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Metacognitions, worry and sleep in everyday life: Studying bidirectional pathways using Ecological Momentary Assessment in GAD patients

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ABSTRACT

Background: The metacognitive model of generalized anxiety disorder proposes that negative metacognitive beliefs are crucial in the maintenance of excessive worry. Furthermore, according to the cognitive model of insomnia, worry leads to problems falling or staying asleep and poor sleep quality. In order to test the assumed causal relationships, the present study examined the time-dependent course of negative metacognition and worry as well as worry and sleep quality, using Ecological Momentary Assessment (EMA).

Method: Negative metacognitions, worry and sleep were assessed by self-report questionnaires as well as EMA in 56 GAD patients who carried a portable device for 1 week and logged sleep quality, negative metacognition and worry processes four times a day.

Results: Metacognitions, worry and sleep were significantly correlated. Structural equation modeling using multilevel analyses showed a unidirectional relationship of negative metacognitions leading to prolonged worry processes and a bidirectional relationship of worry and sleep quality.

Conclusions: These findings support the theoretically derived assumptions on the relationship between negative metacognitions, worry and sleep. Implications for further research as well as clinical implications are discussed.

1. Introduction

Worry is a normal and everyday phenomenon experienced by most people. However, in some individuals, worrying becomes problematic and leads to significant distress and/or impairment in daily functioning. Pathological worry can be distinguished from normal worry by two key characteristics: it is excessive and it is perceived as uncontrollable (e.g., Ruscio & Borkovec, 2004). Consequently, excessive worry that is perceived as uncontrollable is the defining feature of the current diagnostic criteria for generalized anxiety disorder (GAD; American Psychiatric Association, 2013).

In his *metacognitive model*, Wells (1995) suggests that the perception of worrying as uncontrollable is not only a phenomenological feature of GAD, but also a key process that is causally involved in the maintenance of the disorder. The act of worrying is proposed to only become problematic when it is negatively appraised, for example, as uncontrollable. The model postulates a sequential process with positive metacognitions (i.e., "Worry helps me cope."), initiating *Type 1 worries* (worries about internal or external cues; e.g., "My husband might have an accident."), which in turn trigger negative metacognitions (i.e., "Worry is dangerous for me."), leading to *Type 2 worry* (meta-worry; i.e., "If I keep worrying, it will drive me mad."). Importantly, Type 2 worries are suggested to trigger negative emotions and vain attempts to stop worrying (i.e. thought suppression, reassurance-seeking or avoidance), both of which contribute to worry being maintained (e.g., Andor, Gerlach, & Rist, 2008). This vicious circle of negative metacognitions and continuous worry is then perceived by the individual as confirmation for the belief that worry is uncontrollable.

To date, evidence for the model assumptions mainly derives from correlational investigations. A large number of studies have

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shown significant and substantial bivariate associations between metacognitions and worry (for a review, see Behar, DiMarco, Hekler, Mohlman, & Staples, 2009; Wells, 2004), with negative metacognitions related to uncontrollability and danger of worrying showing the closest and most consistent connection (Cartwright-Hatton & Wells, 1997; Davis & Valentiner, 2000; Ruscio & Borkovec, 2004). Although these results provide some support for the metacognitive model, they remain silent about the precise nature of the relationship between worry and metacognitions. Additionally, measuring worry retrospectively may lead to recall biases. Global self-report was shown to only account for a small part of variance in everyday worry (Verkuil, Brosschot, & Thayer, 2007).

In order to overcome these limitations and also more closely examine the dynamic nature of the relationship between the two processes proposed by the metacognitive model, the use of *Ecological Momentary Assessment* (EMA), logging current states and/or experiences in real time and natural environments, is promising (e.g., Ebner-Priemer, Kubiak, & Pawlik, 2009). The use of EMA has been shown to be a beneficial addition to retrospective measurement (Ebner-Priemer & Trull, 2009).

A number of earlier studies used EMA to assess worry in everyday life and investigate its association with other relevant processes (e.g., heart rate variability, trait worry or sleep; Brosschot, Van Dijk, & Thayer, 2007; Takano, Sakamoto, & Tanno, 2014; Verkuil et al., 2007). However, to our knowledge, only one earlier study has used EMA to assess the relationship between negative metacognitions regarding uncontrollability and worry. In this study, non-clinical participants first filled in a self-report questionnaire of negative metacognitions and then recorded upcoming worry several times a day during the following week (Thielsch, Andor, & Ehring, in press). Results showed that negative metacognitions significantly and substantially predicted worry recorded in the following week. The first aim of the current study was to extend these findings in two important ways. First, the current study focussed on individuals suffering from GAD instead of non-clinical participants. Secondly, not only worry but also negative metacognitions regarding uncontrollability of worrying were assessed using EMA, allowing to more closely study the lagged relationship between these variables. Based on the metacognitive model, a bidirectional relationship between the two constructs was expected as perceived uncontrollability is assumed to increase worry, whereby excessive worry in turn should maintain the belief that worry is uncontrollable and dangerous.

As described earlier, the metacognitive model suggests that excessive worrying leads to a number of affective, physiological, cognitive and behavioral consequences that further contribute to the maintenance of worry. One particular process that has been suggested to be related to excessive worry in this way is impaired sleep. Examining the relationship between worry and sleep appears especially relevant as sleep disturbance is among the diagnostic criteria for GAD. Furthermore, GAD has been identified as the disorder with highest comorbidity of sleeping problems/insomnia among the anxiety disorders (e.g., Monti & Monti, 2000). These findings provide indirect evidence for a close link between worry and sleep, although more specific research on the association has been carried out as well. In her *cognitive model of insomnia*, Harvey (2002) suggests that worrisome thinking during the day and at bedtime leads to arousal and distress that interferes with sleep onset and/or quality. Decreased sleep quality, in turn, is suggested to lead to increased worrying by triggering selective attention and a biased perception of the sleeping deficit (see also Jansson & Linton, 2006). Many of the specific predictions generated by the cognitive model of insomnia have been empirically tested, whereby their explanatory power could be verified (for a review, see Harvey, 2005). Correlational studies measuring sleep quality as well as cognitive activity at daytime and in bed (e.g., Harvey, 2000) document the relationship of worry and sleeping problems, whereas experimental manipulations indicate a causal nature for worry impairing sleep (i.e., increasing cognitive activity before bed and thereby decreasing sleep quality; Tang & Harvey, 2004) as well as poor sleep quality causing worry (provoking worry by providing false feedback on poor sleep; Neitzert Semler & Harvey, 2005).

Only a few studies have used EMA to assess the association between worry and sleep quality online and in the natural environment (Takano et al., 2014; Wicklow & Espie, 2000) and also found significant associations. To our knowledge, only one study, an unpublished doctoral dissertation, also tested the assumption of a bidirectional relationship between worry and sleep. From this study in high worriers, evidence emerges only for one direction of the relationship: worry at daytime predicted increased sleep disturbance that night, whereas sleep quality did not predict worry the following day (McGowan, 2014). However, the study focussed on a non-clinical undergraduate student sample. The second aim of the current study therefore was to more closely examine the relationship between worry and sleep using EMA in individuals suffering from GAD.

In order to test the mutually maintaining relationships between negative metacognitions regarding uncontrollability and worry on the one hand, and worry and sleep on the other, a sample of GAD patients completed measures of these variables for 7 days on a total of four measurements per day. The following hypotheses, derived from the metacognitive model of GAD and the cognitive model of insomnia, were tested.

Previous perceived uncontrollability significantly contributes to the amount of current worry, while simultaneously controlling for the effect of previous worry (*Hypothesis 1a*). Previous worry significantly contributes to the amount of current uncontrollability, while simultaneously controlling for the effect of previous uncontrollability (*Hypothesis 1b*).

Previous day's mean worry score significantly predicts the amount of poor sleep quality in the following night, while simultaneously controlling for the effect of prior sleep quality (*Hypothesis 2a*). Poor sleep quality in the night before significantly contributes to the mean amount of worry the following day, while simultaneously controlling for the effect of prior day's average worry score (*Hypothesis 2b*).

2. Method

2.1. Participants

Participants were drawn from a sample of patients taking part in a clinical intervention study who had been recruited via local newspaper ads and via general practitioners in Münster (Germany). Inclusion criteria were a DSM-IV principal or co-principal diagnosis of GAD and age between 18 and 65 years. Exclusion criteria included: current psychotherapy, a DSM-IV diagnosis of alcohol or substance abuse, psychotic symptoms, active suicidal ideation or any change in psychotropic medications within the last 3 months (13% of the participants were treated with psychotropic medication; i.e. antidepressants).

56 adults (80% female) between 19 and 65 years of age ($M = 38.25$; SD = 13.47) participated in the study. About 21% of them had completed a non-academic and 39% an academic type of high school, another 39% of them additionally held a university degree. Currently, 32% were students, another 41% employees, 5% self-employed, 11% housewives or -husbands and 5% pensioners.

They had been diagnosed with GAD by two trained clinical psychologists: one conducted a screening interview via telephone that was based on DSM-IV criteria for GAD and the second psychologist met with the participants for an in-lab interview, which included the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID; Spitzer, Williams, Gibbon, & First, 1996; German version: Wittchen, Zaudig, & Fydrich, 1997). About 64% of the participants were diagnosed with a principal diagnosis of GAD only, whereas the rest received at least one comorbid diagnosis: 23% additionally suffered from a depressive disorder, 9% from panic disorder, 5% from specific phobia and 4% from obsessive-compulsive disorder. As expected, mean PSWQ scores ($M = 62.86$, SD = 7.95) as well as MCQ-30 scores (factor 1 – uncontrollability and danger: $M = 17.36$, SD = 3.06; factor 2: $M = 10.77$, SD = 3.95; factor 3: $M = 9.96$, SD = 4.09; factor 4: $M = 16.00$, SD = 3.94; factor 5: $M = 12.04$, SD = 3.64) were in the clinical range.

2.2. Measures

The *Penn State Worry Questionnaire* (*PSWQ*; Meyer, Miller, Metzger, & Borkovec, 1990; German version: Stöber, 1995) measures excessive worry with 16 items targeting at the nature (i.e., "My worries overwhelm me.") and process ("Once I start worrying, I cannot stop.") of worrying. Items are rated on a 5-point Likert-type scale ("not at all typical for me" to "very typical of me"). Good psychometric properties have been reported (Fresco, Heimberg, Mennin, & Turk, 2002) as well as a discriminative function to screen for GAD, with a cut-off score of 45 (range 16–80) achieving high sensitivity and specificity in a GAD sample (Behar, Alcaine, Zuellig, & Borkovec, 2003). In this sample, α was 0.81.

The *Metacognitions Questionnaire* (MCQ; Cartwright-Hatton & Wells, 1997; German version: Möbius & Hoyer, 2003; short English version: Wells & Cartwright-Hatton, 2004) was developed on the basis of the metacognitive model. The original version comprises 65 items referring to metacognitive beliefs about worry (i.e., "My worry is dangerous for me."); the current study used a 30-item short version. Responses are rated on a 4-point Likert-type scale ("do not agree" to "agree very much"). Five subscale scores can be computed (negative beliefs about uncontrollability and danger, positive beliefs about worry, cognitive confidence, cognitive self-consciousness and beliefs about need to control thoughts). Both original English versions and the German language versions have been shown to possess good psychometric properties (Arndt, Patzelt, Andor, Hoyer, & Gerlach, 2011; Wells & Cartwright-Hatton, 2004). In this sample: $0.72 < \alpha < 0.89$ for the different subscales and $\alpha = 0.76$ for the entire instrument.

Ambulatory assessment. Earlier EMA studies have used different indicators of worry, including *worry duration* as the time spent worrying (Brosschot et al., 2007; Dupuy, Beaudoin, Rhéaume, Ladouceur, & Dugas, 2001; Verkuil et al., 2007), *worry frequency* as the number of worry episodes per timeframe (Brosschot et al., 2007; Szabó & Lovibond, 2002; Verkuil et al., 2007) or *worry controllability/uncontrollability* as the perceived ease/difficulty to stop worrying (Szabó & Lovibond, 2002; Takano et al., 2014). Furthermore, worry can be measured event-based (every occurring worry episode is protocolled) or time-based (worry is rated at predefined times per day). As there are no general recommendations for the type or frequency of logging, Ebner-Priemer and Sawitzki (2007) propose to consider the temporal dynamics of the processes under study, besides a reasonable effort for the participants (items per measurement and total survey period). Considering this, we chose the items described subsequently for the measurement of uncontrollability, worry and sleep. Participants completed all items on a mobile electronic device (iPod). General instructions for handling the device and specific information concerning the specially tailored survey application (iDialogPad, programmed by G. Mutz, University of Cologne) were provided to participants. All variables of interest were assessed on 7 consecutive days, whereby the assessment strategy can be describe as a combination of event-based and time-based measurements (cf. Fig. 1).

Sleep. Sleep quality was measured with one item concerning sleep quality ("How well did you sleep last night?": 5-point Likert-type scale, ranging from "very bad" to "very good"). Participants were asked to complete this item event-based right after getting up in the morning. Four additional sleep-related items were included in this measurement for a different research question not of relevance for the current analyses. Results will be reported elsewhere.

Worry. Worry frequency ("How often did worries occur since the last report?": 5-point Likert-type scale, ranging from "not at all" to "always"), and worry duration ("How many minutes did you worry since the last report?": "not at all" to ">120 minutes") were recorded three times a day using two time-based (t0: 12:00 and t1: 18:00 p.m.; the iPod-application signaled the assessments by a beep) and one event-based assessment (t2: before going to bed). Worry duration was the main variable of interest included in our analyses, as unlike worry frequency it is thought to reflect the lack of success of stopping worrisome thoughts and therefore to specifically catch problematic worry processes (Brosschot et al., 2007). In order to test the robustness of the findings, all analyses were repeated using worry frequency in a second step. Five additional items assessing distress and burden associated with worry were included at each assessment for a different research question not of relevance for the current analyses. Again, results will be reported elsewhere.

Uncontrollability. Perceived uncontrollability of worry was assessed using four items at the same three assessment points (t0–t2) as worry ("My worry is uncontrollable." and three additional items taken from the MCQ-30 factor 1 uncontrollability and danger: "My worrying thoughts persist, no matter how I try to stop them.", "When I start worrying I cannot stop." and "I cannot ignore my worrying thoughts."; 5-point Likert-type scale, ranging from "not at all" to "very"; t0: $\alpha = 0.96$, t1: $\alpha = 0.97$, t2: $\alpha = 0.96$ for all four items). A mean score of all four uncontrollability items was used in all analyses.

2.3. Procedure

After screening for GAD via telephone, a diagnostic appointment was scheduled in which participants first provided informed written consent. After that, they completed a pack of questionnaires (including demographics, PSWQ, MCQ-30 and further inventories not included in the current analyses) and completed the SCID interview. At the end of the session, participants received detailed instructions on how to perform the assessment on the iPod, including the completion of test trials on the device. Participants also received written instructions to take with them. They started logging uncontrollability, worry and sleep for 7 days the week after the session (cf. Fig. 1).

2.4. Ethical considerations

The study was approved by the local Research Ethics Committee.

2.5. Statistical analyses

Descriptive parameters, correlational relationships between the variables of interest and the change in scores over the course of time were computed using SPSS (IBM; version 21).

As the data assessed via EMA (i.e., ratings of uncontrollability, worry and sleep) were nested within individuals, we used multilevel modeling to test our hypotheses. Specifically, a multilevel repeated-measures analysis was conducted to examine autoregressive (e.g., worry at a specific time-point is predicted by worry at the previous time-point) and cross-lagged (e.g.,

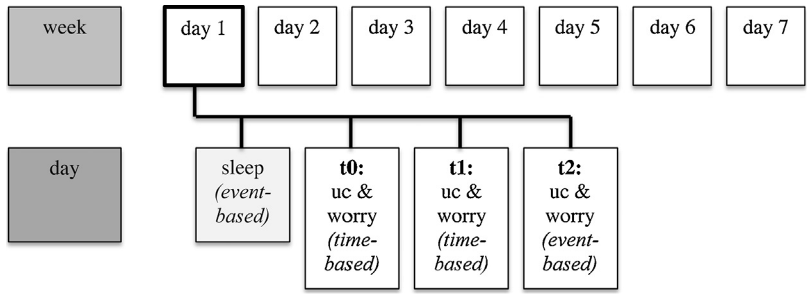

Fig. 1. Sampling plan. *Note*: event-based: sleep protocol = after getting up in the morning, t2 = before going to bed; time-based: t0 = 12:00 and t1 = 18:00 p.m.; sleep = sleep quality, uc = uncontrollability, worry = worry duration/frequency.

worry at a specific time-point is predicted by uncontrollability of the previous time-point) within-person relationships. In all cases, lagged predictor variables were person-centered (also called group-mean centering) prior to the analysis in order to measure true within-person fluctuations and dependencies, instead of between-person differences. Furthermore, all analyses were conducted in Mplus (Muthèn & Muthèn, 1998–2012): Parameters were estimated using a robust maximum likelihood approach and missing data were handled with full information maximum likelihood.

An advantage of Mplus is that it allows examining multiple longitudinal data pathways in the same (multilevel structural equation) model. As a result, one cannot only examine the lagged influences in each of the pathways in isolation but can also relate the pathways to each other, comparing the strength of the particular associations. In our case, we estimated three combined models.

Model 1 (Fig. 2): Uncontrollability (previous) predicting worry (current) while controlling for worry (previous) and worry (previous) predicting uncontrollability (current) while controlling for uncontrollability (previous).

Model 2a (Fig. 3): Worry (previous day) predicting sleep (subsequent night) while controlling for sleep (previous night) and sleep predicting worry (subsequent day) while controlling for worry (previous day).

Additionally, in order to prevent from non-significant results due to overly long lapse of time between the assessments of worry and sleep, we also implemented a model with shortened periods between the assessments, referring to worry before bed and at the first measurement in the morning in *Model 2b* (Fig. 4).

3. Results

3.1. Descriptive statistics and compliance with ambulatory assessment

A data set of 56 (persons)[1] × 7 (days) × 3 (measurements) = 1176 possible observations with 1006 recorded assessments corresponds to an overall response rate across participants of 86% as for the uncontrollability/worry protocol (t0–t2), while 334 and with that 85% of 392 sleep protocols (56 persons × 7 days) could be entered into further analyses, which reflects good compliance. Table 1 shows range, means and standard deviations for the items assessed via EMA.

[1] Maas and Hox (2005) recommend a minimum of $n = 50$ at level 2 (group level) when conducting multilevel analyses.

3.2. Correlational analyses

Data acquired by the different methods (retrospectively via questionnaire vs. online via ambulatory assessment) revealed small but significant correlations (Table 2).

Tables 2 and 3 show intercorrelations between the different variables assessed using EMA. All hypothesized correlations reached significance. Uncontrollability showed significant and large bivariate associations with worry scores ($r = 0.73$ and 0.80, both p's < 0.001). Parameters between sleep quality and daily worry scores were also significant but in the lower range ($r = -0.26$ and -0.27, both p's < 0.001).

3.3. Course of worry intensity during the week and day

There were no fixed effects for day or time of day on worry duration (day: $\beta = 0.00$, SE = 0.03, $t = 0.12$; $p = 0.90$; time of day: $\beta = 0.03$, SE = 0.04, $t = 0.75$; $p = 0.46$) or worry frequency (day: $\beta = -0.02$, SE = 0.02, $t = -0.86$; $p = 0.39$; time of day: $\beta = -0.01$, SE = 0.03, $t = -0.25$; $p = 0.81$).

3.4. Multilevel modeling

All models were estimated with random intercepts and fixed slopes. The addition of random slopes either did not improve model fit or led to convergence problems (due to the small random slope variance). Overall, this indicates that the autoregressive coefficients and cross-lagged coefficients hardly varied between individuals.

3.4.1. Bidirectional relationship between uncontrollability and worry

First, multilevel modeling was used to test *Model 1* (Fig. 2). As anticipated, uncontrollability and worry measured simultaneously showed significant correlations (Table 4).

For worry duration as well as for worry frequency, previous uncontrollability emerged as a significant predictor for current uncontrollability (path s1; cf. Fig. 2 and Table 4). Additionally, previous worry frequency significantly predicted current worry

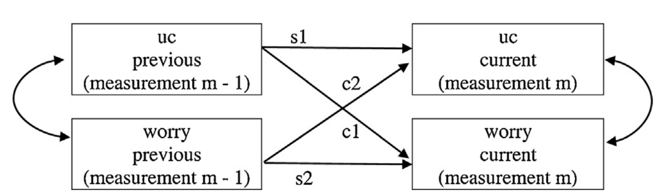

Fig. 2. Model 1 – lagged multilevel modeling: uncontrollability–worry relationship. *Note*: uc = uncontrollability, worry = worry duration/frequency, s1–2 = slopes (stability); c1–2 = slopes (cross-lagged effects).

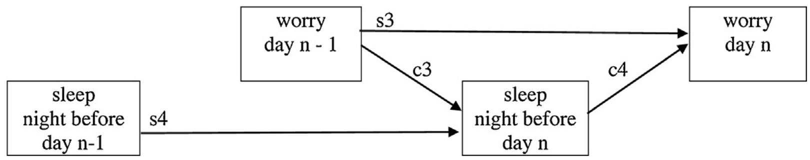

Fig. 3. Model 2a – lagged multilevel modeling: worry (daily)–sleep relationship. *Note.* worry = worry duration/frequency, sleep = sleep quality, s3–4 = slopes (stability); c3–4 = slopes (cross-lagged effects).

Table 1
Range, mean and standard deviations of EMA items.

	Item	Minimum	Maximum	*M*	SD
Worry	Frequency	0*	4 (“always”)	1.50	1.09
	Duration***	0*	6 (“>120 minutes”)	1.80	1.54
Uncontrollability (MCQ-30 items)	Uncontrollability	0*	4**	1.12	1.16
	Persistence	0*	4**	1.20	1.20
	Unstoppability	0*	4**	1.21	1.24
	Un-ignorability	0*	4**	1.51	1.32
	Total score	0	4	1.26	1.16
Sleep	Quality	0 (“very bad”)	4 (“very good”)	2.42	1.09

*Not at all; **Very; ***0 = not at all; 1 = <15 min, 2 = 15–30 min, 3 = 30–45 min, 4 = 45–60 min, 5 = 60–90 min, 6 = >120 min (all other items: numeric scales with verbal anchors at minimum and maximum).

Table 2
Mean, standard deviations, correlations among variables of interest for the uncontrollability–worry relationship.

		Variable	(1)	(2)	(3)	(4)	(5)
Q	(1)	Neg. MC: MCQ f1	–	0.57**	0.13**	0.13**	0.19**
	(2)	Worry: PSWQ		–	0.18**	0.19**	0.11**
EMA	(3)	Neg. MC: uncontrollability			–	0.80**	0.73**
	(4)	Worry frequency				–	0.81**
	(5)	Worry duration					–

Note: Q = questionnaire; EMA = Ecological Momentary Assessment; Neg. MC = negative metacognition; MCQ-30 f1 = Metacognitions Questionnaire-30 factor 1 (uncontrollability and danger); PSWQ = Penn State Worry Questionnaire; $^{*}p < 0.05$ and $^{**}p < 0.01$.

frequency. This autoregressive path was not significantly different from zero in the case of worry duration (path s2).

In order to test our first two hypotheses, we investigated the cross-lagged effects of interest. In line with our first hypothesis, previous uncontrollability significantly predicted current worry duration (path c1; *Hypothesis 1a*; Fig. 2 and Table 4). However, this effect was not significant when looking at worry frequency (Table 4). In contrast to our second hypothesis, previous worry duration/frequency did not significantly predict current uncontrollability (path c2, *Hypothesis 1b*).

3.4.2. Bidirectional relationship between worry and sleep

Worry (daily) and sleep. In order to examine the relationship between worry and sleep, *Model 2a* was first tested (Fig. 3). The two paths representing stability of worry/sleep were not significant (paths s3 and s4; Table 5). When looking at the cross-lagged effects, only the path leading from sleep to subsequent worry (path c4; *Hypothesis 2b*) reached significance, whereas worry did not predict subsequent sleep quality (path c3; *Hypothesis 2a*). The pattern of results was the same when looking at worry duration or frequency.

Worry (t0/t2) and sleep. To minimize time intervals between the assessments, we also tested *Model 2b*, which differed from *Model 2a* in that worry scores were not averaged over a whole day. Instead, the last worry assessment of the day (t2) was used to predict sleep quality by worry, and the first worry assessment on the following day (t0) was used to predict worry by sleep quality (Fig. 4).

Of the autoregressive paths, the one with worry measured in the evening (t2) predicting worry the next day (t0) turned out as significant for both worry frequency and duration (path s3; Table 6). However, sleep quality during one night did not significantly predict sleep during the subsequent night (path s4). Looking at the cross-lagged paths, sleep quality significantly predicted worry frequency and duration on the next day (path c4; cf. *Hypothesis 2b*). The reverse path from worry before bedtime to sleep quality (path c3; cf. *Hypothesis 2a*) was also significant when looking at worry frequency but not for worry duration.

4. Discussion

The first aim of our study was to test the suggestion derived from the metacognitive model that negative metacognitions related to uncontrollability/danger lead to heightened levels of worry, which in turn strengthen the metacognitions (Wells, 2005). To our knowledge, this is the first study using EMA to investigate

Table 3
Mean, standard deviations, correlations among variables of interest for the worry–sleep relationship.

		Variable	(1)	(2)	(3)	(4)
Q	(1)	Worry: PSWQ	–	0.21**	0.12**	–0.14**
EMA	(2)	Worry frequency (daily)		–	0.82**	–0.26**
	(3)	Worry duration (daily)			–	–0.27**
	(4)	Sleep quality (daily)				–

Note: Q = questionnaire; EMA = Ecological Momentary Assessment; PSWQ = Penn State Worry Questionnaire; $^{*}p < 0.05$ and $^{**}p < 0.01$.

Table 4
Lagged multilevel modeling – uncontrollability–worry relationship: Model 1.

Worry measure	Correlation time point *previous* (with simultaneously measured uncontrollability)		Correlation time point *current* (with simultaneously measured uncontrollability)		c1 (uncontrollability previous predicts worry current)		s1 (uncontrollability previous predicts uncontrollability current)		c2 (worry previous predicts uncontrollability current)		s2 (worry previous predicts worry current)	
	r	*p*	*r*	*p*	Estimate (SE)	*p*	Estimate (SE)	*p*	Estimate (SE)	*p*	Estimate (SE)	*p*
Duration	0.52	<0.001	0.54	<0.001	0.24 (0.09)	<0.01	0.20 (0.07)	<0.01	−0.02 (0.04)	0.60	0.06 (0.06)	0.30
Frequency	0.39	<0.001	0.40	<0.001	0.07 (0.07)	0.28	0.15 (0.07)	0.03	0.03 (0.05)	0.49	0.16 (0.06)	<0.01

Note: $n = 1064$ observations were included in the analysis.

Table 5
Lagged multilevel modeling – worry (daily)–sleep relationship: Model 2a.

Worry measure	c3 (worry day *n*−1 predicts sleep quality night before day *n*)		s3 (worry day *n*−1 predicts worry day *n*)		c4 (sleep quality night before day *n* predicts worry day *n*)		s4 (sleep quality night before day *n*−1 predicts sleep quality night before day *n*)	
	Estimate (SE)	*p*	Estimate (SE)	*p*	Estimate (SE)	*p*	Estimate (SE)	*p*
Duration	0.02 (0.07)	0.75	−0.07 (0.08)	0.38	−0.15 (0.07)	<0.05	0.04 (0.08)	0.67
Frequency	0.01 (0.09)	0.96	−0.10 (0.07)	0.15	−0.14 (0.05)	<0.01	0.04 (0.08)	0.66

Note: $n = 290$ observations were included in the analysis.

Table 6
Lagged multilevel modeling – worry (t0/t2)–sleep relationship: Model 2b.

Worry measure	c3 (worry day $n-1$ predicts sleep quality night before day n)		s3 (worry day $n-1$ predicts worry day n t0)		c4 (sleep quality night before day n predicts worry day n t0)		s4 (sleep quality night before day $n-1$ predicts sleep quality night before day n)	
	Estimate (SE)	p	Estimate (SE)	p	Estimate (SE)	p	Estimate (SE)	p
Duration	−0.08 (0.06)	0.17	0.33 (0.07)	<0.001	−0.17 (0.09)	<0.05	0.03 (0.08)	0.70
Frequency	−0.18 (0.08)	0.02	0.44 (0.05)	<0.001	−0.13 (0.06)	0.03	0.05 (0.08)	0.58

Note: n = 286 observations were included in the analysis.

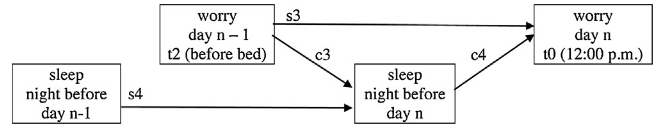

Fig. 4. Model 2b – lagged multilevel modeling: worry (t0/t2)–sleep relationship. *Note*: worry = worry duration/frequency, sleep = sleep quality, s3–4 = slopes (stability); c3–4 = slopes (cross-lagged effects).

the relationship between these two variables. Results show that previous perceived uncontrollability affects subsequent worry duration. This is in line with Wells' (e.g., 2005) theory, suggesting that metacognitive beliefs are a cause of excessive worry. Our study extends earlier findings by investigating the dynamic nature of the relationship between these variables. Importantly, in our statistical model, prior uncontrollability beliefs significantly predicted current worry duration whereas prior worry duration did not contribute additional variance. Some authors have questioned the explanatory value of negative metacognitions to account for excessive worry, arguing that there is a conceptual overlap between the two constructs (cf. Behar et al., 2009). Our results counter this idea by showing that uncontrollability predicts worry duration over and above previous worry scores (see also Thielsch et al., in press, for similar findings). Interestingly, uncontrollability only significantly predicted subsequent worry duration but not subsequent worry frequency. This pattern of findings confirms the idea that worry duration is the superior variable in catching ongoing problematic worry as suggested by Brosschot et al. (2007).

In contrast to our hypotheses, neither worry duration nor frequency predicted subsequent metacognitions regarding uncontrollability/danger. The original hypothesis was based on Wells' suggestion that prolonged worrying further reinforces the beliefs that worry is uncontrollable. However, this was not supported by our data. Interestingly, metacognitive beliefs assessed via EMA were found to be rather stable, as evidenced by significant and substantial stability paths (see s1 in Fig. 2). Arguably, GAD sufferers had ample time to establish the conviction that excessive worrying has detrimental effects. Consequently, the daily experience of excessive worrying may no longer increase beliefs in negative metacognitions concerning worrying.

The second aim of our study was to test assumptions regarding a bidirectional relationship between worry and sleep quality, as suggested by the cognitive model of insomnia (Harvey, 2002). Our results showed a stable effect of reduced sleep quality on increased levels of worry on the next morning upon awakening as well as mean levels of worrying during the subsequent day. This implies that a night with poor sleep quality causes vulnerability for worrisome thinking and thereby exacerbates how often worry occurs and how long worry episodes last the next day. There was also some evidence for the reverse relationship in that worry assessed directly before going to bed predicted subsequent poor sleep quality. However, this was not the case when looking at mean levels of worry during the previous day.

Taken together, the findings are in line with the cognitive model of insomnia (Harvey, 2002), suggesting that worrisome thinking leads to arousal and distress, which contributes to sleeping problems, as well as a feedback loop from sleep quality back to worrying, where the perception of the deficit leads to excessive negatively toned cognitive activity. Our results support the idea of a mutually maintaining relationship between worry and poor sleep, whereby worry experienced immediately before bedtime appears to be especially important. Interestingly, an earlier study focusing on non-clinical population only showed a significant effect of worry on sleep but not vice versa (McGowan, 2014). This discrepancy between studies may suggest a threshold effect, whereby poor sleep only affects worrying on the next day if sleeping problems and/or worry proneness is in the clinical range.

To our knowledge, this is the first study investigating the relationships between uncontrollability beliefs and worry, and worry and sleep, respectively, using EMA in clinical participants. EMA shows a number of advantages allowing an assessment of the processes of interest in daily life, thereby reducing biases inherent to retrospective and/or highly summarized measurements. Our findings show that EMA can successfully be used in GAD patients. In addition, reactivity was found to be low as response rates were very high, and no changes in worry frequency or duration were found over the course of the week. It therefore appears promising to continue using EMA to investigate the temporal dynamics of the interaction between worry and other processes. Importantly, the relationship of ambulatory assessed worry or metacognitions with global self-report measurements (PSWQ, MCQ-30) appears to be rather weak, suggesting that the two types of assessments aim at different facets of these constructs. Future research should therefore combine the different assessment methods.

Although the findings from the current study emerge as promising, some limitations are noteworthy. First, self-report was used to determine the quality of sleep. This appears generally defendable as theoretical models suggest that the perception of sleep quality is especially relevant. Nevertheless, future research should additionally make use of sleep laboratory data (cf. Takano et al., 2014) to compare the relationship between objective versus subjective sleep parameters and worry. Secondly, although participants were recruited widely from a treatment-seeking population and using newspaper ads, the sample was not entirely representative as 78% of participants had an academic background. As monitoring abstract constructs, such as metacognitions, requires a certain level of cognitive capacities, a replication of findings in a non-academic sample appears desirable to test the generalizability of the findings. Thirdly, only a small number of assessments were taken per day, leading to relatively large amounts of time that elapsed in between measurements. It therefore cannot be ruled out that we may have underestimated the strength of cross-lagged relationships that are more short-lived (e.g., effects of worry and uncontrollability). Thus, results need be replicated in studies using a higher frequency of assessments in order to test the robustness of the findings.

5. Conclusions

Despite these limitations, a number of conclusions can be drawn from the current findings. Our results clearly support a key assumption of the metacognitive model of worry emphasizing the role of metacognitions related to uncontrollability/danger in the maintenance of worry. These metacognitive beliefs are a key target in metacognitive treatment for GAD (Hjemdal, Hagen, Nordahl, & Wells, 2013; Wells, 1997), which has shown high effect sizes in the treatment of GAD (Normann, van Emmerik, & Morina, 2014; van der Heiden, Muris, & van der Molen, 2012). In addition, our findings replicate earlier results regarding a mutually maintaining relationship between worry and sleep, with worry leading to poorer sleep quality and vice versa (Harvey, 2005). This may suggest that interventions aiming at breaking the vicius circle of sleep-affecting worry and worry-impairing sleep are needed in the treatment of both GAD and insomnia. Most important, however, our results suggest that it is promising to use EMA when studying antecedents and effects of excessive worry in GAD.

Conflict of interest

All authors state that they have no actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three years of beginning the work submitted that could inappropriately influence or bias their work.

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