), Insel et al., 2010). Fifth, sleep disturbances is a broad term that includes physiological and psychological complaints at different stages of sleep (Franzen & Buysse, 2008). This paper looks at subjective sleep ratings only, which limits interpretation of the results to the subjective experience of the participants. Since sleep appraisals in this study are subjective, and there is evidence that people have difficulty accurately assessing their own sleep and other parameters (Rinner et al., 2019), the results have to be interpreted as participants' subjective experiences of their sleep and no generalizability to their objective sleep can be made. Comparing our results with objective data may deepen understanding. Nevertheless, subjective ratings have been linked to sleep outcomes. For example, perceived stress has been associated with subjective sleep quality, but not with actigraphy measures (Tworoger, Davis, Vitiello, Lentz, & McTiernan, 2005). Furthermore, as a bidirectional link between sleep and other factors has been posited

(Kahn, Sheppes, & Sadeh, 2013), future studies should investigate the effects of subjective sleep quality on the subsequent experience of anticipatory stress.

Notwithstanding these limitations, this study showed that for a CG anticipatory stress is negatively associated and for a clinical group (MDD and SP) openness and engagement is positively associated with subjective sleep quality. As this study only uses data from one week, future studies should investigate if gains in openness and engagement over a longer time contribute to stable increases in sleep quality, especially if these skills have been targeted in an intervention. This could be accomplished using lagged analysis, where it could also be investigated if effects of anticipatory stress carry over longer terms.

The results of this study identify openness and engagement as a trainable protective factor, associated with better sleep. Training openness and engagement may also be protective of future stress for patients, but this warrants further investigation. Further studies should build on these findings and test how they can be used in clinical work and if these findings can be replicated. Increasing openness and engagement and reducing future stressors, and therefore anticipatory stress, where possible could prove a useful intervention target.

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OPENNESS AND ENGAGEMENT, STRESS AND SLEEP

Table 1

Sample Characteristics with mean and SD

	Total N=284	Control Group N=119	Major Depressive Disorder N=118	Social Phobia Disorder N=47
Age				
Mean	31.8 (11.5)	32.2 (12.0)	32.7 (12.0)	28.3 (7.8)
Sex				
Female	66.5	67.2	66.1	66.0
Male	33.5	32.8	33.9	34.0
Insomnia Severity (ISI)	8.9 (6.3)	5.2 (4.6)	12.6 (5.8)	8.8 (5.8)
ESM-Sleep Quality ⁺	59.1 (24.3)	69.0 (21.8)	50.3 (22.7)	55.3 (24.7)
ESM- Anticipatory Stress ⁺	44.4 (28.6)	36.7 (27.3)	51.3 (28.8)	47.0 (26.9)
ESM- Openness and Engagement ⁺	79.2 (21.5)	89.5 (14.3)	70.8 (23.0)	73.9 (21.8)

Note. Sex in %, ISI = Insomnia Severity Index, scores taken from T2, ⁺scale from 0-100, with higher scores meaning better outcome for sleep and openness and engagement, and worse outcome for stress, values are means of the ESM measurements.