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The Association between Perseverative Cognition and Sleep in Non-Clinical Populations: A Systematic Review and Meta-Analysis

Clancy, F., Prestwich, A., Caperon., L., Tsipa, A., & O'Connor, D. B.

Faye Clancy, PhD, School of Psychology, Faculty of Medicine and Health, The University of Leeds, fayeclancy17@gmail.com

Andrew Prestwich, PhD, School of Psychology, Faculty of Medicine and Health, The University of Leeds, a.j.prestwich@leeds.ac.uk

Lizzie Caperon, PhD, Leeds Institute of Health Sciences, Faculty of Medicine and Health, The University of Leeds, e.l.v.caperon@leeds.ac.uk

Anastasia Tsipa, PhD, Primary Affiliation: School of Psychology, Faculty of Medicine, The University of Leeds, Leeds, UK; Secondary Affiliation: Department of Clinical, Educational and Health Psychology, University College London; Tertiary Affiliation, Camden and Islington Foundation Trust, anastasia.tsipa.18@ucl.ac.uk

Daryl B O'Connor, PhD, School of Psychology, Faculty of Medicine and Health, The University of Leeds, d.b.o'connor@leeds.ac.uk

Abstract

Associations have been found between perseverative cognition (PC: worry and rumination) and somatic markers of ill-health. Further studies have reported associations between sleep and both PC and poorer health. As such, sleep disturbance may represent a pathway between PC and ill-health. Therefore, studies assessing the relationship between PC and sleep in non-clinical populations were synthesized. Meta-analyses (k = 55) revealed small- to medium-sized associations between higher PC and poorer sleep quality (SQ, r = -0.28), shorter total sleep time (TST, r = -0.15) and longer sleep onset latency (SOL, r = -0.16). Variations included associations between SQ and rumination (r = -.33) and worry (r = -.23). Associations were stronger in studies measuring SQ via self-report rather than actigraphy, and where SOL and TST outcomes were cross-sectional. Associations with SOL were stronger when outcomes were from non-diary studies and when trait, rather than state PC, was measured, but weaker where studies incorporated more measures of PC. Effect sizes were generally larger where studies were higher quality and being female may act as a protective factor between PC and longer SOL. Therefore, there is a consistent association between PC and sleep which may partially explain the link between PC and ill-health.

Keywords: Worry, Rumination, Perseverative Cognition, Stress, Sleep

Perseverative Cognition and Sleep Disturbance

The American Academy of Sleep Medicine advises that adults should sleep for 7 or more hours per night to reduce the risk of negative health outcomes (Watson et al., 2015). In a review of the literature, the panel reported evidence for associations between short sleep duration and poorer general, cardiovascular, metabolic, mental and immunologic health, as well as greater experience of pain and greater overall rates of mortality. Similarly, sleep disturbance has been associated with markers of inflammation in a recent meta-analysis (Irwin, Olmstead, & Carroll, 2016).

In 2017, the UK Sleep Council surveyed 5002 British adults and found that 74% slept for less than 7 hours per night and this percentage had risen from 2013. Most survey respondents (61%) slept between 5 and 7 hours each night and 12% reported sleeping for less than 5 hours (a 5% rise since 2013). As well, nearly a third reported regular poor-quality sleep. Similarly, in a sample of 25,580 adults from 7 European countries, 10.8% reported experiencing non-restorative sleep and this rose to 16.1% when the UK was analyzed separately (Ohayon, 2005). Likewise, in the US, a trend analysis of sleep duration from 1985-2012 found that the number of adults reporting 6 or fewer hours of sleep per night had risen by 31% (Ford, Cunningham, & Croft, 2015). This divergence from sleep recommendations, and the associated health consequences, suggests that identifying the predictors of disturbed sleep is of vital importance from a public health perspective.

Research has identified an association between negative over-thinking and sleep difficulties. Harvey, Tang, and Browning (2005) reviewed studies exploring the prevailing cognitive explanations for insomnia. They provided evidence for the role of repetitive thought processes including cognitive arousal, intrusive and worrisome thoughts and unhelpful beliefs about sleep in the incidence of insomnia. Studies in non-clinical samples have also reported an association between thought processes such as worry and rumination

and difficulty falling asleep (McGowan, Behar, & Luhmann, 2016; Zoccola, Dickerson, & Lam, 2009), poorer quality sleep (Barclay & Gregory, 2010; Cropley, Rydstedt, Devereux, & Middleton, 2015) and shorter total sleep duration (Cropley, Dijk, & Stanley, 2006; Nota & Coles, 2015).

Such thought processes are included within the conceptualization of perseverative cognition proposed by Brosschot, Gerin, and Thayer (2006). They described perseverative cognition as any type of stress-related negative, repetitive thought. This term encompasses thoughts about feared future events (worry) and thoughts about distressing past experiences or current negative feelings (rumination). In their Perseverative Cognition Hypothesis, Brosschot et al. (2006) suggest that stressful thoughts activate the body's stress response in the same way as stressors in the physical environment and serve to prolong the hypothalamic-pituitary-adrenal-axis stress response. A recent systematic review and meta-analysis by Ottaviani et al. (2016) found an association between perseverative cognition and higher systolic and diastolic blood pressure, increased heart and lower heart rate variability and higher cortisol levels in both cross-sectional and experimental studies. Furthermore, as physiological arousal has been found to predict sleep disturbance (Bonnet & Arand, 2003; Hall et al., 2007), perseverative cognition and its accompanying physiological activation may play a role in explaining an inability to fall asleep, stay asleep or an overall disruption in the quality of sleep.

Ottaviani et al. (2016) argue that the effects of perseverative cognition on somatic markers of ill-health mediate the pathogenic pathway between perseverative cognition and long-term disease outcomes. More recently, Clancy, Prestwich, Caperon, and O'Connor (2016) have extended the Perseverative Cognition Hypothesis to incorporate health behaviors. Specifically, in a recent systematic review and meta-analysis of perseverative cognition and health behaviors, Clancy et al. (2016) found that perseverative cognition was

associated with higher performance of health-risk behaviors (e.g. substance use and unhealthy eating). Taken together, this evidence suggests that perseverative cognition may act on health both directly and indirectly. Given that both perseverative cognition and sleep have been found to negatively impact on cardiovascular and endocrine processes, it is possible that another route by which perseverative cognition predicts ill-health is via sleep disturbance.

Potential Moderators of Perseverative Cognition and Sleep

Perseverative cognition is an umbrella term which encompasses different types of negative, repetitive thought processes. The most common of which are rumination and worry. These processes are temporally distinct. Worry describes negative repetitive thoughts about anticipated *future* events whereas rumination describes negative repetitive thinking about events in the *past* (Watkins, Moulds & Mackintosh, 2005). Moreover, worry and rumination have been found to more strongly predict certain mental health disorders than others (anxiety disorders and depression respectively) (Brosschot et al., 2006; Nolen-Hoeksema, 2000). Additionally, Clancy et al. (2016) found that rumination, but not worry, predicted health-risk behaviors. As such, there is evidence from the perseverative cognition literature that, while they share properties, worry and rumination are conceptually distinct thought processes (Ottaviani et al., 2016; Clancy et al., 2016). For these reasons worry and rumination may have differential associations with sleep outcomes. Therefore, we investigated whether the type of perseverative cognition moderated the perseverative cognition – sleep association.

Evidence regarding perseverative cognition and gender tends to show that females are more likely to engage in perseverative thinking. For instance, in a recent meta-analysis, it was found that women displayed a greater tendency towards rumination than men (Johnson & Whisman, 2013) and it has been suggested that this may explain the greater prevalence of depression in women (Nolen-Hoeksema, Larson, & Grayson, 1999). A similar greater

tendency to engage in worry has also been found in women (Robichaud, Dugas, & Conway, 2003; Zlomke & Hahn, 2010). On the other hand, review evidence suggests that although women evidence more self-reported sleep complaints, such as inadequate sleep time and insomnia, their overall sleep quality (measured via actigraphy) is better (Krishnan & Collop, 2006). This may reflect a greater sensitivity to poor sleep in women suggesting that, compared to men, they more reliably report poor sleep. Alternatively, the lack of correspondence between self-reported and objectively verified sleep in women may reflect less reliable reporting of sleep in women compared to men. A potential difference in the reliability of reporting sleep in women versus men could lead to possible differences in the associations between perseverative cognition and sleep, given reliability of construct measurement influences the size of the correlation between two variables (Goodwin & Leech, 2006). Thus, sex may moderate the association between perseverative cognition and sleep outcomes. Given it is unclear whether sleep (and perseverative cognition) are more reliably reported by women or men, and no such studies have directly tested whether such associations vary across the sexes, we present an exploratory test and no directional predictions are made.

Another factor which may moderate the perseverative cognition-sleep association is the level of measurement of both of these variables. In their review, Ottaviani et al. (2016) assessed whether outcomes differed depending upon whether perseverative cognition was measured at a state or trait level. That is, the difference between engaging in perseverative cognition at a point in time versus the overall tendency to engage in perseverative cognition. They found that this variable moderated the association between perseverative cognition and heart rate and heart rate variability. A significant association between perseverative cognition and heart rate and heart rate variability was only found in studies assessing state, as opposed to trait perseverative cognition. It is therefore possible that state and trait perseverative

cognition may have different associations with other health/behavioral outcomes, including sleep.

Similarly, another measurement type which may moderate the perseverative cognition-sleep association is whether sleep is measured by self-report or actigraphy. Lauderdale, Knutson, Yan, Liu, and Rathouz (2008) found that, compared to objectively measured sleep duration (actigraphy), self-reported sleep was systematically over-reported. It can be concluded from this that objectively measured sleep and participant's perception of their sleep are arguably two different outcomes and that it is therefore important to assess whether perseverative cognition is associated with both. This is especially important as it has been found that worry may sensitize individuals to health complaints (Verkuil, Brosschot, & Thayer, 2007), making high worriers more likely to recall health complaints, and it is therefore possible that this may also apply to sleep complaints. Consequently, an association between perseverative cognition and actigraphy-measured sleep would be more definitive as sleep measured in this way would not be prone to any distorted perception of sleep which might be evident in high worriers.

Overall, several studies have reported an association between perseverative cognition and shorter sleep duration (Cropley et al., 2006; Nota & Coles, 2015), longer sleep onset latency (McGowan et al., 2016; Zoccola et al., 2009) and poorer overall sleep quality (Barclay & Gregory, 2010; Cropley et al., 2015) in non-clinical populations. To date, these studies have not been reviewed or subject to meta-analysis. In the insomnia literature, some attention has been given to the contribution of cognitive processes and negative thinking to sleep (Harvey, 2002; Hiller, Johnston, Dohnt, Lovato, & Gradisar, 2015), but similar research in non-clinical populations has not been synthesized, despite widespread sleep problems at a population level. Furthermore, even if assumptions were made about perseverative cognition and sleep in healthy populations based on the insomnia literature, the association between

cognitive processes and clinical sleep disorders has not been reviewed systematically nor were the effect sizes subject to meta-analysis.

If a relationship between perseverative cognition and poorer sleep is established, interventions which focus upon managing perseverative cognition may prove effective in improving sleep quality and associated health outcomes. However, firstly, this evidence must be considered systematically to assess whether an association is found between perseverative cognition and sleep in the existing literature and to examine the strength and direction of this relationship. Furthermore, it is of importance to assess the moderators of this association to address questions such as whether associations between perseverative cognition and sleep are found across all or only some categories of perseverative cognition (e.g. worry and rumination) and sleep outcomes (sleep onset latency, sleep quality and total sleep time), whether state or trait perseverative cognition is more predictive of sleep outcomes, whether differences are found across sleep measurement and whether differences are found across gender. Such review evidence will enable researchers to identify gaps in the existing literature and can be used to inform the development of intervention studies.

Aims

The primary aim of the current review was to establish whether there is an association between perseverative cognition and sleep in non-clinical populations, across all study designs. Studies with non-clinical samples were chosen as mental health conditions such as depression and anxiety have shown an association with sleep disturbance (Alvaro, Roberts, & Harris, 2013), as have various physical conditions such as cancer (Davidson, MacLean, Brundage, & Schulze, 2002) and diabetes (Resnick et al., 2003) and individuals who suffer from insomnia have been found to show distorted perception of sleep (Harvey & Tang, 2012). Therefore, to reduce the risk of confounding factors, only studies of non-clinical participants

were included in this review. Specifically, the primary objective was to examine the association between perseverative cognition and sleep onset latency, total sleep time and sleep quality. The secondary objective was to test whether this relationship was moderated by other variables (i.e. gender, study quality, study design, state versus trait perseverative cognition measurement, self-reported versus actigraphy-measured sleep, the time between measures of perseverative cognition and sleep, and the number of perseverative cognition measurements).

Method

Eligibility Criteria

Eligible studies had to (1) include a measure of perseverative cognition, (2) include a measure of sleep (3) report the relationship between the measures of perseverative cognition and sleep within a statistical analysis that could be used to estimate an effect size. Studies were excluded if they were (1) not peer-reviewed (including dissertations and unpublished papers), (2) not an empirical investigation, (3) were reviews, editorials or 'think pieces', book chapters and protocols, (4) if all study participants had been diagnosed with physical or mental health problems (including insomnia and other clinical sleep disorders) but included if a sample of healthy participants were analyzed separately, (5) excluded if the paper could not be retrieved after trying to contact authors. Apart from criteria relating to sleep, these eligibility criteria are identical to those reported in Clancy et al. (2016).

Search Strategy

PsycINFO (1806 to Present) and Medline (1946 to Present) were searched using OVID. The search was first conducted on the 11th February 2016 and was last performed on the 10th of January 2018 using search terms relating to perseverative cognition and sleep. The

search was limited by (1) English language, (2) human studies and (3) studies published from 1990. The search was restricted to 1990 onwards for the same reasons as Clancy et al. (2016), namely, due to publication of a key measure of worry around this time and to increase the specificity of the search. The titles were screened by the first author (FC). All abstracts and full-texts of papers from 1990-2016 that were not excluded at the title screening stage were independently double-screened (LC) and any discrepancies were resolved via discussion. There was 100% agreement between the two reviewers regarding the studies to be included from this period and therefore it was deemed justifiable for only the first author to screen papers returned from the second search. The full review strategy is published with PROSPERO (PROSPERO 2017 CRD42017070757).

Search Terms

Perseverative cognition terms, reported in Clancy et al. (2016) and adapted from Querstret and Cropley (2013) and Ottaviani et al. (2016), combined with OR were: (1) perseverati∗ AND cogniti∗ (2) reflection (3) brooding (4) ruminat∗ (5) reflect∗ AND thought∗ OR thinking (6) brood∗ AND thought∗ OR thinking (7) perseverative AND thought∗ OR thinking (8) repetitive AND thought∗ OR thinking (9) intrusive AND thought∗ OR thinking (10) negative AND thought∗ OR thinking (11) self-referential AND thought∗ OR thinking (12) stress AND thought∗ OR thinking (13) obsessive AND thought∗ OR thinking (14) worry (15) unconscious stress∗ (16) implicit stress∗ (17) anticipat∗ stress∗ (17) cognitive intrusion∗. Sleep terms, adapted from Hu et al. (2015), were combined with OR, (1) exp[1] Sleep, (2) (sleep adj3[2] (promot* or help* or support* or initiat*)).mp.[3], (3) sleep.ti,ab[4].

[1]exp = the explode function. In addition to searching for the term 'sleep', also searches for terms listed under the subject heading (database specific)
[2]adj3 = this adjacency function returned papers where sleep was within three words of the terms in parentheses
[3]mp = default/multi-purpose search

It should be noted that, psychological detachment was not included within the search criteria. Psychological detachment is a concept from occupational psychology and can broadly be described as the absence of thoughts about work (Sonnentag & Fritz, 2015). In their review, Wendsche and Lohmann-Haislah (2017) consider psychological detachment from work to be the inverse of thought processes such as work rumination. However, Sonnentag and Fritz (2015) argue that psychological detachment only refers to the absence of work thoughts, which means that repetitively negatively thinking about one's health or family, for instance, would still be categorized as psychological detachment. Furthermore, this construct is unspecific about valence as the work-related thoughts need not necessarily be negative and therefore it does not necessarily refer to an absence of negative thoughts. This is incompatible with the definition of perseverative cognition put forward in this paper and therefore, in the current review and meta-analysis, psychological detachment was not included in the search, nor were psychological detachment outcomes retrieved from the search included in this review.

Data Extraction

The following data was extracted for each study: (1) the type of perseverative cognition reported, categorized as worry (reported as worry in the paper or as any type of future-oriented negatively affect-laden repetitive thought), rumination (reported as rumination in the paper or as any type of past-oriented negatively affect-laden repetitive thought e.g. nocturnal regret), non-specific perseverative cognition (reported as perseverative cognition in the paper or categorized as any type of negatively affect-laden repetitive thought in which a past/future orientation was not specified e.g. pre-sleep cognitive arousal). It should be noted that, within the non-specific perseverative cognition category, there were measures of

[4]ti,ab = this function was used to search titles and abstracts for the term 'sleep'

perseverative cognition which combined both worry and rumination (i.e. both a past and future orientation) as well as papers which did not specify a temporal focus. Also, where perseverative cognition and sleep were conflated, for example, the Sleep Disturbance Ascribed to Worry Scale (Kelly, 2002) outcomes were excluded; (2) perseverative cognition assessment (state, trait or both). Perseverative cognition measures were coded as trait when reference was made to the habitual tendency to engage in perseverative cognition, within no specific time-period, whereas perseverative cognition measures were coded as state when there was a particular time-focus (e.g. to what extent participants engaged in perseverative cognition that day, month, year); (3) the type of sleep outcome (total sleep time, sleep onset latency or sleep quality). Other parameters such as sleep efficiency and the number of nighttime awakenings are also found across the sleep literature but, to maintain an adequate sample size in these meta-analyses, such parameters were considered under the classification of sleep quality, as is done in the widely used Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989); (4) sleep assessment (actigraphy, self-report or both); (5) the study design (multiple outcomes were possible in this case e.g. a study could report both cross-sectional and longitudinal outcomes); (6) for diary designs, at outcome level, analyses were coded as being between- or within-person; (7) the age range of participants (the mean or median were extracted if this was not available), then categorized as children (0-12), adolescents (12-18), adults (18-65), older adults (65+) or a combination of these categories; (8) the percentage of female participants (averaged if this differed across study outcomes); (9) the number of times that perseverative cognition was measured in the study; (10) the longest amount of time between measures of perseverative cognition and sleep in each study; (11) whether perseverative cognition measures were multi- or single-item; (12) whether (self-reported) sleep measures were multi- or single-item; (13) whether perseverative cognition measures were reported as validated; (14) whether sleep measures (self-report and

actigraphy) were reported as validated; (15) whether perseverative cognition measures were reported as reliable in that sample (Cronbach's $\alpha \geq .70$); (16) whether (self-reported) sleep measures were reported as reliable in that sample (Cronbach's $\alpha \geq .70$); (17) effect size data for relationships between perseverative cognition and sleep; (18) whether any covariates were included. If any of this information was not available, first authors were contacted for this information or for clarifications. In the event of no response, second authors were contacted. If simple statistical associations could not be obtained, sensitivity analyses were performed for studies which included covariates.

Study quality was assessed using scores from items 11-16 from the data extraction process. All items (whether all perseverative cognition and sleep measures included within that study were multi-item and whether all perseverative cognition and sleep were reported as reliable and valid) were coded as 0 for no and 1 for yes. One score was produced per study and therefore, the item was only coded as yes if this was true for all measures within that study. These items were analyzed as individual moderators rather than combined as (1) summing scores would include an element of double-counting e.g. a single item measure would be penalized for being a single item and for not being reliable, (2) combining scores is problematic as it is difficult to ascertain the importance of each individual criterion and (3) the Cochrane handbook (Higgins & Green, 2008) advises against such an approach. Note that these items were selected to assess study quality as they are applicable to all included study designs (and no such validated quality assessment tool was available).

To maximize reliability of the data extraction process, data extraction was completed by a second reviewer for 20% of included papers (AP & DO) except in the case of effect size data in which effect sizes from all 1990-2016 papers were extracted by a second reviewer (AT), which equates to approximately 70% of the total papers. As there was 100% agreement between reviewers for effect size data from 1990-2016, effect sizes from 2016-18 were only

extracted by the first author (FC). In all cases, discrepancies were resolved via discussion. The data is available at the Open Science Framework (URL: https://osf.io/5769j/?view_only=c9ef8bdaa75c4b98a190a510d11826cd).

Method of Analysis

Comprehensive Meta-Analysis software (Borenstein, Rothstein, & Cohen, 2005) was used to calculate effect sizes and perform the meta-analyses. To account for the issue of dependence resulting from multiple outcomes per study, mean effect sizes reflecting the strength of the association between a specific type of perseverative cognition and sleep outcome were used in analysis. For instance, several studies measured more than one type of perseverative cognition, some studies used more than one measure of perseverative cognition and sleep and several studies included more than one time-point. All such effect sizes were included as there was no theoretical justification to exclude outcomes (e.g., first versus second versus last follow-up; one type of sleep quality measure over another) on any of these bases. This method has the limitation of increasing the type II error rate (Scammacca, Roberts, & Stuebing, 2014) and therefore this should be taken into consideration when interpreting the findings of these analyses. This was deemed preferable to increasing the type I error rate when assuming independence between non-independent outcomes.

A random effects model was chosen for all analyses based on the assumption that effect sizes would be similar but not identical across studies (Borenstein, Hedges, Higgins, & Rothstein, 2011). The association between combined perseverative cognition categories and each category of sleep outcome (sleep quality, total sleep time and sleep onset latency) was analyzed. Additionally, the association between each category of perseverative cognition (worry, rumination and non-specific perseverative cognition) and each sleep outcome was analyzed.

In all analyses, the correlation between measures is reported and a negative correlation reflects an association between higher levels of perseverative cognition and poorer sleep (i.e. worse quality sleep, longer sleep onset latency and shorter total sleep time). An effect size of the magnitude r = .1 - .3 was considered small, .3 - .5 was considered medium and .5 and above was considered large. Q and I^2 values were used in assessing heterogeneity. Significant Q values indicate between-study heterogeneity and I^2 values of .25, .50 and .75 relate to low, moderate and high between-study heterogeneity (as used in Ottaviani et al., 2016). Egger's regression test (Egger, Smith, Schneider, & Minder, 1997) was used to assess publication bias for each sleep outcome and Duval and Tweedie's Trim and Fill analysis (Duval & Tweedie, 2000) was used to adjust for any existing publication bias.

Three sets of sensitivity analyses were conducted. Studies which reported effect sizes that accounted for covariates were removed (sensitivity analysis 1). The following studies were excluded on this basis: Fichten et al. (2001), Kocoglu, Akin, Cingil, and Sari (2013), LaBrash et al. (2008), McGowan et al. (2016) and Rodríguez-Muñoz, Notelaers, and Moreno-Jiménez (2011).

Effect sizes for perseverative cognition measures that only broadly met the specified conceptualization of perseverative cognition were removed (sensitivity analysis 2). The Pre-Sleep Arousal Scale (Nicassio, Mendlowitz, Fussell, & Petras, 1985) was removed as, although this measure includes items which encapsulate perseverative cognition (e.g. 'worry about falling asleep' and 'worry about problems other than sleep'), it also includes other items assessing more general overthinking which were not necessarily negatively valanced (e.g. 'review and ponder events of the day' and 'being mentally alert, active'). Studies using the measure were Doos Ali Vand, Gharraee, Farid, and Bandi (2014), Fichten et al. (2001), Wicklow and Espie (2000) and Yeh, Wung, and Lin (2015). The same issue was apparent in

pre-sleep arousal measured by the Glasgow Content of Thoughts Inventory (Harvey & Espie, 2004). This measure was used in Loft and Cameron (2014). Similarly, both Åkerstedt et al. (2002) and Åkerstedt, Nordin, Alfredsson, Westerholm, and Kecklund (2012) used a measure of work preoccupation. In the former, it is not clear whether these are preoccupations with negative aspects of work, and, in the latter, one item refers to work problems but the other two relate to over-thinking more generally. As such, both were excluded in these sensitivity analyses.

As there were too few studies including only children, adolescents and older adults to perform sub-group analyses, analyses were conducted only on studies with exclusively adult samples (sensitivity analysis 3). This was deemed necessary as research has found that sleep patterns differ in children and older adults (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004). The following studies were excluded on this basis: Annunziata, Muzzatti, Flaiban, Giovannini, and Carlucci (2016), Bagley, Kelly, Buckhalt, and El-Sheikh (2015), Barclay and Gregory (2010), Fichten et al. (2001), Hartz, Ross, Noyes, and Williams (2013), Jean-Louis et al. (2009), Lin, Xie, Yan, and Yan (2017), Liu et al. (2017), Querstret and Cropley (2012), Schmidt, Renaud, and van der Linden (2011) and Yan et al. (2014). Age was not analyzed as a continuous moderator as, upon initial inspection of the included papers, several papers did not report mean age, hence age categories were used instead.

Analyzed as moderators were (1) gender (percentage female); (2) perseverative cognition assessment (state or trait); (3) sleep assessment (at least one measure of actigraphy or self-report only); (4) study design (cross-sectional only (yes/no), longitudinal only (yes/no), diary study (yes/no). Note that ‘yes’ in response to cross-sectional only and longitudinal only refers to studies in which study outcomes were only generated from cross-sectional or longitudinal designs, not mixed design studies. Experimental outcomes were removed in these analyses as there were too few studies to analyze experimental outcomes

separately); (5) the maximum reported amount of time between the perseverative cognition and sleep measures in diary studies. Note that the time between measures of perseverative cognition and sleep was only analyzed as a moderator in diary studies as, across other study designs, these outcomes were very heterogenous (e.g. 1 day to 5 years) and therefore difficult to assess as a continuous moderator. Within diary studies, these outcomes were coded by the number of days (e.g. '0' for cross-sectional outcomes, '0.5' for up to half a day between measures, '1' for 1 day between measures); (6) the number of times that perseverative cognition was measured in all but experimental studies; (7) whether the outcomes were analyzed at a within- or between-person level i.e. between-only (yes/no). Between-only was assessed as a moderator as diary studies enable analysis of levels within a dataset (i.e. the within-person and between-person level) and there is evidence that correlations tend to differ across levels (McCormick, Reeves, Downes, Li, & Ilies, 2018). Also, a Pearson's chi square analysis was conducted to assess the association between within/between-person analyses and state/trait outcomes, as it was expected that there may be an element of confounding between these variables. This analysis was significant χ^2 (df = 1) = 36.01, p < .001 and revealed that all within-person analyses related to a state perseverative cognition predictor. Due to this potential confounding between these moderators (between-only and state/trait), state/trait was analyzed as a moderator of the association between combined perseverative cognition and outcomes generated only from between-person analyses; (8) study quality items.

Consistent with Ottaviani et al. (2016), a minimum of 5 studies per subgroup was selected as the criterion for categorical moderator analyses so it was not possible to perform all moderator analyses on all sleep outcomes (see Table 3). Where meta-regressions revealed significant moderation by categorical variables, sub-group analyses were reported per category in order to decompose this effect. Continuous and categorical moderators were analyzed via meta-regression using a maximum likelihood method. Meta-regressions were

only conducted on the relationship between combined perseverative cognition categories and sleep quality, sleep onset latency and total sleep time due to the limited number of studies in analyses investigating the relationship between perseverative cognition subtypes and sleep outcomes.

Results

Overview of Included Studies

The search retrieved 2106 papers which were screened for inclusion. The screening process is depicted in Figure 1. After duplicates were removed, 1360 papers remained and 1230 were then excluded during title and abstract screening. A further 77 papers were excluded at full text screening. Full texts were excluded on the basis of (1) being a review paper (n = 2), (2) the paper did not include a measure of perseverative cognition which met inclusion criteria (n = 27), (3) the paper did not include a measure of sleep which met inclusion criteria (n = 1), (4) perseverative cognition and sleep were conflated (n = 4), (5) the population was a clinical sample and no non-clinical subset was analyzed (n = 33), (6) the statistical association between perseverative cognition and sleep was not reported (n = 5), (7) it was not possible to access the full-text (n = 4), (8) data from the same sample was analyzed in an earlier paper which already met inclusion criteria (n = 1). The 53 papers remaining met the inclusion criteria of the review and an additional 2 eligible papers were identified via hand-search. The final 55 papers comprised of data from 181,366 participants (see Table 1). Of these, 41 measured worry, 32 measured rumination and 29 measured non-specific perseverative cognition. See Table 1 for additional information regarding included studies.

[insert Figure 1]

[insert Table 1]

Sleep Quality

Fifty papers measured sleep quality. Higher combined perseverative cognition was associated with worse sleep quality, $k = 50$, $r = -.28$, $p < .001$, and there was a significant amount of heterogeneity amongst effect sizes, $Q = 661.67$, $p < .001$, $I^2 = 92.59$. These findings were similar across sensitivity analyses (see Table 2). In meta-analyses of the association between perseverative cognition categories and sleep quality, worry was associated with poorer sleep quality, $k = 23$, $r = -.23$, $p < .001$, as was rumination, $k = 23$, $r = -.33$, $p < .001$, and non-specific perseverative cognition, $k = 12$, $r = -.29$, $p < .001$. These findings were similar across sensitivity analyses (see Table 2 for a summary of the meta-analyses and the supplementary material (Figure S1) for a forest plot of these associations).

[insert Table 2]

The association between combined perseverative cognition and sleep quality was stronger in studies which: (1) employed multi-item, $k = 43$, $r = -.30$, *95% CI* = -.33 to -.26, $Z = 14.72$, $p < .001$, as opposed to single-item, $k = 7$, $r = -.14$, 95% *CI* = -.20 to -.08, $Z = 4.30$, $p < .001$, measures of perseverative cognition; (2) where sleep resulted from self-report, $k = 41$, $r = -.29$, 95% *CI* = -.32 to -.25, $Z = -15.66$, $p < .001$, as opposed to actigraphy measurement, $k = 9$, $r = -.18$, 95 *CI* = -.27 to -.08, $Z = -3.46$, $p = .001$. All other moderators were non-significant (see Table 3).

[insert Table 3]

Sleep Onset Latency

Sixteen studies included a measure of sleep onset latency. Higher combined perseverative cognition was associated with longer sleep onset latency, $k = 16$, $r = -.16$, $p < .001$, and there was a significant degree of heterogeneity in effect sizes, $Q = 37.75$, $p = .001$, $I^2 = 60.26$. Worry was associated with longer sleep onset latency, $k = 7$, $r = -.16$, $p < .001$, as was rumination, $k = 5$, $r = -.15$, $p = .001$, and non-specific perseverative cognition, $k = 8$, $r = -.21$, $p = .01$. These findings were similar across sensitivity analyses (see Table 2). See the supplementary material (Figure S2) for a forest plot of these associations.

Stronger associations between a combined measure of perseverative cognition and longer sleep onset latency were detected when studies: (1) included a lower percentage of female participants, $k = 16$, *Coefficient* = .004, $p = .002$; (2) incorporated fewer measures of perseverative cognition, $k = 15$, *Coefficient* = .003, $p < .001$; (3) incorporated reliable, $k = 10$, $r = -.18$, 95% *CI* = -.25 to -.11, $Z = -4.84$, $p < .001$, rather than non-reliable measures of perseverative cognition, $k = 6$, $r = -.09$, 95% *CI* = -.14 to -.05, $Z = -3.96$, $p < .001$; (4) employed multi-item, $k = 5$, $r = -.20$, 95% *CI* = -.23 to -.16, $Z = -10.50$, $p < .001$, compared to single-item measures of sleep, $k = 10$, $r = -.13$, 95% *CI* = -.22 to -.04, $Z = -2.78$, $p = .01$; (5) employed trait, $k = 6$, $r = -.20$, 95% *CI* = -.24 to -.16, $Z = -9.16$, $p < .001$, as opposed to state measures of perseverative cognition, $k = 8$, $r = -.13$, 95% *CI* = -.23 to -.02, $Z = -2.37$, $p = .02$; (6) were non-diary, $k = 9$, $r = -.19$, 95% *CI* = -.23 to -.15, $Z = -8.31$, $p < .001$, as opposed to diary studies, $k = 6$, $r = -.17$, 95% *CI* = -.31 to -.04, $Z = -2.46$, $p = .01$; (7) consisted of only cross-sectional outcomes, $k = 8$, $r = -.19$, 95% *CI* = -.23 to -.15, $Z = -9.45$, $p < .001$, as opposed to studies which included outcomes generated from non-cross-sectional study designs, $k = 7$, $r = -.15$, 95% *CI* = -.26 to -.03, $Z = -2.38$, $p = .02$. All other moderators were non-significant (see Table 3).

Total Sleep Time

Nineteen studies measured total sleep time. Higher combined perseverative cognition was associated with shorter total sleep time, $k = 19$, $r = -.15$, $p < .001$, and there was little heterogeneity in effect sizes, $Q = 25.92$, $p = .10$, $I^2 = 30.57$. These findings were similar across sensitivity analyses (see Table 2). Worry was associated with shorter total sleep time, $k = 11$, $r = -.14$, $p < .001$, as was rumination, $k = 4$, $r = -.17$, $p = .001$, and non-specific perseverative cognition, $k = 9$, $r = -.18$, $p < .001$. See the supplementary material (Figure S3) for a forest plot of these associations.

Stronger associations between a combined measure of perseverative cognition and shorter total sleep time were detected when studies consisted of only cross-sectional outcomes, $k = 9$, $r = -.19$, 95% $CI = -.22$ to $-.16$, $Z = -11.36$, $p < .001$, as opposed to studies which included outcomes generated from non-cross-sectional study designs, $k = 9$, $r = -.11$, 95% $CI = -.15$ to $-.07$, $Z = -5.71$, $p < .001$. There were no other significant moderators of the association between combined perseverative cognition and total sleep time (see Table 3).

Publication Bias

Egger's regression coefficient was significant for the association between combined perseverative cognition and sleep quality, which indicated potential publication bias, $t = 3.56$, $df = 48$, $p < .001$. To consider the potential impact of these missing studies, Duval and Tweedie's Trim and Fill analyses were conducted. These results suggested that no studies were missing from the right-side of the mean effect, but 1 study was missing from the left-side of the mean effect. After imputing these, the imputed point estimate, $r = -0.28$, 95% $CI = -0.31$ to -0.24, suggested that the association between combined perseverative cognition and sleep quality is almost identical when accounting for publication bias. Egger's regression coefficient was non-significant for the association between combined perseverative cognition

and sleep onset latency, $t = 0.57$, $df = 14$, $p = .58$, and combined perseverative cognition and total sleep time, $t = 0.53$, $df = 17$, $p = .30$, indicating an absence of publication bias in these meta-analyses.

Discussion

In this systematic review and meta-analysis, the aim was to assess the direction and magnitude of the association between perseverative cognition and sleep outcomes (sleep quality, sleep onset latency and total sleep time). The primary findings from this review were that there is a small-sized association between perseverative cognition and poorer quality sleep, shorter sleep duration and longer sleep onset latency. Regarding the association between different types of perseverative cognition and sleep outcomes, rumination had a small association with shorter sleep duration and longer sleep onset latency and a medium-sized association with poorer sleep quality. Worry had a small association with shorter sleep duration, longer sleep onset latency and poorer sleep quality. This was also evident in the associations between non-specific perseverative cognition and all sleep outcomes. All effect sizes were statistically significant, and, for all perseverative cognition types, the strongest associations were with sleep quality.

These findings are consistent with the Perseverative Cognition Hypothesis (Brosschot, Gerin, & Thayer, 2006) as poor sleep is associated with both perseverative cognition and ill-health (Irwin et al., 2016; Watson et al., 2015). The findings of this meta-analysis are commensurate with recent theorizing that disturbed sleep may act as a mediator in the relationship between perseverative cognition and ill-health in addition to other physiological (Ottaviani et al., 2016) and behavioral pathways (Clancy et al., 2016). Overall, all types of perseverative cognition appear to be significant predictors of poorer sleep in non-clinical populations. This is in comparison to the Clancy et al. (2016) review in which no relationship

between worry and health behaviors was found. Thus, perseverative cognition appears to have a stronger and more consistent association with sleep compared to other health behaviors. The strongest association in the Clancy et al. (2016) review was between rumination and health-risk behaviors and was small (r = .12) whereas the strongest association in this review, between rumination and sleep quality, was medium-sized (r = .33). However, this pattern of results is only suggestive as it is difficult to make comparisons across reviews, and especially as there were fewer studies, and behavior types were much more heterogenous in the Clancy et al. (2016) review.

Importantly, there were some notable moderators of the association between perseverative cognition and sleep. First, the type of sleep assessment was found to moderate the association between perseverative cognition and sleep, with a stronger association being found in studies measuring sleep quality via self-report as opposed to actigraphy. This may suggest that as perseverative cognition levels increase, so does a bias for perceiving and reporting poorer quality sleep. However, there was still a small significant association between perseverative cognition and poorer sleep quality measured via actigraphy, indicating a 'real' association with disturbed sleep. Omvik et al. (2007) explicitly compared the discrepancy between self-reported and actigraphy-measured sleep in high and low worriers and, across several sleep outcomes, only found a greater underestimation of sleep efficiency in the high worry group. Nevertheless, in this review, the effect size doubled for self-reported sleep, indicating a substantial negative reporting bias.

The type of perseverative cognition assessment also significantly moderated the association between perseverative cognition and longer sleep onset latency, and these associations were stronger in studies measuring trait, as opposed to state perseverative cognition. This suggests that it is the overall tendency to engage in perseverative cognition rather than discrete instances of negative repetitive thinking that are more likely to influence

longer sleep onset latency. However, state perseverative cognition measurements were more varied and less likely to be validated than trait measurements which could partially explain the smaller effect size. This is reflected by the fact that, in instances where study quality outcomes moderated the association between perseverative cognition and sleep, effect sizes were larger where studies were of a higher quality (e.g. employing multi-item measures which were reliable and valid) which allows for more confidence in the findings.

On the other hand, study design moderated the association between perseverative cognition and sleep onset latency and total sleep time such that these associations were stronger in studies with only cross-sectional outcomes. In addition, as the number of perseverative cognition measurements increased, there was a weaker association between perseverative cognition and sleep onset latency, all suggesting that perseverative cognition is less predictive of sleep onset latency and sleep duration over time. Furthermore, diary study status moderated the association between perseverative cognition and longer sleep onset latency such that this association was stronger in non-diary studies. This perhaps also indicates that this association is weaker when these variables are measured at a state/daily level. It is suggested that future studies incorporate daily longitudinal measurements to investigate these associations in more detail.

There was a moderating effect of gender such that being female appears to act as a protective factor between perseverative cognition and longer sleep onset latency. It is first important to acknowledge that it was not possible to analyze male and female samples separately and therefore the percentage of female participants in the sample was used as a proxy for gender. As such, any conclusions drawn on this basis are only tentative. The findings may reflect evidence that although women report more sleep-related complaints, their overall sleep quality has been found to be better, including shorter sleep onset latency (Krishnan & Collop, 2006). One possible explanation for this may be that women employ

more effective coping strategies to ameliorate the impact of perseverative cognition on their sleep. Therefore, studies which experimentally compare levels of perseverative cognition and subsequent sleep outcomes in males and females would be a useful avenue for future research, particularly if women are shown to develop coping strategies which could inform sleep interventions. Nevertheless, it is worth noting that there were considerably more significant moderators of the association between perseverative cognition and sleep onset latency which may indicate that this relationship is less robust than associations between perseverative cognition and sleep quality and total sleep time. However, it could also reflect the small number of studies reporting sleep onset latency outcomes, or greater heterogeneity between studies.

Directions for Future Research

Overall, few of the proposed moderators influenced the associations between perseverative cognition and sleep and effect sizes remained stable across sensitivity analyses, suggesting that these associations are relatively robust. The strength and consistency of these findings makes perseverative cognition a good candidate for interventions which aim to improve sleep. Existing literature points to some potentially effective interventions. Systematic review evidence suggests that, in patient samples, mindfulness-based stress reduction (MBSR) techniques are associated with better sleep by reducing worry (Winbush, Gross, & Kreitzer, 2007). Further empirical work included in this review suggests that MBSR interventions can be delivered online for periods as short as 4 weeks to improve sleep quality by reducing rumination (Querstret et al., 2017). Also, a self-compassion intervention has recently been found to improve sleep quality via reduced rumination (Butz & Stahlberg, 2018). Nonetheless, the evidence to date is limited which makes it difficult to draw firm conclusions regarding the efficacy of particular interventions. It is recommended that future

research tests the effectiveness of interventions aimed at improving sleep outcomes through a reduction in perseverative cognition.

The causal direction of the relationship between perseverative cognition and sleep is unknown from this review as most studies were correlational and in nearly all studies which investigated the direction of this relationship, the effect of perseverative cognition on sleep was measured rather than the effect of sleep on perseverative cognition. Unfortunately, too few studies tested the latter for this to be analyzed. This may be important as a recent meta-analysis has found that sleep disturbance was associated with an increased relative risk of suicidal ideation (Pigeon, Pinquart, & Conner, 2012), providing some evidence that poor sleep can lead to negative thought patterns. As such, it is possible that rather than perseverative cognition being a precursor to poor sleep, poor sleep may be a precursor to increased perseverative cognition or the two may interact in a damaging, bi-directional cycle. Daily diary studies would be valuable in investigating this as they would allow for measuring the impact of last night's sleep on the following day's thought patterns and that day's thought patterns on that night's sleep. Likewise, there were too few experimental studies to directly assess the causal association between perseverative cognition and sleep and therefore it is suggested that future studies address this.

The authors of this review acknowledge that, as the review was limited to English language papers, some relevant studies may have been missed. Likewise, only published studies were reviewed which could have led to an over-estimation of the effect sizes due to publication bias. The decision to exclude unpublished studies was based on two arguments. First, we were concerned that, in the absence of peer review, the quality of the reporting of key moderators may be insufficient for reliable coding. Second, we were concerned that there may be differences between the unpublished data that authors were willing to share, and that data which authors were not willing to share, and this would result in a different type of

systematic bias. Furthermore, analyses revealed no major issues with publication bias, such that we found that there was no indication of publication bias for meta-analyses of total sleep time and sleep onset latency and only one study was missing from sleep quality. Moreover, the association between combined perseverative cognition and sleep quality was almost identical when accounting for publication bias.

Conclusions

In summary, the current findings are important as they are consistent with the Perseverative Cognition Hypothesis and provide tentative evidence for an additional explanatory pathway between perseverative cognition and adverse health outcomes via sleep disturbance. Specifically, perseverative cognition was found to be associated with worse overall sleep i.e. shorter sleep duration, longer sleep onset latency and poorer quality sleep. As poor sleep is associated with numerous adverse health outcomes, interventions which improve sleep are important and this review provides evidence that targeting perseverative cognition may prove effective in improving sleep. It is suggested that future research ascertains whether the association between perseverative cognition and sleep is causal and whether there is a bi-directional association between perseverative cognition and sleep.

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References

*Åkerstedt, T., Knutsson, A., Westerholm, P., Theorell, T., Alfredsson, L., & Kecklund, G. (2002). Sleep disturbances, work stress and work hours: A cross-sectional study. *Journal of Psychosomatic Research, 53*(3), 741-748.

*Åkerstedt, T., Nordin, M., Alfredsson, L., Westerholm, P., & Kecklund, G. (2012). Predicting changes in sleep complaints from baseline values and changes in work demands, work control, and work preoccupation - the WOLF-project. *Sleep Medicine, 13*(1), 73-80.

Alvaro, P. K., Roberts, R. M., & Harris, J. K. (2013). A systematic review assessing bidirectionality between sleep disturbances, anxiety, and depression. *Sleep, 36*(7), 1059-1068.

*Annunziata, M. A., Muzzatti, B., Flaiban, C., Giovannini, L., & Carlucci, M. (2016). Mood states in long-term cancer survivors: An italian descriptive survey. *Supportive Care in Cancer, 24*(7), 3157-3164.

*Bagley, E. J., Kelly, R. J., Buckhalt, J. A., & El-Sheikh, M. (2015). What keeps low-ses children from sleeping well: The role of presleep worries and sleep environment. *Sleep Medicine, 16*(4), 496-502.

*Baker, L. D., Baldwin, D. S., & Garner, M. (2015). Daytime intrusive thoughts and subjective insomnia symptoms. *Psychiatry Research, 229*(3), 1038-1042.

*Barclay, N. L., & Gregory, A. M. (2010). The presence of a perseverative iterative style in poor vs. Good sleepers. *Journal of Behavior Change Therapy and Experimental Psychiatry, 41*(1), 18-23.

Bonnet, M. H., & Arand, D. L. (2003). Situational insomnia: Consistency, predictors, and outcomes. *Sleep, 26*(8), 1029-1036.

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2011). *Introduction to meta-analysis*: John Wiley & Sons.

Borenstein, M., Rothstein, D., & Cohen, J. (2005). Comprehensive meta-analysis: A computer program for research synthesis [computer software]. *Englewood, NJ: Biostat*.

Brosschot, J. F., Gerin, W., & Thayer, J. F. (2006). The perseverative cognition hypothesis: A review of worry, prolonged stress-related physiological activation, and health. *Journal of Psychosomatic Research, 60*(2), 113-124.

Butz, S., & Stahlberg, D. (2018). Can self-compassion improve sleep quality via reduced rumination? *Self and Identity, 17*(6), 666-686.

Buysse, D. J., Reynolds III, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Research, 28*(2), 193-213.

*Carciofo, R., Song, N., Du, F., Wang, M. M., & Zhang, K. (2017). Metacognitive beliefs mediate the relationship between mind wandering and negative affect. *Personality and Individual Differences, 107*, 78-87.

*Carney, C. E., Edinger, J. D., Meyer, B., Lindman, L., & Istre, T. (2006). Symptom-focused rumination and sleep disturbance. *Behavioral Sleep Medicine, 4*(4), 228-241.

Clancy, F., Prestwich, A., Caperon, L., & O'Connor, D. B. (2016). Perseverative cognition and health behaviors: A systematic review and meta-analysis. *Frontiers in Human Neuroscience, 10.*

*Cox, R. C., Ebesutani, C., & Olatunji, B. O. (2016). Linking sleep disturbance and maladaptive repetitive thought: The role of executive function. *Cognitive Therapy and Research, 40*(1), 107-117.

*Cropley, M., Dijk, D. J., & Stanley, N. (2006). Job strain, work rumination, and sleep in school teachers. *European Journal of Work and Organizational Psychology, 15*(2), 181-196.

*Cropley, M., Rydstedt, L. W., Devereux, J. J., & Middleton, B. (2015). The relationship between work-related rumination and evening and morning salivary cortisol secretion. *Stress and Health, 31*(2), 150-157.

Davidson, J. R., MacLean, A. W., Brundage, M. D., & Schulze, K. (2002). Sleep disturbance in cancer patients. *Social Science & Medicine, 54*(9), 1309-1321.

*Doos Ali Vand, H., Gharraee, B., Farid, A. A., & Bandi, M. G. (2014). Prediction of insomnia severity based on cognitive, metacognitive, and emotional variables in college students. *EXPLORE: The Journal of Science and Healing, 10*(4), 233-240.

Duval, S., & Tweedie, R. (2000). Trim and fill: A simple funnel plot–based method of testing and adjusting for publication bias in meta-analysis. *Biometrics, 56*(2), 455-463.

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ, 315*(7109), 629-634.

*Fichten, C. S., Libman, E., Creti, L., Amsel, R., Sabourin, S., Brender, W., & Bailes, S. (2001). Role of thoughts during nocturnal awake times in the insomnia experience of older adults. *Cognitive Therapy and Research, 25*(6), 665-692.

Ford, E. S., Cunningham, T. J., & Croft, J. B. (2015). Trends in self-reported sleep duration among US adults from 1985 to 2012. *Sleep, 38*(5), 829-832.

Goodwin, L. D., & Leech, N. L. (2006). Understanding correlation: Factors that affect the size of r. *The Journal of Experimental Education, 74(3),* 249-266.

*Hairston, I. S., & Shpitalni, R. (2016). Procrastination is linked with insomnia symptoms: The moderating role of morningness-eveningness. *Personality and Individual Differences, 101*, 50-56.

Hall, M., Thayer, J. F., Germain, A., Moul, D., Vasko, R., Puhl, M., . . . Buysse, D. J. (2007). Psychological stress is associated with heightened physiological arousal during nrem sleep in primary insomnia. *Behavioral Sleep Medicine, 5*(3), 178-193.

*Hartz, A., Ross, J. J., Noyes, R., & Williams, P. (2013). Somatic symptoms and psychological characteristics associated with insomnia in postmenopausal women. *Sleep Medicine, 14*(1), 71-78.

*Harvey, A.G., Gregory, A. M., & Bird, C. (2002). The role of cognitive processes in sleep disturbance: A comparison of japanese and english university students. *Behavioural and Cognitive Psychotherapy, 30*(3), 259-270.

Harvey, A. G., Tang, N. K., & Browning, L. (2005). Cognitive approaches to insomnia. *Clinical Psychology Review, 25*(5), 593-611.

Harvey, A. G. (2002). A cognitive model of insomnia. *Behaviour Research and Therapy, 40*(8), 869-893.

Harvey, A. G., & Tang, N. K. Y. (2012). (Mis) perception of sleep in insomnia: A puzzle and a resolution. *Psychological Bulletin, 138*(1), 77-101.

Harvey, K. J., & Espie, C. A. (2004). Development and preliminary validation of the Glasgow content of thoughts inventory (GCTI): A new measure for the assessment of pre-sleep cognitive activity. *British Journal of Clinical Psychology, 43*(4), 409-420.

Higgins, J. P., & Green, S. (2008). Cochrane handbook for systematic reviews of interventions.

Hiller, R. M., Johnston, A., Dohnt, H., Lovato, N., & Gradisar, M. (2015). Assessing cognitive processes related to insomnia: A review and measurement guide for Harvey's cognitive model for the maintenance of insomnia. *Sleep Medicine Reviews, 23*, 46-53.

Hu, R. F., Jiang, X. Y., Chen, J., Zeng, Z., Chen, X. Y., Li, Y., ... & Evans, D. J. (2015). Non‐pharmacological interventions for sleep promotion in the intensive care unit. *Cochrane Database of Systematic Reviews, (10).*

*Huhtala, M., Kinnunen, U., & Feldt, T. (2017). School psychologists' ethical strain and rumination: Individual profiles and their associations with weekly well-being. *Psychology in the Schools, 54*(2), 127-141.

Irwin, M. R., Olmstead, R., & Carroll, J. E. (2016). Sleep disturbance, sleep duration, and inflammation: A systematic review and meta-analysis of cohort studies and experimental sleep deprivation. *Biological Psychiatry, 80*(1), 40-52.

*Jean-Louis, G., Magai, C., Consedine, N., Zizi, F., Casimir, G. J., Solomon, W., & Brown, C. D. (2009). Cancer worry and insomnia complaints among american women. *Behavioral Sleep Medicine, 7*(2), 63-72.

Johnson, D. P., & Whisman, M. A. (2013). Gender differences in rumination: A meta-analysis. *Personality and Individual Differences, 55*(4), 367-374.

*Joormann, J., & Stöber, J. (1999). Somatic symptoms of generalized anxiety disorder from the dsm-iv: Associations with pathological worry and depression symptoms in a nonclinical sample. *Journal of Anxiety Disorders, 13*(5), 491-503.

*Kelly, W. E. (2002). Worry and sleep length revisited: Worry, sleep length, and sleep disturbance ascribed to worry. *The Journal of Genetic Psychology, 163*(3), 296-304.

*Kocoglu, D., Akin, B., Cingil, D., & Sari, E. (2013). Insomnia in rural communities and dysfunctional beliefs and attitudes about sleep as a risk factor of insomnia. *Journal of Cognitive & Behavioral Psychotherapies, 13,* 211-225.

*Kompier, M. A., Taris, T. W., & van Veldhoven, M. (2012). Tossing and turning--insomnia in relation to occupational stress, rumination, fatigue, and well-being. *Scandinavian Journal of Work, Environment & Health, 38*(3), 238-246.

Krishnan, V., & Collop, N. A. (2006). Gender differences in sleep disorders. *Current Opinion in Pulmonary Medicine, 12*(6), 383-389.

*LaBrash, L. F., Pahwa, P., Pickett, W., Hagel, L. M., Snodgrass, P. R., & Dosman, J. A. (2008). Relationship between sleep loss and economic worry among farmers: A survery of 94 active Saskatchewan noncorporate farms. *Journal of Agromedicine, 13*(3), 149-154.

Lauderdale, D. S., Knutson, K. L., Yan, L. L., Liu, K., & Rathouz, P. J. (2008). Sleep duration: How well do self-reports reflect objective measures? The cardia sleep study. *Epidemiology, 19*(6), 838-845.

*Lin, R.-M., Xie, S.-S., Yan, Y.-W., & Yan, W.-J. (2017). Intolerance of uncertainty and adolescent sleep quality: The mediating role of worry. *Personality and Individual Differences, 108*, 168-173.

*Liu, Q-Q., Zhou, Z.-K., Yang, X.-J., Kong, F.-C., Niu, G.-F., & Fan, C.-Y. (2017). Mobile phone addiction and sleep quality among chinese adolescents: A moderated mediation model. *Computers in Human Behavior, 72*, 108-114.

*Loft, M., & Cameron, L. (2014). The importance of sleep: Relationships between sleep quality and work demands, the prioritization of sleep and pre-sleep arousal in day-time employees. *Work & Stress, 28*(3), 289-304.

*MacNeil, S., Deschenes, S. S., Caldwell, W., Brouillard, M., Dang-Vu, T. T., & Gouin, J. P. (2017). High-frequency heart rate variability reactivity and trait worry interact to predict the development of sleep disturbances in response to a naturalistic stressor. *Annals of Behavioral Medicine, 51*(6), 912-924.

McCormick, B. W., Reeves, C. J., Downes, P. E., Li, N., & Ilies, R. (2018). Scientific Contributions of Within-Person Research in Management: Making the Juice Worth the Squeeze. *Journal of Management.* https://doi.org/10.1177/0149206318788435

*McGowan, S. K., Behar, E., & Luhmann, M. (2016). Examining the relationship between worry and sleep: A daily process approach. *Behavior Therapy, 47*(4), 460-473.

*Mitchell, L., Mogg, K., & Bradley, B. P. (2012). Relationships between insomnia, negative emotionality and attention control. *Sleep and Biological Rhythms, 10*(3), 237-243.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The prisma statement. *PLoS Medicine, 6*(7).

Nicassio, P. M., Mendlowitz, D. R., Fussell, J. J., & Petras, L. (1985). The phenomenology of the pre-sleep state: The development of the pre-sleep arousal scale. *Behaviour Research and Therapy, 23*(3), 263-271.

Nolen-Hoeksema, S., Larson, J., & Grayson, C. (1999). Explaining the gender difference in depressive symptoms. *Journal of Personality and Social Psychology, 77*(5), 1061-1072.

Nolen-Hoeksema, S. (2000). The role of rumination in depressive disorders and mixed anxiety/depressive symptoms. *Journal of Abnormal Psychology, 109*(3), 504-511.

*Nota, J. A., & Coles, M. (2015). Duration and timing of sleep are associated with repetitive negative thinking. *Cognitive Therapy and Research, 39*(2), 253-261.

*Nota, J. A., Schubert, J. R., & Coles, M. E. (2016). Sleep disruption is related to poor response inhibition in individuals with obsessive-compulsive and repetitive negative thought symptoms. *Journal of Behavior Therapy and Experimental Psychiatry, 50*, 23-32.

O'Connor, D. B., Armitage, C. J., & Ferguson, E. (2014). Randomized test of an implementation intention-based tool to reduce stress-induced eating. *Annals of Behavioral Medicine, 49*(3), 331-343.

Ohayon, M. M. (2005). Prevalence and correlates of nonrestorative sleep complaints. *Archives of Internal Medicine, 165*(1), 35-41.

Ohayon, M. M., Carskadon, M. A., Guilleminault, C., & Vitiello, M. V. (2004). Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: Developing normative sleep values across the human lifespan. *Sleep, 27*(7), 1255-1273.

*Omvik, S., Pallesen, S., Bjorvatn, B., Thayer, J., & Nordhus, I. H. (2007). Night-time thoughts in high and low worriers: Reaction to caffeine-induced sleeplessness. *Behaviour Research and Therapy, 45*(4), 715-727.

Ottaviani, C., Thayer, J. F., Verkuil, B., Lonigro, A., Medea, B., Couyoumdjian, A., & Brosschot, J. F. (2016). Physiological concomitants of perseverative cognition: A systematic review and meta-analysis. *Psychological Bulletin, 142*(3), 231-259.

Pigeon, W. R., Pinquart, M., & Conner, K. (2012). Meta-analysis of sleep disturbance and suicidal thoughts and behaviors. *The Journal of Clinical Psychiatry, 73(9),* e1160-e1167.

*Querstret, D., & Cropley, M. (2012). Exploring the relationship between work-related rumination, sleep quality, and work-related fatigue. *Journal of Occupational Health Psychology, 17*(3), 341.

*Querstret, D., Cropley, M., & Fife-Schaw, C. (2017). Internet-based instructor-led mindfulness for work-related rumination, fatigue, and sleep: Assessing facets of mindfulness as mechanisms of change. A randomized waitlist control trial. *Journal of Occupational Health Psychology, 22*(2), 153-169.

*Querstret, D., Cropley, M., Kruger, P., & Heron, R. (2015). Assessing the effect of a cognitive behaviour therapy (CBT)-based workshop on work-related rumination, fatigue, and sleep. *European Journal of Work and Organizational Psychology, 25*(1), 50-67.

*Radstaak, M., Geurts, S. A., Beckers, D. G., Brosschot, J. F., & Kompier, M. A. (2014). Work stressors, perseverative cognition and objective sleep quality: A longitudinal study among dutch helicopter emergency medical service (HEMS) pilots. *Journal of Occupational Health, 56*(6), 469-477.

Resnick, H. E., Redline, S., Shahar, E., Gilpin, A., Newman, A., Walter, R., . . . Punjabi, N. M. (2003). Diabetes and sleep disturbances: Findings from the sleep heart health study. *Diabetes Care, 26*(3), 702-709.

Robichaud, M., Dugas, M. J., & Conway, M. (2003). Gender differences in worry and associated cognitive-behavioral variables. *Journal of Anxiety Disorders, 17*(5), 501-516.

*Rodríguez-Muñoz, A., Notelaers, G., & Moreno-Jiménez, B. (2011). Workplace bullying and sleep quality: The mediating role of worry and need for recovery. *Psicologia Conductual, 19*(2), 453-469.

Scammacca, N., Roberts, G., & Stuebing, K. K. (2014). Meta-analysis with complex research designs: Dealing with dependence from multiple measures and multiple group comparisons. *Review of Educational Research, 84*(3), 328-364.

*Schmidt, R. E., Renaud, O., & van der Linden, M. (2011). Nocturnal regrets and insomnia in elderly people. *International Journal of Aging and Human Development, 73*(4), 371-393.

*Slavish, D. C., & Graham-Engeland, J. E. (2015). Rumination mediates the relationships between depressed mood and both sleep quality and self-reported health in young adults. *Journal of Behavioral Medicine, 38*(2), 204-213.

Sonnentag, S., & Fritz, C. (2015). Recovery from job stress: The stressor-detachment model as an integrative framework. *Journal of Organizational Behavior, 36(S1)*, S72–S103. https://doi.org/10.1002/job.1924

*Stoia-Caraballo, R., Rye, M. S., Pan, W., Brown Kirschman, K. J., Lutz-Zois, C., & Lyons, A. M. (2008). Negative affect and anger rumination as mediators between forgiveness and sleep quality. *Journal of Behavioral Medicine, 31*(6), 478-488.

*Syrek, C. J., & Antoni, C. H. (2014). Unfinished tasks foster rumination and impair sleeping - particularly if leaders have high performance expectations. *Journal of Occupational Health Psychology, 19*(4), 490-499.

*Syrek, C. J., Weigelt, O., Peifer, C., & Antoni, C. H. (2017). Zeigarnik's sleepless nights: How unfinished tasks at the end of the week impair employee sleep on the weekend through rumination. *Journal of Occupational Health Psychology, 22*(2), 225-238.

*Takano, K., Iijima, Y., & Tanno, Y. (2012). Repetitive thought and self-reported sleep disturbance. *Behavior Therapy, 43*(4), 779-789.

*Takano, K., Sakamoto, S., & Tanno, Y. (2014). Repetitive thought impairs sleep quality: An experience sampling study. *Behavior Therapy, 45*(1), 67-82.

*Tang, N. K., & Harvey, A. G. (2004). Effects of cognitive arousal and physiological arousal on sleep perception. *Sleep, 27*(1), 69-78.

*Thomsen, D. K., Yung Mehlsen, M., Christensen, S., & Zachariae, R. (2003). Rumination - relationship with negative mood and sleep quality. *Personality and Individual Differences, 34*(7), 1293-1301.

UK Sleep Council. (2017). The Great British Bedtime Report.

*Vahle-Hinz, T., Bamberg, E., Dettmers, J., Friedrich, N., & Keller, M. (2014). Effects of work stress on work-related rumination, restful sleep, and nocturnal heart rate variability experienced on workdays and weekends. *Journal of Occupational Health Psychology, 19*(2), 217-230.

*Van Laethem, M., Beckers, D. G., Kompier, M. A., Kecklund, G., van den Bossche, S. N., & Geurts, S. A. (2015). Bidirectional relations between work-related stress, sleep quality and perseverative cognition. *Journal of Psychosomatic Research, 79*(5), 391-398.

*Van Laethem, M., Beckers, D. G., van Hooff, M. L., Dijksterhuis, A., & Geurts, S. A. (2016). Day-to-day relations between stress and sleep and the mediating role of perseverative cognition. *Sleep Medicine, 24*, 71-79.

Verkuil, B., Brosschot, J. F., & Thayer, J. F. (2007). A sensitive body or a sensitive mind? Associations among somatic sensitization, cognitive sensitization, health worry, and subjective health complaints. *Journal of Psychosomatic Research, 63*(6), 673-681.

Watkins, E., Moulds, M., Mackintosh, B. (2005). Comparisons between rumination and worry in a non-clinical population. *Behaviour Research and Therapy, 43*(12), 1577-1585.

Watson, N. F., Badr, M. S., Belenky, G., Bliwise, D. L., Buxton, O. M., Buysse, D., . . . Tasali, E. (2015). Joint consensus statement of the american academy of sleep medicine and sleep research society on the recommended amount of sleep for a healthy adult: Methodology and discussion. *Sleep, 38*(8), 1161-1183.

*Weise, S., Ong, J., Tesler, N. A., Kim, S., & Roth, W. T. (2013). Worried sleep: 24-h monitoring in high and low worriers. *Biological Psychology, 94*(1), 61-70.

Wendsche, J., & Lohmann-Haislah, A. (2017). A meta-analysis on antecedents and outcomes of detachment from work. *Frontiers in Psychology, 7.*

*Wicklow, A., & Espie, C. (2000). Intrusive thoughts and their relationship to actigraphic measurement of sleep: Towards a cognitive model of insomnia. *Behaviour Research and Therapy, 38*(7), 679-693.

Winbush, N. Y., Gross, C. R., & Kreitzer, M. J. (2007). The effects of mindfulness-based stress reduction on sleep disturbance: A systematic review. *EXPLORE: The Journal of Science and Healing, 3*(6), 585-591.

*Yan, Y., Lin, R., Tang, X., He, F., Cai, W., & Su, Y. (2014). The relationship between worry tendency and sleep quality in Chinese adolescents and young adults: The mediating role of state-trait anxiety. *Journal of Health Psychology, 19*(6), 778-788.

*Yeh, Z.-T., Wung, S.-K., & Lin, C.-M. (2015). Pre-sleep arousal as a mediator of relationships among worry, rumination, and sleep quality. *International Journal of Cognitive Therapy, 8*(1), 21-34.

*Zawadzki, M. J., Graham, J. E., & Gerin, W. (2013). Rumination and anxiety mediate the effect of loneliness on depressed mood and sleep quality in college students. *Health Psychology, 32*(2), 212.

Zlomke, K. R., & Hahn, K. S. (2010). Cognitive emotion regulation strategies: Gender differences and associations to worry. *Personality and Individual Differences, 48*(4), 408-413.

*Zoccola, P. M., Dickerson, S. S., & Lam, S. (2009). Rumination predicts longer sleep onset latency after an acute psychosocial stressor. *Psychosomatic Medicine, 71*(7), 771-775.

Table 1. Summary of Included Studies

Authors, Year	**Design**	**Perseverative Cognition Reported in Paper**	**Perseverative Cognition Category**	**Perseverative Cognition (State or Trait)**	**Sleep Outcome**	**Measure of Sleep**	**%Female**	**Age of Participants (range in years)[a]**	**Sample Size (n = 181,366)**
Åkerstedt et al. (2002)	Cross-Sectional	Work Preoccupation	Perseverative Cognition	Trait	Sleep Quality	Self-Report	43%	Adults (18-45+)	5231
Åkerstedt et al. (2012)	Longitudinal	Work Preoccupation	Perseverative Cognition	Trait	Sleep Quality	Self-Report	17%	Adults (median = 42.0)	3637
Annunziata et al. (2016)	Cross-Sectional	Health Worry	Worry	Trait	Sleep Quality	Self-Report	58%	Adults and Older Adults (28-75)	112
Bagley et al. (2015)	Diary (between-person)	Pre-Sleep Worry	Worry	State	Sleep Quality	Actigraphy and Self-Report	47%	Children (10-12)	271
Baker, Baldwin,	Cross-Sectional	Intrusive Thoughts	Worry	State	Sleep Quality, SOL and TST	Self-Report	82%	Adults (mean = 20.7)	109

and Garner (2015)									
Barclay and Gregory (2010)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality	Self-Report	73%	Adults and Older Adults (20-76)	60
Carciofo, Song, Du, Wang, and Zhang (2017)	Cross-Sectional and Longitudinal	Uncontrollable Thoughts and Associated Danger	Worry	Trait	Sleep Quality, SOL and TST	Self-Report	68%	Adults (18-28)	370
Carney, Edinger, Meyer, Lindman, and Istre (2006)	Cross-Sectional	Self- and Symptom-Focused Rumination	Rumination	Trait	Sleep Quality	Self-Report	87%	Adults (18-39)	243
Cox,	Cross-	Rumination and	Rumination	Trait	Sleep Quality	Self-Report	82%	Adults[b]	341

Ebesutani, and Olatunji (2016)	Sectional	Worry	and Worry					(18-66, mean = 33.56)	
Cropley et al. (2006)	Diary (between-person)	Work Rumination	Rumination	State	Sleep Quality and TST	Self-Report	87%	Adults (21-59)	98
Cropley et al. (2015)	Diary (between-person)	Work Rumination	Rumination	State	Sleep Quality	Self-Report	83%	Adults (21-61)	108
Doos Ali Vand et al. (2014)	Cross-Sectional	Pre-Sleep Cognitive Arousal and Worry	Perseverative Cognition and Worry	Trait	Sleep Quality	Self-Report	59%	Adults (20-46)	400
Fichten et al. (2001)	Cross-Sectional	Pre-Sleep Cognitive Arousal and Worry	Perseverative Cognition and Worry	Trait	Sleep Quality and TST	Self-Report	69%	Adults and Older Adults (55-89)	220

Hairston and Shpitalni (2016)	Cross-Sectional	Rumination	Rumination	Trait	Sleep Quality	Self-Report	74%	Adults (18-37)	598
Hartz et al. (2013)	Cross-Sectional	Worry about Expressing Anger	Worry	Trait	Sleep Quality	Self-Report	100%	Adults and Older Adults (49-81)	148,938
Harvey, Gregory, and Bird (2002)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality	Self-Report	62%	Adults (mean ranges from 18-21)	120
Huhtala, Kinnunen, and Feldt (2017)	Longitudinal	Rumination and Dilemma Rumination	Rumination	Trait	Sleep Quality	Self-Report	95%	Adults (25-64)	133
Jean-Louis et al. (2009)	Cross-Sectional	Breast Cancer Worry	Worry	State	Sleep Quality	Self-Report	100%	Adults and Older Adults (50-70)	1038

Joormann and Stöber (1999)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality	Self-Report	75%	Adults (mean = 25.7)	183
Kelly (2002)	Cross-Sectional	Worry	Worry	Trait	TST	Self-Report	69%	Adults (18-65)	222
Kocoglu et al. (2013)	Cross-Sectional	Worry about Insomnia	Worry	Trait	Sleep Quality	Self-Report	60%	Adults (18-65)	523
Kompier, Taris, and van Veldhoven (2012)	Cross-Sectional	Work Rumination	Rumination	Trait	Sleep Quality	Self-Report	48%	Adults (mean = 38.9)	5210
LaBrash et al. (2008)	Cross-Sectional	Financial Worry	Worry	State	TST	Self-Report	40%	Adults (16+)	195
Lin et al. (2017)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality, SOL and TST	Self-Report	52%	Adolescents (11-18)	2286

Liu et al. (2017)	Cross-Sectional	Rumination	Rumination	Trait	Sleep Quality	Self-Report	47%	Adolescents and Adults (14-20)	1196
Loft and Cameron (2014)	Cross-Sectional	Pre-Sleep Cognitive Arousal	Perseverative Cognition	Trait	Sleep Quality	Self-Report	66%	Adults (21-65)	73
MacNeil et al. (2017)	Cross-Sectional and Longitudinal	Worry	Worry	Trait	Sleep Quality	Self-Report	78%	Adults (mean = 21.0)	102
McGowan et al. (2016)	Diary (within-person)	Pre-Sleep Worry	Worry	State	Sleep Quality, SOL and TST	Self-Report	82%	Adults (mean = 19.72)	50
Mitchell, Mogg, and Bradley (2012)	Cross-Sectional	Rumination and Worry	Rumination and Worry	Trait	Sleep Quality	Self-Report	88%	Adults (mean = 19.9)	196
Nota and	Cross-	Perseverative	Perseverative	Trait	SOL and TST	Self-Report	58%	Adults[b]	100

Coles (2015)	Sectional	Thinking, Brooding and Worry	Cognition, Rumination and Worry					(17-33)	
Nota, Schubert, and Coles (2016)	Cross-Sectional	Perseverative Thinking	Perseverative Cognition	Trait	TST	Self-Report	69%	Adults (mean = 19.5)	67
Omvik, Pallesen, Bjorvatn, Thayer, and Nordhus (2007)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality, SOL and TST	Actigraphy and Self-Report	100%	Adults (mean = 21.2)	96
Querstret and Cropley (2012)	Cross-Sectional	Work Rumination	Rumination	Trait	Sleep Quality	Self-Report	49%	Adults and Older Adults (19-69)	719

Querstret, Cropley, Kruger, and Heron (2015)	Cross-Sectional, Longitudinal and Experimental	Work Rumination	Rumination	State	Sleep Quality	Self-Report	63%	Adults[b] (22-66)	227
Querstret, Cropley and Fife-Schaw (2017)	Cross-Sectional and Experimental	Work Rumination	Rumination	State	Sleep Quality	Self-Report	81%	Adults (21-62)	118
Radstaak, Geurts, Beckers, Brosschot, and Kompier (2014)	Diary (between-person)	Perseverative Cognition about Work	Perseverative Cognition	State	Sleep Quality, SOL and TST	Actigraphy and Self-Report	4%	Adults (mean = 44.1)	23
Rodríguez-	Cross-	Work Worry	Worry	Trait	Sleep Quality	Self-Report	44%	Adults	4068

Muñoz et al. (2011)	Sectional							(19-64)	
Schmidt et al. (2011)	Cross-Sectional	Rumination and Worry	Rumination and Worry	Trait	Sleep Quality	Self-Report	70%	Adults and Older Adults (51-98)	81
Slavish and Graham-Engeland (2015)	Cross-Sectional	Rumination	Rumination	Trait	Sleep Quality	Self-Report	64%	Adults (mean = 20.38)	165
Stoia-Caraballo et al. (2008)	Cross-Sectional	Anger Rumination	Rumination	Trait	Sleep Quality and SOL	Self-Report	55%	Adults (18-23)	277
Syrek and Antoni (2014)	Diary (within- and between-person)	Rumination	Rumination	State	Sleep Quality	Self-Report	26%	Adults[b] (17-46)	89
Syrek, Weigelt,	Diary (within- and between	Affective Rumination	Rumination	State	Sleep Quality	Self-Report	67%	Adults (21-59)	59

Peifer, and Antoni (2017)	person)								
Takano, Iijima, and Tanno (2012)	Cross-Sectional and Longitudinal	Rumination and Worry	Rumination and Worry	Trait	Sleep Quality	Self-Report	25%	Adults (mean = 19.0)	208
Takano, Sakamoto, and Tanno (2014)	Diary (within-person)	Repetitive Thought	Perseverative Cognition	State	Sleep Quality, SOL and TST	Actigraphy	78%	Adults (mean = 19.4)	43
Tang and Harvey (2004)	Experimental	Pre-Sleep Cognitive Activity	Perseverative Cognition	State	SOL and TST	Actigraphy and Self-Report	53%	Adults (18-40)	36
Thomsen, Yung Mehlsen,	Cross-Sectional	Rumination	Rumination	Trait	Sleep Quality	Self-Report	60%	Adults (19-40)	118

Christensen, and Zachariae (2003)									
Vahle-Hinz, Bamberg, Dettmers, Friedrich, and Keller (2014)	Diary (between-person)	Rumination	Rumination	State	Sleep Quality	Self-Report	4%	Adults (mean = 42.0)	50
Van Laethem et al. (2015)	Cross-Sectional and Longitudinal	Perseverative Cognition	Perseverative Cognition	Trait	Sleep Quality	Actigraphy and Self-Report	36%	Adults[b] (23-66)	877
Van Laethem, Beckers, van Hooff,	Diary (within- and between-person)	Perseverative Cognition	Perseverative Cognition	State	Sleep Quality, SOL and TST	Actigraphy and Self-Report	80%	Adults (mean = 35.0)	44

Dijksterhuis, and Geurts (2016)									
Weise, Ong, Tesler, Kim, and Roth (2013)	Diary (within- and between-person)	Pre-Sleep Worry and Worry	Worry	Both	Sleep Quality, SOL and TST	Actigraphy and Self-Report	85%	Adults (mean ranges from 36.1-37.1)	55
Wicklow and Espie (2000)	Diary (between-person)	Pre-Sleep Cognitive Arousal	Perseverative Cognition	State	Sleep Quality and SOL	Actigraphy and Self-Report	67%	Adults (mean = 36.0)	21
Yan et al. (2014)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality	Self-Report	62%	Adolescents and Adults (12-22)	1072
Yeh et al. (2015)	Cross-Sectional	Pre-Sleep Cognitive Arousal, Active Cognitive	Perseverative Cognition, Rumination and Worry	Trait	Sleep Quality, SOL and TST	Self-Report	64%	Adults (18-30)	202

		Appraisal, Dwelling on the Negative and Worry Engagement							
Zawadzki, Graham, and Gerin (2013)	Cross-Sectional	Rumination	Rumination	Trait	Sleep Quality	Self-Report	57%	Adults (mean = 20.3)	218
Zoccola et al. (2009)	Experimental	Rumination and Stressor-Specific Rumination	Rumination	Both	SOL and TST	Actigraphy and Self-Report	63%	Adults (18-26)	70

Note. SOL = sleep onset latency, TST = total sleep time. [a]The range is reported where this was available. If this was not available, the mean (or median) was reported and categories based on this. [b]age range falls slightly outside of category grouping.

Table 2. Summary of Meta-Analyses

Type of Perseverative Cognition	**Type of Sleep**	***k***	***r***	**95% CI**		***Z***	**Sensitivity Analyses: *Z***		
				Lower	**Upper**		**1**	**2**	**3**
Combined	Sleep Quality	50	-0.28***	-0.31	-0.24	-15.76	-14.96	-13.27	-11.67
Combined	SOL	16	-0.16***	-0.22	-0.11	-5.60	-5.82	-4.95	-4.55
Combined	TST	19	-0.15***	-0.19	-0.11	-7.75	-12.00	-6.77	-7.05
Worry	Sleep Quality	23	-0.23***	-0.27	-0.20	-12.88	-11.60	-11.84	-6.92
Worry	SOL	7	-0.16***	-0.22	-0.10	-4.94	-10.36	-4.25	-3.48
Worry	TST	11	-0.14***	-0.19	-0.09	-5.52	-6.93	-4.86	-4.86
Rumination	Sleep Quality	23	-0.33***	-0.37	-0.29	-14.75	n/a	-14.87	-12.66
Rumination	SOL	5	-0.15**	-0.24	-0.06	-3.32	n/a	-2.04	-3.32
Rumination	TST	4	-0.17**	-0.27	-0.08	-3.46	n/a	-2.36	-3.46
Non-Specific PC	Sleep Quality	12	-0.29***	-0.37	-0.21	-6.51	-6.01	-3.27	-6.01
Non-Specific PC	SOL	8	-0.21*	-0.35	-0.05	-2.56	n/a	-1.81	n/a
Non-Specific PC	TST	9	-0.18***	-0.24	-0.12	-5.68	-4.92	-4.43	-4.92

Note. PC = Perseverative Cognition, TST = total sleep time, SOL = sleep onset latency, *** significant at the <.001 level, **significant at the <.01 level, *significant at the .05 level

Table 3. Summary of Moderator Analyses

Moderator	**Type of Sleep**	***k***	**Coefficient**	**Std Error**	**95% CI**		***Z***
					Lower	**Upper**	
%Female	Sleep Quality	50	.001	.001	-.001	.003	1.40
%Female	SOL	16	.004**	.001	.002	.01	3.16
%Female	TST	19	.002	.001	-.000	.004	1.71
PC Measure	Sleep Quality	50	-.15**	.05	-.25	-.05	-2.83
Multi-Item PC Measure	Sleep Quality	50	-.04	.04	-.12	.04	-1.02
Reliable							
PC Measure Reliable	SOL	16	-.09***	.03	-.15	-.04	-3.31
PC Measure Reliable	TST	19	-.06	.03	-.12	.01	-1.70
PC Measure	Sleep Quality	50	-.08	.04	-.15	.002	-1.91
Valid							
PC Measure	SOL	16	.08	.05	-.02	.18	1.62
Valid							
PC Measure	TST	19	-.03	.04	-.11	.05	-0.76
Valid							
PC Assessment Type[a]	Sleep Quality	48	.07	.04	-.02	.15	1.58
PC Assessment Type[a]	SOL	14	.10***	.03	.05	.16	3.65
PC Assessment Type[a]	TST	17	.05	.03	-.02	.11	1.32
Sleep Measure Multi-Item	Sleep Quality	49	-.05	.05	-.15	.05	-0.94

Sleep Measure Multi-Item	SOL	15	-.10***	.03	-.15	-.04	-3.46
Sleep Measure Multi-Item	TST	18	-.06	.03	-.12	.01	-1.80
Sleep Measure Reliable	Sleep Quality	50	-.02	.04	-.10	.06	-0.46
Sleep Measure Reliable	TST	19	-.02	.04	-.11	.06	-0.56
Sleep Measure Valid	Sleep Quality	50	-.04	.04	-.12	.05	-0.85
Sleep Measure Valid	SOL	16	-.04	.05	-.13	.05	-0.90
Sleep Measure Valid	TST	19	-.05	.03	-.12	.02	-1.39
Sleep Assessment Type[b]	Sleep Quality	50	.13*	.06	.01	.24	2.15
Sleep Assessment Type[b]	SOL	16	.07	.06	-.04	.18	1.23
Sleep Assessment Type[b]	TST	19	.01	.05	-.08	.10	0.28
Cross Sectional Only	Sleep Quality	50	-.08	.04	-.17	.00	-1.96
Cross Sectional Only	SOL	15	-.11***	.03	-.16	-.05	-3.66
Cross Sectional Only	TST	18	-.08**	.03	-.13	-.03	-3.28
Longitudinal Only	Sleep Quality	50	.10	.06	-.03	.22	1.55
Longitudinal Only	TST	15	-.03	.06	-.14	.09	-0.46
Diary Study	Sleep Quality	50	.03	.05	-.07	.13	0.62
Diary Study	SOL	15	.10***	.03	.04	.15	3.44
Diary Study	TST	15	.02	.05	-.07	.11	0.38
Time between PC and Sleep (diary only)	Sleep Quality	12	.02	.02	-.03	.07	0.78
Number of PC	Sleep Quality	50	.003	.002	-.001	.01	1.37

Measurements							
Number of PC Measurements	SOL	15	.003***	.001	.002	.005	4.00
Number of PC Measurements	TST	18	.000	.001	-.002	.003	0.29
Between Participants Only (diary only)	Sleep Quality	12	.03	.11	-.18	.23	0.24
Between Participants Only (State vs Trait)	Sleep Quality	43	.06	.05	-.04	.15	1.11
Between Participants Only (State vs Trait)	TST	13	.03	.05	-.06	.12	0.57

Note. PC = Perseverative Cognition, TST = total sleep time, SOL = sleep onset latency, *** significant at the <.001 level, **significant at the <.01 level, *significant at the <.05 level, for yes/no responses, No = 0, Yes = 1, [a]PC Assessment Type: Trait = 0, State = 1, [b]Sleep Assessment Type: Self-Report = 1, Actigraphy Only or Actigraphy and Self-Report = 2.

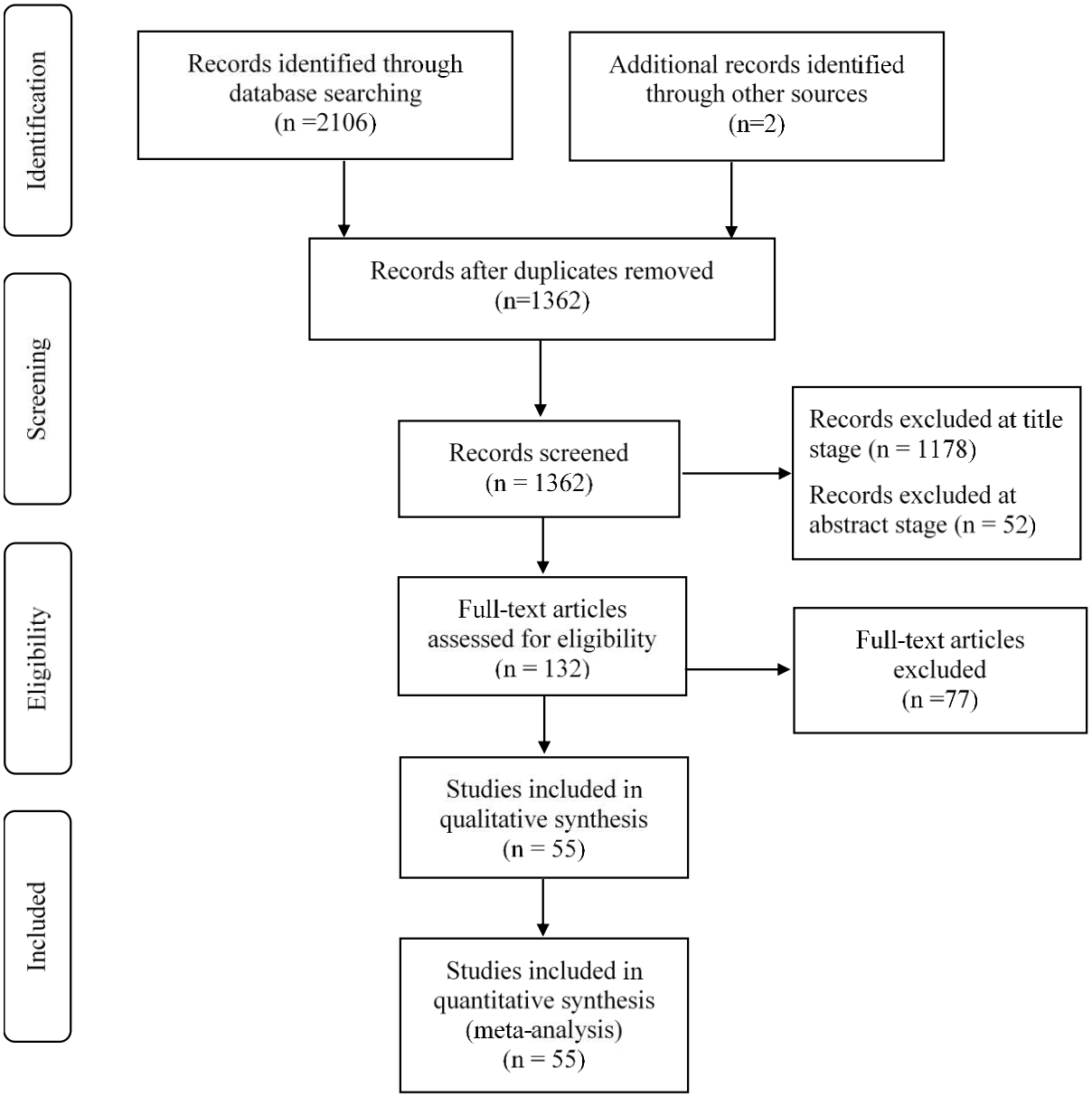

Figure 1. PRISMA flow diagram depicting the study selection process, adapted from Moher, Liberati, Tetzlaff, and Altman (2009)

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	7
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	8
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	10
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	9
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	9
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	10
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	10
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	11
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	9

Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	13
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	15
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency ($e.g., I^2$) for each meta-analysis.	14, 15

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	39
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	15, 16
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	18
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	18
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Supplementary material
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Supplementary material
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Table 2
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Supplementary material
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	34-39 & Table 3
DISCUSSION			

Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	40-45
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	44-45
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	40-45
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	45

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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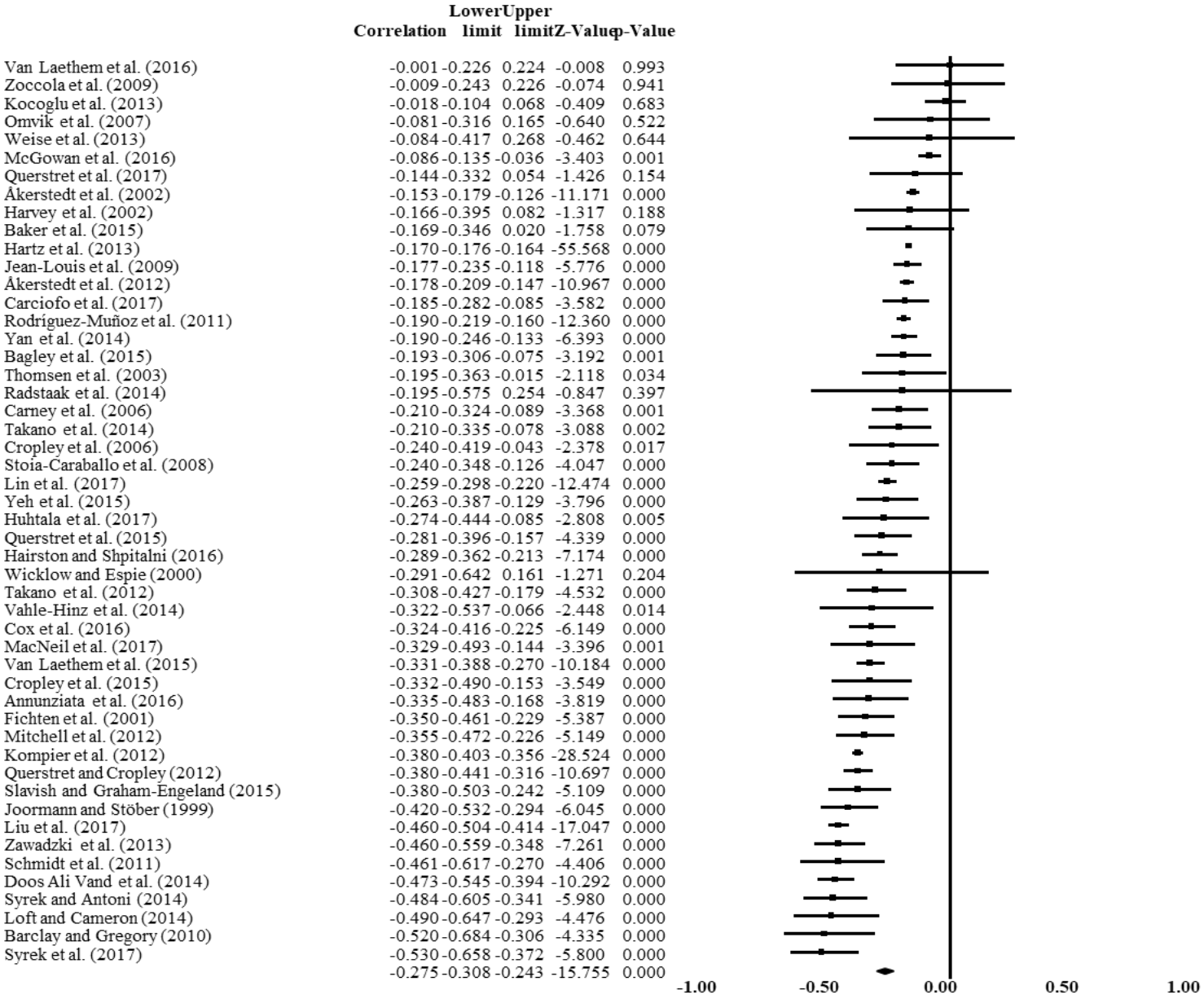
Lower Upper
Correlation limit limit Z-Value p-Value
Van Laethem et al. (2016) -0.001 -0.226 0.224 -0.008 0.993
Zoccola et al. (2009) -0.009 -0.243 0.226 -0.074 0.941
Kocoglu et al. (2013) -0.018 -0.104 0.068 -0.409 0.683
Omvik et al. (2007) -0.081 -0.316 0.165 -0.640 0.522
Weise et al. (2013) -0.084 -0.417 0.268 -0.462 0.644
McGowan et al. (2016) -0.086 -0.135 -0.036 -3.403 0.001
Querstret et al. (2017) -0.144 -0.332 0.054 -1.426 0.154
Åkerstedt et al. (2002) -0.153 -0.179 -0.126 -11.171 0.000
Harvey et al. (2002) -0.166 -0.395 0.082 -1.317 0.188
Baker et al. (2015) -0.169 -0.346 0.020 -1.758 0.079
Hartz et al. (2013) -0.170 -0.176 -0.164 -55.568 0.000
Jean-Louis et al. (2009) -0.177 -0.235 -0.118 -5.776 0.000
Åkerstedt et al. (2012) -0.178 -0.209 -0.147 -10.967 0.000
Carciofo et al. (2017) -0.185 -0.282 -0.085 -3.582 0.000
Rodríguez-Muñoz et al. (2011) -0.190 -0.219 -0.160 -12.360 0.000
Yan et al. (2014) -0.190 -0.246 -0.133 -6.393 0.000
Bagley et al. (2015) -0.193 -0.306 -0.075 -3.192 0.001
Thomsen et al. (2003) -0.195 -0.363 -0.015 -2.118 0.034
Radstaak et al. (2014) -0.195 -0.575 0.254 -0.847 0.397
Carney et al. (2006) -0.210 -0.324 -0.089 -3.368 0.001
Takano et al. (2014) -0.210 -0.335 -0.078 -3.088 0.002
Cropley et al. (2006) -0.240 -0.419 -0.043 -2.378 0.017
Stoia-Caraballo et al. (2008) -0.240 -0.348 -0.126 -4.047 0.000
Lin et al. (2017) -0.259 -0.298 -0.220 -12.474 0.000
Yeh et al. (2015) -0.263 -0.387 -0.129 -3.796 0.000
Huhtala et al. (2017) -0.274 -0.444 -0.085 -2.808 0.005
Querstret et al. (2015) -0.281 -0.396 -0.157 -4.339 0.000
Hairston and Shpitalni (2016) -0.289 -0.362 -0.213 -7.174 0.000
Wicklow and Espie (2000) -0.291 -0.642 0.161 -1.271 0.204
Takano et al. (2012) -0.308 -0.427 -0.179 -4.532 0.000
Vahle-Hinz et al. (2014) -0.322 -0.537 -0.066 -2.448 0.014
Cox et al. (2016) -0.324 -0.416 -0.225 -6.149 0.000
MacNeil et al. (2017) -0.329 -0.493 -0.144 -3.396 0.001
Van Laethem et al. (2015) -0.331 -0.388 -0.270 -10.184 0.000
Cropley et al. (2015) -0.332 -0.490 -0.153 -3.549 0.000
Annunziata et al. (2016) -0.335 -0.483 -0.168 -3.819 0.000
Fichten et al. (2001) -0.350 -0.461 -0.229 -5.387 0.000
Mitchell et al. (2012) -0.355 -0.472 -0.226 -5.149 0.000
Kompier et al. (2012) -0.380 -0.403 -0.356 -28.524 0.000
Querstret and Cropley (2012) -0.380 -0.441 -0.316 -10.697 0.000
Slavish and Graham-Engeland (2015) -0.380 -0.503 -0.242 -5.109 0.000
Joormann and Stöber (1999) -0.420 -0.532 -0.294 -6.045 0.000
Liu et al. (2017) -0.460 -0.504 -0.414 -17.047 0.000
Zawadzki et al. (2013) -0.460 -0.559 -0.348 -7.261 0.000
Schmidt et al. (2011) -0.461 -0.617 -0.270 -4.406 0.000
Doos Ali Vand et al. (2014) -0.473 -0.545 -0.394 -10.292 0.000
Syrek and Antoni (2014) -0.484 -0.605 -0.341 -5.980 0.000
Loft and Cameron (2014) -0.490 -0.647 -0.293 -4.476 0.000
Barclay and Gregory (2010) -0.520 -0.684 -0.306 -4.335 0.000
Syrek et al. (2017) -0.530 -0.658 -0.372 -5.800 0.000
-0.275 -0.308 -0.243 -15.755 0.000
-1.00
-0.50
0.00
0.50
1.00

Figure S1. Forest plot depicting the associations between combined perseverative cognition and sleep quality

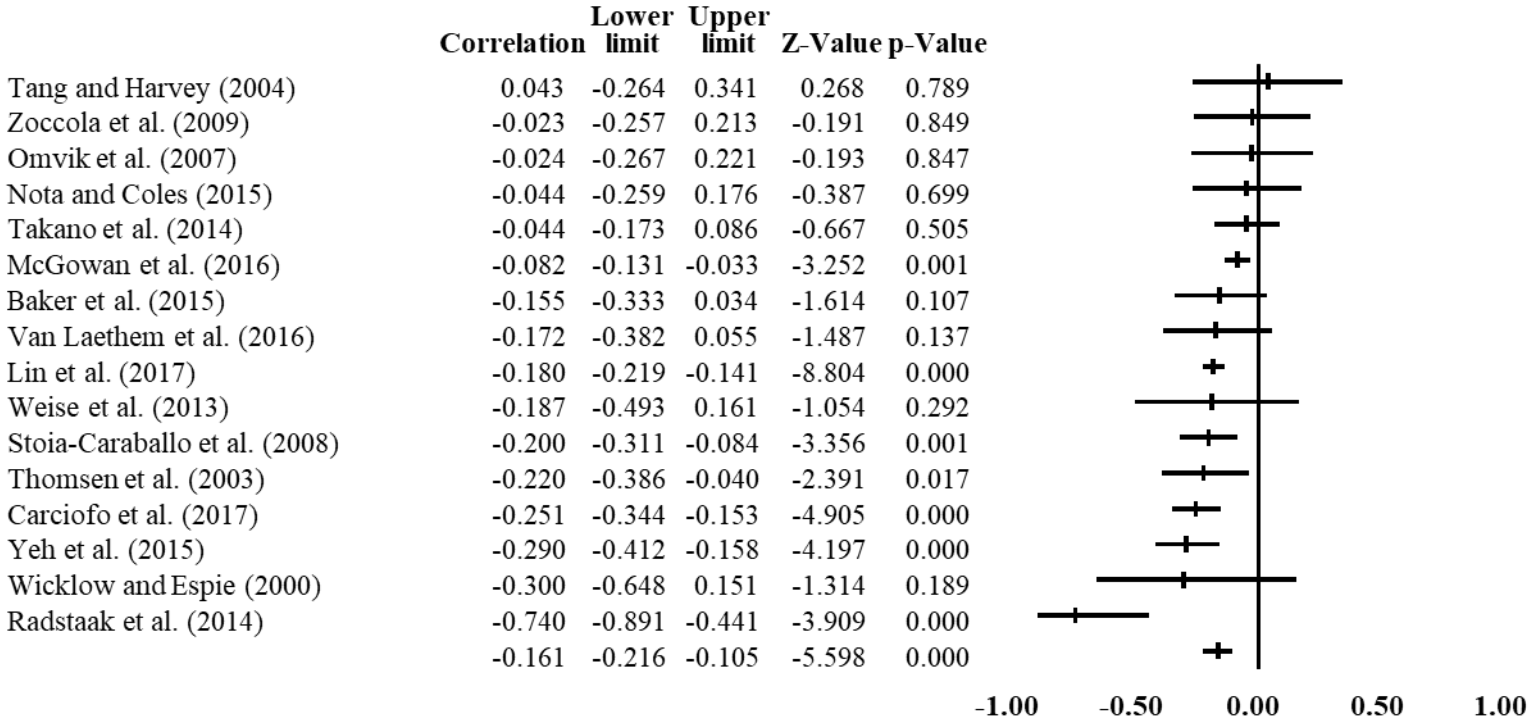

Figure S2. Forest plot depicting the associations between combined perseverative cognition and sleep onset latency

	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Omvik et al. (2007)	0.008	-0.234	0.249	0.064	0.949
Zoccola et al. (2009)	-0.028	-0.261	0.209	-0.225	0.822
Nota et al. (2016)	-0.070	-0.304	0.172	-0.563	0.574
Tang and Harvey (2004)	-0.075	-0.375	0.238	-0.465	0.642
Carciofo et al. (2017)	-0.083	-0.184	0.019	-1.589	0.112
McGowan et al. (2016)	-0.087	-0.136	-0.038	-3.476	0.001
Van Laethem et al. (2016)	-0.092	-0.311	0.136	-0.786	0.432
LaBrash et al. (2008)	-0.111	-0.247	0.030	-1.542	0.123
Fichten et al. (2001)	-0.134	-0.261	-0.001	-1.978	0.048
Bagley et al. (2015)	-0.140	-0.255	-0.021	-2.303	0.021
Baker et al. (2015)	-0.160	-0.338	0.029	-1.664	0.096
Yeh et al. (2015)	-0.161	-0.292	-0.024	-2.295	0.022
Cropley et al. (2006)	-0.210	-0.392	-0.012	-2.079	0.038
Lin et al. (2017)	-0.210	-0.249	-0.170	-10.189	0.000
Takano et al. (2014)	-0.234	-0.357	-0.102	-3.441	0.001
Kelly (2002)	-0.240	-0.361	-0.111	-3.604	0.000
Weise et al. (2013)	-0.244	-0.538	0.103	-1.387	0.165
Radstaak et al. (2014)	-0.250	-0.623	0.216	-1.055	0.291
Nota and Coles (2015)	-0.257	-0.450	-0.041	-2.322	0.020
	-0.149	-0.186	-0.112	-7.749	0.000

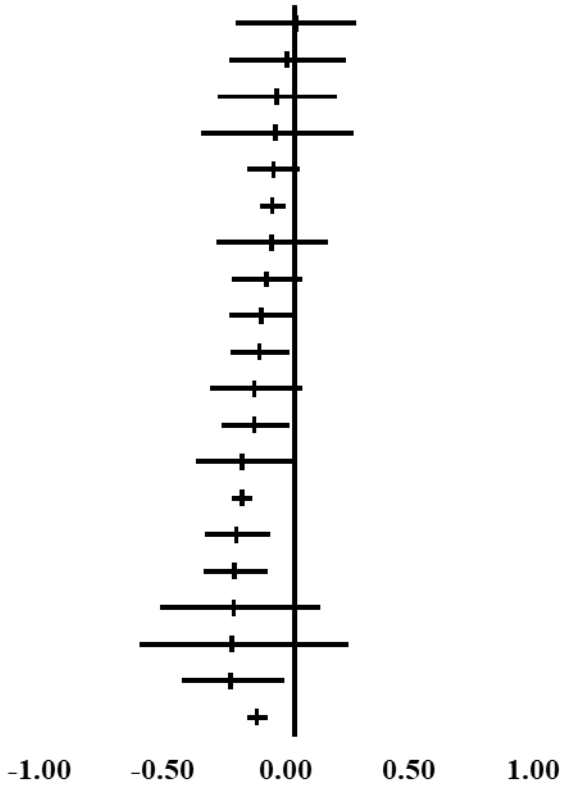

Figure S3. Forest plot depicting the associations between combined perseverative cognition and total sleep time

Table S1. Risk of Bias for Each Study

	PC Multi-Item	Sleep Multi-Item	PC Reliable	PC Valid	Sleep Reliable	Slee p Valid
Åkerstedt et al. (2002)	0	1	0	0	0	1
Åkerstedt et al. (2012)	1	1	1	0	1	1
Annunziata et al. (2016)	0	0	0	0	0	0
Bagley et al. (2015)	1	1	1	0	1	1
Baker et al. (2015)	0	1	0	0	1	1
Barclay and Gregory (2010)	1	1	0	1	0	1
Carciofo et al. (2017)	1	1	1	0	0	1
Carney et al. (2006)	1	1	1	1	0	1
Cox et al. (2016)	1	1	1	0	1	1
Cropley et al. (2006)	1	1	1	0	1	0
Cropley et al. (2015)	1	1	0	0	0	1
Doos Ali Vand et al. (2014)	1	0	0	1	0	1
Fichten et al. (2001)	1	0	0	1	0	1

Hairston and Shpitalni (2016)	1	1	1	0	1	0
Hartz et al. (2013)	1	1	0	0	0	0
Harvey et al. (2002)	0	1	0	0	0	1
Huhtala et al. (2017)	0	1	0	0	0	0
Jean-Louis et al. (2009)	1	1	1	0	1	1
Joormann and Stöber (1999)	1	0	1	1	0	0
Kelly (2002)	1	0	0	1	0	0
Kocoglu et al. (2013)	0	1	0	1	0	1
Kompier et al. (2012)	1	1	0	0	0	0
LaBrash et al. (2008)	0	0	0	0	0	0
Lin et al. (2017)	1	1	1	1	0	1
Liu et al.(2017)	1	1	1	1	1	1
Loft and Cameron (2014)	1	1	1	1	1	1
MacNeil et al. (2017)	1	1	1	1	0	0
McGowan et al. (2016)	0	0	0	1	0	0
Mitchell et al. (2012)	1	1	1	1	1	1

Nota and Coles (2015)	1	0	1	1	0	1
Nota et al. (2016)	1	0	1	1	0	1
Omvik et al. (2007)	1	0	1	1	0	0
Querstret and Cropley (2012)	1	1	1	1	0	1
Querstret et al. (2017)	1	1	1	1	1	1
Querstret et al. (2015)	1	1	1	1	1	1
Radstaak et al. (2014)	1	0	1	0	0	0
Rodríguez-Muñoz et al. (2011)	1	1	1	0	1	0
Schmidt et al. (2011)	1	1	0	0	1	1
Slavish and Graham-Engeland (2015)	1	1	0	1	0	1
Stoia-Caraballo et al. (2008)	1	0	1	1	0	0
Syrek and Antoni (2014)	1	1	1	1	1	0
Syrek et al. (2017)	1	1	1	1	1	1
Takano et al. (2012)	1	1	1	1	0	1
Takano et al. (2014)	1	n/a	1	1	1	1

Tang and Harvey (2004)	1	0	1	0	0	0
Thomsen et al. (2003)	1	1	1	0	0	1
Vahle-Hinz et al. (2014)	1	1	1	0	1	1
Van Laethem et al. (2015)	1	1	1	0	1	1
Van Laethem et al. (2016)	1	0	0	0	0	0
Weise et al. (2013)	1	0	0	0	0	0
Wicklow and Espie (2000)	1	0	0	1	0	0
Yan et al. (2014)	1	1	1	1	1	1
Yeh et al. (2015)	1	1	1	1	1	1
Zawadzki et al. (2013)	1	1	1	1	0	1
Zoccola et al. (2009)	1	0	0	1	1	1

Note. No = 0, Yes = 1