An investigation and replication of sleep-related cognitions, acceptance and behaviours as predictors of short- and long-term outcome in cognitive behavioural therapy for insomnia

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Funding Information
Fredrik & Ingrid Thuring Foundation; Söderström-Königska Sjukhemnets Foundation; Lars Hierta Foundation; Psykiatrifonden; Stiftelsen Promobilia

Summary
The objectives were to investigate the potential for sleep-related behaviours, acceptance and cognitions to predict outcome (insomnia severity) of cognitive behavioural therapy for insomnia (CBT-I). Baseline and outcome data from four randomised controlled trials (n = 276) were used. Predictors were the Dysfunctional Beliefs and Attitudes about Sleep-10 (DBAS-10), Sleep-Related Behaviours Questionnaire (SRBQ), and Sleep Problems Acceptance Questionnaire (SPAQ), and empirically derived factors from a factor analysis combining all items at baseline (n = 835). Baseline values were used to predict post-treatment outcome, and pre–post changes in the predictors were used to predict follow-up outcomes after 3–6 months, 1 year, or 3–10 years, measured both as insomnia severity and as better or worse long-term sleep patterns. A majority (29 of 52) of predictions of insomnia severity were significant, but when controlling for insomnia severity, only two (DBAS-10 at short-term and SRBQ at mid-term follow-up) of the 12 predictions using established scales, and three of the 40 predictions using empirically derived factors, remained significant. The strongest predictor of a long-term, stable sleep pattern was insomnia severity reduction during treatment. Using all available predictors in an overfitted model, 21.2% of short- and 58.9% of long-term outcomes could be predicted. We conclude that although the explored constructs may have important roles in CBT-I, the present study does not support that the DBAS-10, SRBQ, SPAQ, or factors derived from them, would be unique predictors of outcome.

Keywords
long-term follow-up, prediction, psychology, sleep

1 | INTRODUCTION

Insomnia is a disorder affecting ~10% of the population (Ohayon & Roth, 2003), with serious impact on quality of life and large costs for society (Daley et al., 2009). Cognitive behavioural therapy for insomnia (CBT-I) is an effective treatment in reducing insomnia symptoms, both face-to-face (van Straten et al., 2018), in a therapist-guided self-help including digital format (Zachariae et al., 2016), and as unguided digital treatments (Soh et al., 2020). Still, not much is known about who will benefit from treatment and why, and most...
studied treatments show results with room for improvements (Morin et al., 2006).

There is a need to identify factors related to outcomes in order to better understand who may potentially benefit from CBT-I, also in the long term. Ideally, such knowledge can be used to develop models that would enable us to enhance treatment outcome, e.g. by matching patients to the treatment option most likely to be beneficial, or use an adaptive treatment strategy to predict the risk of treatment failure early in treatment and adjust the treatment for those with a high risk (Forsell, Jernelöv, et al., 2019). A strong, and often pragmatically available, predictor of future symptom levels, are previous symptoms measured in the same way (Forsell, Isacsson, et al., 2019; Schibbye et al., 2014). However, it is likely that additional predictors need to be weighed in, in order for a prediction model to be optimised and clinically useful. Previous studies have investigated and ruled out, e.g. sex, education, marital status, occupational status, medical illness, duration of insomnia and sleep medication use as predictors (Espie et al., 2001; Gagné & Morin, 2001), while one found age and self-efficacy to be predictors for older adults with insomnia (Lovato et al., 2013).

CBT-I is designed to address a model of insomnia encompassing a biological model, the so-called two-process model based on circadian rhythm and homeostatic pressure (Borbely, 1982), which are addressed by sleep restriction and stimulus control, and a cognitive model, i.e. mental arousal prohibiting sleep, which is addressed mainly by cognitive reappraisal (Harvey, 2002). The way patients with insomnia behave and think about their sleep has been shown to change during CBT-I (Lorenz et al., 2019; Norell-Clarke et al., 2017; Okajima et al., 2011), which has made measures of these processes candidates when we look for predictors of CBT-I outcomes. There is a wealth of studies on the importance of cognitive processes, e.g. worry, rumination (Carney et al., 2010) and metacognitive processes (Ong et al., 2012), in insomnia. Among these, there is a study supporting that dysfunctional beliefs about sleep can play a role in predicting treatment outcome in CBT-I (Edinger et al., 2008). There are also studies supporting dysfunctional beliefs as mediators of sleep outcome during CBT-I interventions (Chow et al., 2018; Norell-Clarke et al., 2017; Sunnhed & Jansson-Fröjmark, 2015). A recent study questions the importance of dysfunctional beliefs about sleep by suggesting that while sleep-related worry and pre-sleep arousal mediated the effects of CBT-I on insomnia severity and sleep efficiency, dysfunctional beliefs about sleep did not (Lancee et al., 2019). In addition, the aforementioned study by Lovato et al. (Lovato et al., 2013) found that dysfunctional beliefs did not predict outcome, measured as sleep efficiency, of CBT-I. Behavioural factors are less thoroughly investigated compared to cognitive factors, but there are studies on safety behaviours and their association with a outcome in CBT-I (Lancee et al., 2015; Norell-Clarke et al., 2017) and behavioural factors have been found to correlate with insomnia severity scores and mediate outcome (Bothelius et al., 2015; Lancee et al., 2015; Norell-Clarke et al., 2017), which is an indication that it could be a potential predictor.

It has been argued that theoretically, acceptance may be an important factor in insomnia. The main inspiration comes from the field of chronic pain, where psychological flexibility and acceptance are believed to be crucial mechanisms of change (McCracken & Gutierrez-Martinez, 2011). A qualitative study of insomnia treatment indicated this as a possible mechanism of change and an area for future research (Blom et al., 2016). Acceptance has not previously been tested as a predictor of treatment outcome in insomnia, although one preliminary study has pointed to acceptance and commitment therapy (ACT) as a potentially useful treatment for non-responders to CBT-I (Hertenstein et al., 2014). Experiences from the treatment of pain and other behavioural medicine problems suggest that acceptance may prove to be an indicator of a successful treatment (McCracken, 2011). Along this line, one study found that sleep-related acceptance may be more strongly associated with sleep difficulties than dysfunctional beliefs or sleep-related safety behaviours (Bothelius et al., 2015).

The previous studies that have investigated cognitive and behavioural processes as predictors do, to the best of our knowledge, not control for pre-treatment values of the predicted outcome measure itself, with one exception (Lovato et al., 2013), nor for the change in outcome measure pre–posttreatment when predicting long-term outcome. This means that the additional, or unique, predictive value of cognitive and behavioural factors is unknown, or at least inconclusive.

There is also a conceptual question regarding the previous research, which opens up for the possibility to find useful predictors: the measures commonly used to measure cognitions and behaviours related to sleep, the Dysfunctional Beliefs and Attitudes about Sleep (DBAS) (Edinger & Wohlgemuth, 2001) and the Sleep-Related Behaviours Questionnaire (SRBQ) (Ree & Harvey, 2004), do not necessarily measure specific, clear-cut concepts or factors. A basic thematic comparison of items included in these scales indicates a possible conceptual overlap. This means that the total sum of each scale might not be the optimal representation of different concepts, which in turn could limit their potential as predictors, as items or sub-concepts that might have unique predictive capabilities might be mixed up and diluted with non-predictive items or sub-concepts. A better chance of finding predictors might be to combine the items from all scales into new factors, consisting of items with a high level of co-variance.

The primary aim of the present study was to investigate and, in some cases, replicate the short- and long-term predictive value of sleep-related behaviours, acceptance and cognitions, while controlling for baseline insomnia symptoms. The change of behaviours, acceptance, and thoughts during treatment can also be assumed to have a predictive value, and hence we aimed to include this as well as control for change in insomnia symptoms during treatment in the long-term predictions. We also wanted to test if a data-driven set of predictors, derived from a joint factor analysis of all items in three different scales, would constitute a better base for prediction, and explore the maximum potential for predicting treatment outcome using all available data.
More specifically, the following questions were examined:

1. Do baseline levels of sleep-related behaviours, acceptance and cognitions predict insomnia severity immediately after CBT-I, when controlling for initial insomnia symptoms?
2. Do baseline levels together with the change during treatment in the three scales predict insomnia severity at short-, mid- and long-term follow-up after CBT-I, when controlling for baseline and pre-post change in insomnia symptoms?
3. Are factors that are derived empirically, from a combined pool of all items in these scales, better predictors than the traditional summed scores of the scales?
4. Can the original scales predict if a participant has a more consistent pattern of better or worse sleep, measured over all available follow-up points?
5. When all available data are combined, what is then the maximum predictive potential in a model that is allowed to be overfitted?

2 | METHODS

2.1 | Participants, sub-samples, and procedures

The sample in this study was collected from four previous studies, which all had the scales DBAS-10 (Edinger & Wohlgemuth, 2001), SRQ-B (Ree & Harvey, 2004) and Sleep Problems Acceptance Questionnaire (SPAQ) (Bothelius et al., 2015), administered before and after treatment to enable prediction analyses. All participants were assessed face-to-face or by telephone in a structured anamnestic and diagnostic interview, done by a physician, a psychologist or a clinical psychology Master’s student under supervision. All studies used the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5) (American Psychiatric Association & A., 2013) criteria or, before the release of DSM-5, the research criteria described by Edinger et al. (Edinger et al., 2004), which are similar to the DSM-5 (details can be found in the original articles). In the first by Jernelöv et al. (Jernelöv et al., 2012), the authors compared bibliotherapy with therapist guidance via telephone (n = 44) to bibliotherapy without therapist guidance (n = 45), and to a waitlist control group (n = 44). The waitlist control group got delayed bibliotherapy without therapist guidance (n = 44). In the second included study, by Blom et al. (Blom, Jernelöv, et al., 2015), patients with insomnia and depression were randomised to either CBT-I or CBT for depression, both therapist-guided internet-delivered treatments. In the sample used in the present analysis, we included only participants who received CBT-I (n = 22). The third included study, also by Blom et al. (Blom, Tarkian Tillgren, et al., 2015), compared group-delivered CBT-I (n = 24) to therapist-guided internet-delivered CBT-I (n = 24). Both groups were included in the present sample. In the fourth included study, by Kaldo et al. (Kaldo et al., 2015), therapist-guided internet-delivered CBT-I was compared to an active internet-based control condition. We have only included the CBT-I group from that study (n = 73) as the control group was not treated with a full CBT-I protocol.

Importantly, all studies used the same CBT-I manual, in the first study in the form of a book with telephone support (Jernelöv et al., 2012), then in a digital format with similar support via the internet. The content of the support was similar in all studies, as training and supervision was provided by the same clinicians (KB and SJ). Also, all samples were ecologically representative and similar in that they allowed comorbidities except those primarily requiring other treatment. Medication use was handled in the same way in all studies (i.e. antidepressant medication should be stable and sleep and other medication use was allowed). Studies two (Blom, Jernelöv, et al., 2015) and four (Kaldo et al., 2015) had a shared recruitment, where patients applied for a single project and were only later divided into the two studies, depending on whether or not they had a comorbid major depression diagnosis. Studies two and four could thus be seen as one sample with varying degrees of depressive symptoms. The studies had slightly different treatment durations, in study two a compromise due to depression treatments (the control treatment) usually being longer in time than CBT-I. All in all, the participants in the sample used for analyses in the present study, are those in each study that were randomised to, and started a full CBT-I treatment (i.e. intent-to-treat).

The sample also contains long-term follow-up assessments from all studies presented above. The follow-up assessments were made at 3 (Jernelöv et al., 2012), 6 (Blom, Jernelöv, et al., 2015; Blom, Tarkian Tillgren, et al., 2015; Kaldo et al., 2015), and 12 months (Blom, Jernelöv, et al., 2015; Kaldo et al., 2015), and 3 (Blom et al., 2016, 2017) and 10 years (manuscript in preparation with 12 months and 10 years of follow-up of Jernelöv et al. (2012)) after treatment. The follow-up data were collapsed into the categories short-, mid- and long-term follow-up. Short-term consisted of 3- and 6-months follow-ups, mid-term of 12-months follow-ups, and long-term of 3- and 10-year follow-ups.

To create empirically derived factors and use those as alternative predictors instead of total scale scores, a factor analysis used data from all participants who completed all three scales at the same time, either at screening or before treatment, in all four trials (n = 835), i.e. this included those who were later not randomised or offered treatment within the trials.

2.1.1 | Patient characteristics at baseline

The baseline characteristics of the combined sample used for prediction analyses (n = 276) are presented in Table 1.

2.2 | Measures

2.2.1 | Outcome

Insomnia symptoms were measured with the Insomnia Severity Index (ISI) (Bastien et al., 2001; Morin, 1993), in all studies, a seven-item scale with a score ranging from 0 to 28 points, where ≥11 points
TABLE 1 Baseline characteristics of participants

|                      | Jernelöv et al. (2012) (n = 133) | Blom, Jernelöv, et al. (2015) (n = 22) | Blom, Tarkian Tillgren, et al. (2015) (n = 48) | Kaldo et al. (2015) (n = 73) |
|----------------------|----------------------------------|--------------------------------------|-----------------------------------------|--------------------------|
| Age, years, mean (SD)| 47.9 (13.9)                      | 46.1 (13.6)                          | 54.4 (13.7)                             | 47 (15.2)                |
| Women, n (%)         | 33 (75)                          | 8 (35)                               | 31 (65)                                 | 59 (81)                  |
| University education, n (%) | 109 (82)                           | 14 (64)                               | 24 (50)                                 | 54 (74)                  |
| Working/studying, n (%) | 82 (62)                           | 13 (59)                               | 28 (64)                                 | 58 (80)                  |
| Currently on sleep medication, n (%) | 59 (44)                           | 14 (64)                               | 30 (63)                                 | 33 (45)                  |
| ISI at screening, mean (SD) | 18.3 (3.3)                         | 20.4 (3.7)                            | 18.4 (4.2)                              | 19.0 (4.4)               |

ISI, Insomnia Severity Index; SD, standard deviation.

indicate clinical severity. The scale is a commonly used primary outcome in insomnia research. Internal consistency is high (Cronbach’s \( \alpha = 0.90 \)) and it is sensitive (86%) and specific (88%) for detecting insomnia and sensitive to change (Morin et al., 2011).

### 2.2.2 Predictors

#### Cognitions – DBAS-10

The DBAS-10 (Espie et al., 2000), is a 10-item scale with statements such as “I need 8 hr of sleep to feel refreshed and function well during the day” that respondents rate from 0 (strongly disagree) to 10 (strongly agree). High scores indicate more dysfunctional beliefs about sleep and sleep management. Internal consistency is acceptable (Cronbach’s \( \alpha = 0.69 \)), the scale is sensitive to change and it correlates highly (\( r = 0.83 \)) with the full-length DBAS (Morin et al., 1993). The scale has previously been shown to load into three factors. However, these three factors only explain 55% of the total variance, indicating a rather large heterogeneity among the items, possibly because these were originally selected due to their sensitivity to change rather than their factorial structure.

#### Behaviour – SRBQ

The SRBQ (Ree & Harvey, 2004), consists of 32 items measuring safety and avoidance behaviours related to sleep problems (e.g. [to manage tiredness or improve sleep] “I catch up on sleep by napping”). Items are rated 0 (almost never) to 4 (almost always). Internal consistency is high (Cronbach’s \( \alpha = 0.92 \)) and the scale can discriminate between normal or poor sleepers, but no factor analysis has been made to further explore possible sub-scales.

#### Acceptance – SPAQ

The SPAQ (Bothelius et al., 2015) is a sleep adapted version of the Chronic Pain Acceptance Questionnaire (McCracken et al., 2004). The scale consists of eight items rated from 0 (completely disagree) to 6 (completely agree) divided into two acceptance related sub-constructs, “Willfulness” (items 1–4; Cronbach’s \( \alpha = 0.73 \)) and “Activity Engagement” (items 5–8 reversed; Cronbach’s \( \alpha = 0.89 \)), explaining 66% of the total variation in the initial factor analysis. The total score ranges from 0 to 48, with higher scores indicating greater acceptance. As the two sub-scales do not correlate strongly (\( r = 0.22 \)), the internal consistency for the total scale is low (Cronbach’s \( \alpha = 0.55 \)). Thus, it is recommended that the sub-scales are used along with the full scale, so that unique variance in each of the two sub-scales do not cancel each other out when used for example for predictive purposes.

**Empirically derived factors as alternative predictors**

As mentioned in the introduction, the scales that will be used as predictors in the present study all have some known conceptual weaknesses, e.g. lack of factor analytical data (SRBQ), heterogeneity and rather weak factors (DBAS-10), or strong sub-scales with only a weak correlation between each other (SPAQ). In addition, a thematic inspection reveals quite a large possible overlap, especially between SRBQ and DBAS-10. Predictors based on summated scores from items that are not very strongly associated with each other could result in suboptimal predictive performance. Therefore, we decided to perform a joint exploratory factor analysis with all items from the SRBQ, DBAS-10, and SPAQ and use these empirically derived factors as alternative predictors.

**Outcome as categories of long-term sleep patterns**

All the included studies had more than one follow-up point, but symptom levels at each single time point do not necessarily say much about the stability of sleep over a longer time period. We therefore defined individual categories of long-term patterns of sleep quality, and used these categories as an alternative outcome to be predicted. All participants who had data for at least two of the follow-ups, were first categorised as remitters (<8 on the ISI (Morin & Espie, 2003)) or responders (ISI change from pretreatment >7 (Morin et al., 2011)) at each time point. They were then categorised as “Better Sleeper” (remitter or responder on at least one of the follow-up time points and score <15 on the ISI at all follow-up time points) or “Poorer Sleeper” (non-remitter and non-responder at all time points, or score >14 on the ISI at all time points). The cut-off at an ISI score of 15 is the established cut-off for mild/subthreshold insomnia and moderate insomnia (Morin & Espie, 2003). The analyses are designed to be powered to discover any predictors that could be useful in clinical practice. Participants who did not fall into any of these categories were therefore not included in the long-term sleep pattern analyses, as clear differences in outcomes make for increased power in prediction analyses.
After treatment, with and without controlling for baseline ISI. When were included in separate regression models aiming to predict ISI predicting long-term ISI, the models also included changes in the and these were bootstrapped with the report package (Makowski were used in a similar way to predict long-term categorical outcome controlling for baseline ISI and changes in ISI. Logistic regressions large number of predictors, which was allowed to be "overfitted", in order to explore the maximum predictive potential using all available data. Hence, the model was highly sample specific and cannot reach the same predictive capacity when used in other samples, and the result should only be seen as a theoretical maximum level of predictive ability when all available data are used. This was based on significant correlations (Spearman) between the two categories (Better or Poorer Sleepers) and baseline and change scores for all single items in the scales, as well as all of the empirically derived factors and ISI baseline and ISI change. For the logistic model, items included in the new factors were excluded from the single-item predictors, so that they would not be included twice in the trajectory analyses, due to smaller sample size. We used backwards elimination with Akaike Information Criterion (AIC) as selection criteria for which predictors to keep in the final model.

### 2.3.1 Factor analysis

Principal component analysis with Varimax rotation using all items from the scales (DBAS-10, SRBQ and SPAQ) was performed in SPSS 26.0 (IBM & C., 2019). The number of factors to extract was initially based on the criteria of Eigenvalues >1, but the number of factors was changed in iterations based on factor loadings and scree plot tests. Some items that had weak or unstable loadings were eventually eliminated until a set of factors with strongly loading items and reasonable face-validity was reached. Factors were then named and factor scores used as predictors.

### 2.3.2 Regression analyses

The statistical analyses using regressions was conducted in R version 3.6.0 (Team & R, 2019). To facilitate statistical reporting “ApaTables” (Stanley, 2018) was used. Delta $R^2$ values were calculated via ApaTables using method described by Alf and Graf (Alf & Graf, 1999), which can sometimes lead to disagreement between the confidence interval (CI) and $p$ value. Before any analyses, the predictors and outcomes that consisted of summed items were Z-transformed (except for categorical sleep pattern outcome in logistic regression analyses).

All original scales and empirically derived factors at baseline were included in separate regression models aiming to predict ISI after treatment, with and without controlling for baseline ISI. When predicting long-term ISI, the models also included changes in the scales/factors between before and after treatment, with and without controlling for baseline ISI and changes in ISI. Logistic regressions were used in a similar way to predict long-term categorical outcome and these were bootstrapped with the report package (Makowski & Lüdecke, 2019) with 500 iterations, to provide robustness of the confidence intervals.

### 2.3.3 Exploration of maximum predictive potential

Finally, we created one exploratory logistic regression including a large number of predictors, which was allowed to be "overfitted", in order to explore the maximum predictive potential using all available data. Hence, the model was highly sample specific and cannot reach the same predictive capacity when used in other samples, and the result should only be seen as a theoretical maximum level of predictive ability when all available data are used. This was based on significant correlations (Spearman) between the two categories (Better or Poorer Sleepers) and baseline and change scores for all single items in the scales, as well as all of the empirically derived factors and ISI baseline and ISI change. For the logistic model, items included in the new factors were excluded from the single-item predictors, so that they would not be included twice in the trajectory analyses, due to smaller sample size. We used backwards elimination with Akaike Information Criterion (AIC) as selection criteria for which predictors to keep in the final model.

### 3 RESULTS

#### 3.1 Response rates and descriptives of predictors and outcome

At baseline, all 276 participants completed all questionnaires. After treatment, 252 (91%) answered. At the short-term follow-up, 230 (83%) completed the questionnaires. The corresponding response rates for the mid- and long-term follow-ups were 171 (75%) and 171 (75%) respectively, out of the 228 who were in the studies that had mid- and long-term follow-ups. Table 2 summarises means and confidence intervals for insomnia symptoms at all time-points and for all predictors before and after treatment.

#### 3.2 Empirically derived predictors from a combined factor analysis including all items in DBAS-10, SRBQ, and SPAQ

The factor analysis was performed in preparation for the main analyses, to produce new potential predictors to be used in the analyses. The iterative process of deciding a final factor solution is presented in the Methods. Data were deemed statistically appropriate for factor analysis, with a Kaiser–Meyer–Olkin (KMO) of 0.82 and a significant Bartlett’s Test of Sphericity ($p < .001$). The final solution

| Scale, mean (95% CI) | PRE CBT-I | POST CBT-I | FU-short | FU-mid | FU-long |
|----------------------|-----------|------------|----------|--------|--------|
| ISI                  | 16.95 (16.30–17.59) | 11.27 (10.40–12.14) | 10.39 (9.52–11.26) | 8.73 (7.95–9.51) | 10.13 (9.22–11.05) |
| DBAS-10              | 55.35 (53.55–57.15) | 38.27 (33.91–38.63) |          |        |        |
| SRBQ                 | 80.32 (78.44–82.20) | 67.94 (65.86–70.02) |          |        |        |
| SPAQ                 | 22.05 (21.11–22.99) | 27.30 (26.34–28.26) |          |        |        |

CBT-I, cognitive behavioural therapy for insomnia; CI, confidence interval; DBAS-10, Dysfunctional Beliefs and Attitudes about Sleep-10 items; FU-long, long-term follow-up (3 or 10 years); FU-mid, mid-term follow-up (12 months); FU-short, short-term follow-up (3 or 6 months); ISI, Insomnia Severity Index; POST, after CBT-I; PRE, before CBT-I; SPAQ, Sleep Problems Acceptance Questionnaire; SRBQ, Sleep-Related Behaviours Questionnaire.
included 10 factors, which explained 70.5% of the variance. Each factor presented in Table 3 was used as an empirically derived predictor in some of the regression models below.

3.3 | Prediction of insomnia symptoms after treatment and at follow-ups

3.3.1 | Using total scores as predictors

As seen in Table 4, in the first step of the prediction analyses, the baseline values of the SRBQ and SPAQ original scales were significant predictors of post-treatment ISI, but not DBAS-10. When controlling for baseline ISI, none of the predictors remained statistically significant. When using baseline plus the change from pre–post of the scales as predictors of short-, mid- and long-term ISI, all were statistically significant predictors for all follow-ups, except SPAQ for the mid-term follow-up. However, when controlling for baseline ISI and the pre–post ISI change, only DBAS-10 at the short-term follow-up and SRBQ at the mid-term follow-up remained statistically significant.

3.3.2 | Using empirically derived factors as predictors

Table 4 also presents the results when the empirically derived factors were used as predictors. The baseline values of Factors 1, 2, 4, 5 and 8 predicted ISI after treatment. When controlling for baseline ISI, Factor 8 (napping) was still a statistically significant predictor for ISI after treatment. For the long-term predictions, using baseline factor sums plus the change from pre–post, factors 1, 2, 4, 5, 7, 8, 9 and 10 were statistically significant predictors in the short term, for the mid-term factors 2, 3, 4 and 10 were statistically significant, and for the long-term only factors 2 and 4 were significant. When controlling for the ISI before treatment value plus change from pre–post, only Factor 10 (Checking time) remained a statistically significant predictor for the short-term follow-up and Factor 3 (Blocking thoughts) for the mid-term follow-up, but neither were a statistically significant predictor for the long-term follow-up.

3.4 | Prediction of long-term sleep pattern categories (Better or Poorer Sleepers)

Each participant’s long-term outcome was divided into two categories; Better Sleepers (n = 150) and Poorer Sleepers (n = 66). The remaining 61 participants did not fall into either category. To keep the number of parameters down, we did not include baseline values for the three original scales, as they were considerably weaker as predictors of long-term outcome compared to the included pre–post change of the scales (Table 4). Both the ISI at baseline and change were significant predictors: a higher pretreatment ISI score decreased the odds of being a Better Sleeper (odds ratio [OR] 0.39, 95% CI 0.25–0.59; p < .001) while a larger improvement in ISI-score instead increased the odds of being a Better Sleeper (OR 5.43, 95% CI 2.85–11.40; p < .001). No other predictors were statistically significant, as can be seen in Table S3. The model’s explanatory power (coefficient of discrimination (Tjur, 2009)) was Tjur’s $R^2 = 0.372$. Due to a violation of linear independence between the predictors and the unbalanced classes, inferences should not be drawn upon this.

3.5 | Maximum predictive potential of all available data

To explore the upper limit of how much of the outcome all the available data could predict, two predictive models were used with low restrictions regarding the number of included predictors and their covariance and no measures were taken to avoid overfitting.

The first regression model predicted the ISI after treatment and the second model used logistic regression to predict Better or Poorer Sleepers throughout all follow-ups. All single items in the three original scales were initially correlated to the ISI after treatment (Table S1) and to the long-term categorical outcome (Table S2). All items with statistically significant correlations, as well as all empirically derived

### TABLE 3 Factors derived from factor analysis of the SRBQ, DBAS-10, and SPAQ

| Factor                      | Items included | Description                                           |
|-----------------------------|----------------|-------------------------------------------------------|
| 1. Acceptance               | SPAQ: 1, 2, 3, 4| Living well in spite of sleep problems                |
| 2. Avoidance daytime        | SRBQ: 2, 19, 20, 21,25| Avoidance behaviours during the day                  |
| 3. Blocking thoughts        | SRBQ: 3,10, 30 | Blocking negative thoughts in bed                     |
| 4. Blaming poor sleep       | DBAS-10: 6, 7, 9| Attributing daytime problems to poor sleep            |
| 5. Saving energy            | SRBQ: 9, 22 | Saving energy during the day                          |
| 6. Fight sleep problems     | SPAQ: 5, 6, 7 | Important to control/ fight sleep problems           |
| 7. Daytime distraction      | SRBQ: 26, 28, 31| Distracting from negative thoughts during the day     |
| 8. Napping                  | SRBQ: 16, DBAS-10 2| Catching up sleep through daytime napping or going to bed earlier following night |
| 9. Early bedtime            | SRBQ: 13, 32| Go to bed early                                       |
| 10. Checking time           | SRBQ: 12, 24| Checking the time during the night                    |

DBAS-10: Dysfunctional Beliefs and Attitudes about Sleep-10 items; ISI, Insomnia Severity Index; SPAQ, Sleep Problems Acceptance Questionnaire; SRBQ, Sleep-related Behaviours Questionnaire.
TABLE 4  Predicting ISI after treatment and at short-, mid- and long-term follow-up after CBT-I, using standard scales and new factors from these scales

| Scale or Factor name | Explained variance of ISI at post-treatment, using baseline predictors | Explained variance of ISI at FU, using both baseline values and change from pre–post as predictors | FU-short | FU-mid | FU-long |
|----------------------|------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|----------|--------|--------|
|                      | Predictors only $R^2$ (95% CI) Controlled for ISI $\Delta R^2$ (95% CI) | Predictors only $R^2$ (95% CI) Controlled for ISI $\Delta R^2$ (95% CI) | Predictors only $R^2$ (95% CI) Controlled for ISI $\Delta R^2$ (95% CI) | Predictors only $R^2$ (95% CI) Controlled for ISI $\Delta R^2$ (95% CI) | Predictors only $R^2$ (95% CI) Controlled for ISI $\Delta R^2$ (95% CI) |
| DBAS-10 Cognitions   | 0.012 (0.00, 0.05) 0.000 (-0.00, 0.00) | 0.000 (-0.00, 0.00) | 0.028** (0.14, 0.32) 0.022* (-0.01, 0.05) | 0.070** (0.01, 0.15) 0.027 (-0.02, 0.07) | 0.065** (0.01, 0.14) 0.018 (-0.01, 0.05) |
|                      | 0.008 (-0.01, 0.03) | 0.012 (-0.01, 0.03) | 0.113** (0.03, 0.20) 0.040* (-0.01, 0.09) | 0.040* (0.01, 0.15) 0.003 (-0.01, 0.02) | 0.070** (0.01, 0.15) 0.011 (-0.01, 0.01) |
| SRBQ Behaviours      | 0.032** (0.00, 0.09) 0.006 (-0.01, 0.02) | 0.003 (-0.01, 0.01) | 0.054** (0.01, 0.13) 0.000 (0.00, 0.06) | 0.070** (0.01, 0.15) 0.011 (-0.01, 0.02) | 0.050* (0.00, 0.12) 0.001 (-0.01, 0.01) |
| SPAQ Acceptance      | 0.038** (0.01, 0.09) 0.006 (-0.01, 0.02) | 0.003 (-0.01, 0.01) | 0.054** (0.01, 0.13) 0.000 (0.00, 0.06) | 0.070** (0.01, 0.15) 0.011 (-0.01, 0.02) | 0.050* (0.00, 0.12) 0.001 (-0.01, 0.01) |
| Acceptance (1)       | 0.038** (0.01, 0.09) 0.010 (-0.01, 0.03) | 0.000 (-0.00, 0.00) | 0.023 (0.00, 0.08) NR | 0.023 (0.00, 0.08) NR | 0.030 NR |
| Avoidance daytime (2) | 0.016* (0.00, 0.06) 0.006 (-0.01, 0.02) | 0.002 (-0.01, 0.01) | 0.038* (0.00, 0.10) 0.012 (-0.02, 0.04) | 0.042* (0.00, 0.11) 0.001 (-0.01, 0.01) | 0.065** (0.01, 0.14) 0.018 (-0.01, 0.05) |
| Blocking thoughts (3) | 0.000 (0.00, 0.00) NR | NR | 0.008 (0.00, 0.04) NR | 0.008 (0.00, 0.04) NR | 0.009 NR |
| Blaming poor sleep (4) | 0.016* (0.00, 0.06) 0.000 (-0.00, 0.00) | 0.001 (-0.01, 0.01) | 0.038* (0.00, 0.10) 0.008 (-0.02, 0.03) | 0.042* (0.00, 0.11) 0.001 (-0.01, 0.01) | 0.065** (0.01, 0.14) 0.018 (-0.01, 0.05) |
| Saving energy (5)   | 0.016* (0.00, 0.06) 0.005 (-0.01, 0.02) | 0.004 (-0.01, 0.02) | 0.005 (0.00, 0.04) NR | 0.005 (0.00, 0.04) NR | 0.008 NR |
| Fight sleep problems (6) | 0.004 (0.00, 0.04) NR | NR | 0.006 (0.00, 0.04) NR | 0.006 (0.00, 0.04) NR | 0.002 NR |
| Daytime distraction (7) | 0.009 (0.00, 0.05) NR | NR | 0.007 (0.00, 0.04) NR | 0.007 (0.00, 0.04) NR | 0.002 NR |
| Napping (8)         | 0.016* (0.00, 0.06) 0.024* (-0.01, 0.06) | NR | 0.007 (0.00, 0.04) NR | 0.007 (0.00, 0.04) NR | 0.002 NR |
| Early bedtime (9)   | 0.006 (0.00, 0.04) NR | NR | 0.051** (0.01, 0.11) 0.001 (-0.01, 0.01) | 0.022 (0.00, 0.08) NR | 0.005 NR |
| Checking time (10)  | 0.007 (0.00, 0.04) NR | NR | 0.015** (0.07, 0.23) 0.025** (-0.01, 0.06) | 0.068** (0.01, 0.15) 0.020 (-0.02, 0.06) | 0.015 NR |
|                      | 0.024* (-0.01, 0.06) | 0.007 (0.00, 0.04) NR | 0.025** (-0.01, 0.06) | 0.068** (0.01, 0.15) 0.020 (-0.02, 0.06) | 0.015 NR |

CI, confidence interval; FU, follow-up; FU-long, ISI sum at 3 or 10 years FU; FU-mid, ISI sum at 12-months FU; FU-short, ISI sum at 3 or 6 months follow-up; ISI, Insomnia Severity Index; NR, not relevant due to non-significant predictor; Post, post-treatment; Pre, pretreatment; $R^2$, explained variance; $\Delta R^2$, explained variance between step 1 and step 2.

Bold values indicates the significance of *p < .05; **p < .01.

aAdditional explained variance when adding the predictor after baseline ISI.
bAdditional explained variance when adding predictors after baseline ISI and ISI pre–post change.
factors’ baseline data were included in each model, with the addition of pre–post change scores in the model predicting long-term Better or Poorer Sleepers.

The best fitted model, predicting the ISI after treatment, explained 21.2% of the variance and is shown in Table S4. Four predictors were statistically significant; baseline ISI, Factor 8 (napping during the day) and SRBQ item 14 (I give up trying to work) and SRBQ item 24 (look at watch to see how long it takes to fall asleep).

The best fitted model predicting long-term categorical outcome (Better or Poorer Sleep) had an explanatory power of 58.9% (Tjur’s $R^2 = 0.589$) and is shown in Table S5, where the 11 significant predictors are marked with bold text. The three strongest predictors were change in ISI (OR 5.70), change in DBAS-10 item 5 (worried about losing control over ability to sleep; OR 4.54), and change in SRBQ item 15 (using sleep medication; OR 4.02).

### 4 | DISCUSSION

The primary goal of the present study was to investigate to what extent sleep-related behaviours, acceptance, and cognitions could predict CBT-I outcome measured as insomnia severity directly after treatment and at long-term follow-ups. All three of the established scales were significant predictors both after treatment and at the three different long-term follow-ups, which fits well with previous findings on prediction and mediation (Edinger et al., 2008) (Chow et al., 2018; Lancee et al., 2015; Norell-Clarke et al., 2017; Sunnhed & Jansson-Fröjmark, 2015). However, if the goal is to assess a predictor’s unique contribution, it is important to control for other relevant predictors.

In the present study, when controlling for baseline insomnia severity and change in insomnia symptoms during treatment, all but two of the 12 predictive attempts, i.e. DBAS-10 predicting short-term follow-up, and SRBQ predicting mid-term follow-up, became statistically non-significant. Thus, our present results show that previous findings must be interpreted with caution, as the predictive ability of the scales could, to a large extent, be explained by their high correlations with initial levels and later change of insomnia symptoms. It should be underscored that their status as mediators of change, which many previous studies (Chow et al., 2018; Norell-Clarke et al., 2017; Sunnhed & Jansson-Fröjmark, 2015) have focussed on, is not put in doubt by our present findings, as we do not examine what occurs during the treatment. However, if the goal is to predict treatment outcome in order to match patients to treatments or to identify failing treatments early on, these scales may be superfluous. For such purposes, our present results indicate that insomnia severity in itself is a very strong predictor and that the additional predictive power provided by the measures of sleep-related cognitions, behaviours, and acceptance may be rather low and possibly negligible. From our present analyses, it is unclear what causes this strong prediction, whether patterns of change differ depending on initial insomnia symptoms or if it is merely an artefact of initial levels and regression to the mean.

We also further tested the possible predictive power of the three scales by using a pragmatic statistical approach and put all items of the three scales into a joint factor analysis to derive new, empirically based concepts. These factors would not, as is the case with the original scale sums, suffer the risk of forcing less related items together and thus possibly hide statistical variability that could turn out to be predictive. However, after controlling for insomnia severity, the 10 factors found produced only three statistically significant predictions (out of 40), i.e. “Napping” predicting post-treatment outcome, “Checking the time during the night” predicting short-term follow-up, and “Blocking thoughts” predicting mid-term follow-up. As for the predictions using the original scales, the low number of statistically significant predictions indicates a clear risk of all of predictors being chance findings. Interestingly, only one of the factors, 8 (catching up sleep through daytime napping or going to bed earlier following night), combined items from different scales, which, on the whole, indicates that the three scales overall measure different constructs.

The maximum predictive potential of all available data was 21% when forecasting post-treatment outcome and 59% when forecasting long-term outcome (Better or Poorer Sleep). It seems more reliable to predict long-term stability of sleep after treatment, when the initial treatment outcome is known, than predicting post-treatment results prior to treatment.

The short-term prediction results can be compared to the study by Forsell, Isacsson, et al. (2019), where 21% variance explained could be reached at baseline or 1 week into treatment using the respective primary symptom measure as the only predictor in Internet-delivered CBT for depression, social anxiety or panic disorder. This resulted in a balanced accuracy of between 51%–64% (50% being pure chance) when predicting the dichotomous outcome “Successful” or “Failed” treatment, which is probably too low to be clinically useful. The long-term value in the present study, of 59% explained variance, could be compared to what Forsell et al. used as a benchmark for clinically useful accuracy.

These two predictive models again support the finding that insomnia severity is the most useful predictor, as improvements in the ISI score pre–post treatment were very strongly related to a stable better sleep after treatment, and that a higher pretreatment score on the ISI somewhat decreased the odds of having a good sleep in the long term. In addition, larger improvements in several individual items from the questionnaires was related to a better long-term sleep, but these specific results are highly preliminary due to clear violation of collinearity of predictors, unbalance between the size of the categories that were predicted, an over-fitted model, and repeated exploratory testing. Possibly, the specific predictors found could be used to formulate hypotheses for future research.

Edinger et al. (2008) found that patients with initial high levels of unhelpful beliefs about sleep improved less than those with low levels. The present study does not corroborate this finding, as the DBAS-10 did not predict outcome after treatment and only predicted one out of three long-term outcomes when controlled for ISI. Sunnhed et al. found, in their mediation analyses, that the DBAS mediated CBT-I outcome, measured with the ISI, at the 3-month follow-up, when controlling for the ISI pretreatment value (Sunnhed &
Jansson-Fröjmark, 2015). Besides being a mediation analysis with a waitlist control group, this analysis differs from ours in that they did not control for the change in the ISI pre–post treatment, which may have impacted their results. Our present findings are more in line with the recent study by Lancée et al., which suggested that dysfunctional beliefs about sleep did not mediate the effects of CBT-I on insomnia severity and sleep efficiency (Lancée et al., 2019).

Previous findings indicating that people using sleep medication do as well with CBT-I as non-users (Blom, Jernelöv, Ruck, et al., 2016; Blom, Tarkian Tillgren, et al., 2015; Taylor et al., 2015) is possibly put in question by the predictive value of the SRBQ item 15 (Using sleep medication) in the over-fitted logistic regression. Still, considering the preliminary nature of this finding and previous evidence, it is likely that sleep medication is not a strong predictor of CBT-I outcome, although this should be further investigated in future studies.

4.1 | Strengths and limitations

A strength with the present study is that we control for the baseline value and change during treatment in the outcome to be predicted, something that is lacking in the previous studies we have found. Another strength is the long follow-up periods of up to 10 years after treatment. A limitation to consider regarding the significant predictors found has already been mentioned – that the exploratory nature of the present study and the large number of predictive tests, without adjustment for multiple comparisons, underscores the need to consider these as preliminary findings, until they are replicated. Also, while baseline value and change had a strong predictive capability, we cannot know whether this is an artefact of ceiling/floor effects, law of initial values, regression to the mean or a pattern of insomnia serving as a predictor. However, the finding that very few predictors were identified, despite the liberal testing procedures, rather strengthens the preliminary nature of this finding and previous evidence, it is likely that sleep medication is not a strong predictor of CBT-I outcome, although this should be further investigated in future studies.

5 | CONCLUSIONS

The present study does not contradict studies indicating that cognitive processes may play an important role in the mechanisms of change of insomnia treatment, but it does not support the use of the DBAS-10, SRBQ, SPAQ, nor empirically derived factors from all items in these scales, as predictors of outcome in CBT-I. Instead, it indicates that measures of initial levels of insomnia severity, and especially its change during treatment, are the best predictors of future treatment outcome.

ACKNOWLEDGEMENTS
This was not an industry funded study. We want to thank the funders: Promobilia Foundation, Söderström-Königska sjukhemmets Foundation, Lars Hierta Foundation, Psykiatrifonden and the Fredrik & Ingrid Thuring Foundation.

CONFLICT OF INTEREST
No conflicts of interest declared.

AUTHOR CONTRIBUTIONS
Primary Investigator: VK; Study design and planning: VK, SJ, KB, and MK; Data collection: KB, EF, AR, MK, SJ, and VK; Analyses: KB, NHI, EF, AR, MK, SJ, and VK; Preparation of manuscript: KB, NHI, EF, AR, MK, SJ, and VK.

DATA AVAILABILITY STATEMENT
The data underlying this article cannot be shared publicly due to legal requirements within the European Union (General Data Protection Regulation [GDPR]). The data will be shared in a manner compatible with GDPR on reasonable request to the corresponding author.

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SUPPORTING INFORMATION
Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Blom K, Hentati Isacsson N, Forsell E, et al. An investigation and replication of sleep-related cognitions, acceptance and behaviours as predictors of short- and long-term outcome in cognitive behavioural therapy for insomnia. J Sleep Res. 2021;00:e13376. https://doi.org/10.1111/jsr.13376