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CLINICAL REVIEW

Sleep and emotions: A focus on insomnia

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SUMMARY

Insomnia disorder is defined as difficulties in initiating/maintaining sleep and/or non-restorative sleep accompanied by decreased daytime functioning, persisting for at least four weeks. For many patients suffering from depression and anxiety, insomnia is a pervasive problem. Many of the aetiological theories of insomnia postulate that heightened emotional reactivity contributes to the maintenance of symptoms. This review focuses on the role of emotional reactivity in insomnia, and how the relationship between insomnia and depression and anxiety may be mediated by emotional reactivity. Furthermore, studies investigating the valence of emotions in insomnia are reviewed. Overall, there is empirical evidence that dysfunctional emotional reactivity might mediate the interaction between cognitive and autonomic hyperarousal, thus contributing to the maintenance of insomnia. Moreover, dysfunctions in sleep–wake regulating neural circuitries seem to be able to reinforce emotional disturbances. It seems plausible that dysfunctional emotional reactivity modulates the relationship between insomnia and depression and anxiety. Considering the interaction between sleep and emotional valence, poor sleep quality seems to correlate with high negative and low positive emotions, both in clinical and subclinical samples. Good sleep seems to be associated with high positive emotions, but not necessarily with low negative emotions. This review underlines the need for future research on emotions in insomnia.

Introduction

The International Classification of Sleep Disorders-2nd edition (ICSD-2)[1] defines insomnia as a difficulty in initiating/maintaining sleep or non-restorative sleep accompanied by decreased daytime functioning, such as fatigue/malaise, daytime sleepiness, mood disturbance/irritability, motivation/energy/initiative reduction and attention/concentration/memory impairment, persisting for a period of at least four weeks. Insomnia is a pervasive problem for many patients suffering from psychiatric conditions such as depression, posttraumatic stress disorder, alcoholism, bipolar disorder, eating disorder, generalized anxiety, and obsessive compulsive disorder.[2] In this article, a systematic review will be presented focussing on the role of emotional reactivity, and of positive and negative emotions, in insomnia and in the relationship between insomnia and depression and anxiety. First, a brief introduction on the conceptualization of emotions from a psychological perspective will be provided. Moreover, in the introductory section the role of emotional reactivity in insomnia, as described by aetiological theories, will be briefly reviewed. Subsequently, the research methodology will be described. This review will then focus on two parts: the involvement of emotional reactivity in the relationship between insomnia and depression and anxiety; and the relationships between sleep and negative and positive emotions (considering first sleep deprivation and then sleep quality/insomnia).

Emotions from a psychological perspective

Emotions are responses to internal and external stimulation characterised by a valence connotation and a specific strength. They include changes in multiple systems: subjective, physiological, behavioural, and relational.[3] Emotions are processes evolved for facilitating appropriate responses to environmental circumstances to reach individual or social goals in quick and effective ways.[3] Emotional reactivity indicates the individual's threshold, peak intensity, rise time, and recovery time in response to emotional stimulation.[4] These characteristics vary continuously across individuals and are linked to stable personality dimensions (e.g., neuroticism, anxiety, and extraversion). High or low emotional

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Nomenclature

AASM	American Academy of Sleep Medicine
APA	American Psychiatric Association
CBT-I	Cognitive behavioural therapy for insomnia
CG	Complicated grief
DSM-IV	Diagnostic and Statistical Manual for Mental Disorders
EEG	Electroencephalography
EMG	Electromyography
fMRI	Functional magnetic resonance imaging
IAPS	International Affective Picture System
ICSD-2	International Classification of Sleep Disorders-2nd edition
MMPI	Minnesota Multiphasic Personality Inventory
PANAS	Positive and Negative Affective Schedule
PFC	Prefrontal cortex
PSG	Polysomnography

Glossary of terms

Affect: a superordinate construct which includes at least four categories of states or conditions that involve good–bad discriminations: emotions, mood, stress, impulses.
Emotion: process triggered by internal and external stimulation characterised by a valence connotation and which include changes in multiple systems: subjective, physiological, behavioural, and relational
Emotion dysregulation: difficulties in regulating emotions (see emotion regulation).
Emotion regulation: process by which people influence the quality, intensity and duration of emotions
Emotional instability: difficulties in tolerating frustration and frequent experience of intense negative emotions.
Emotional reactivity: threshold, peak intensity, rise time, and recovery time of a response to emotional stimulation
Emotional valence: positive or negative tone of an emotion
Emotionality: responsiveness to emotional stimulation
Impulses: responses characterized by a valence connotation, but independent of the context.
Mood: emotional tone that is unprovoked by a stimulus and which refers to a stable condition
Stress: state of negatively toned psycho-physiological activation

reactivity, which results from difficulties in regulating emotions, is a central feature of most psychiatric conditions.[4]

Emotions have been conceptualized as discrete entities or as defined by underlying motivational or personality dimensions. The discrete approach considers a small number of basic emotions reflecting specific neuronal, body/expressive and feeling/motivational pathways (e.g.,[5]). Izard,[5] for example, describes 10 basic emotions: anger, disgust, fear, shyness, interest, joy, surprise, distress, contempt, and guilt. The dimensional approach refers to varying activation in centrally organized appetitive and defensive motivational systems (e.g.,[6,7]). It has been shown that these motivational systems are reciprocally inhibitory, which means that when one system is activated the other one is inhibited.[7] These systems direct behaviour toward appetitive stimuli or away from aversive stimuli. Accordingly, the subjective experience of emotions can be described on the basis of valence (positive vs negative) and arousal level (from low to high). Watson and Tellegen,[8] based on a personality perspective, proposed that the positive and negative affect dimensions are independent and orthogonal dimensions. According to this, the emotional experience is not always a marker of pure positive or negative emotions: surprise, for example, could be a marker of both high positive and negative emotions.

Self-reports are the most common methodology to assess the subjective component of emotions. One of the most frequently used instruments is the Positive and Negative Affective Schedule (PANAS[9]), which is based on the Watson and Tellegen model.[8] The PANAS is a list of 20 adjectives describing affective states, 10 positive (interested, excited, strong, enthusiastic, proud, alert, inspired, determined, attentive, active) and 10 negative (distressed, upset, guilty, scared, hostile, irritable, ashamed, nervous, jittery, afraid). People are instructed to rate how intense they experience each affective state on a five-point scale ranging from 1 (not at all) to 5 (very much).

Studies on the psychophysiological component of emotions have typically focussed on autonomic outputs, such as heart rate, blood pressure, electrodermal activity or muscle tension changes.[7] There is increasing evidence indicating that some autonomic indices capture predominantly the arousal dimension (e.g., skin conductance), while others measure the valence dimension of emotions (e.g., facial EMG).[7] Finally, neuroimaging techniques may lead to a better understanding of the neurobiological correlates of emotions. Neuroimaging studies in major depression have identified structural and functional brain abnormalities in those structures that are involved in the regulation of emotions, for example in the prefrontal cortex, and the amygdala.[10]

Emotional reactivity within the aetiological theories of insomnia

The first theoretical account concerning the role of emotion dysregulation in insomnia was proposed by Kales et al.[11] The authors evaluated personality patterns of 124 people with primary insomnia using the Minnesota Multiphasic Personality Inventory (MMPI). Clinical relevant scores in one or more MMPI scales were reported by 85% of the sample. The scales with the highest scores were: depression, psychasthenia, and conversion hysteria. These results were replicated by the same authors in another study including a control group.[12] Thus, the personality style of people with primary insomnia was characterised more by internalising problems (e.g., depression) than by externalising problems (e.g., acting out or aggression). Based on these findings, Kales et al.[11] proposed the "internalisation of conflicts model" of insomnia. According to this model, the predisposition to internalise psychological conflicts leads to heightened levels of emotional arousal, which in turn provokes physiological hyperarousal and renders the individual unable to sleep.

The majority of current aetiological theories consider heightened levels of autonomic, cortical, cognitive, and emotional arousal to be a stable feature of patients with insomnia (e.g.,[13–16]). Perlis et al.[16] postulated a top-down approach: insomnia results from enhanced cortical hyperarousal, measured objectively, for example, as increased fast frequencies in the sleep EEG. This is experienced subjectively as cognitive hyperarousal (e.g., intrusive thoughts during the sleep-onset period, dysfunctional beliefs), which results in increased autonomic arousal. According to Espie,[15] affect dysregulation mediates the effect of cognitive and autonomic hyperarousal on sleep. Riemann et al.[13] proposed alternatively that a bottom-up process may be involved in the aetiology of insomnia: a genetically determined dysfunction in sleep–wake regulating neural circuitries in conjunction with precipitating stressors may lead to sleep disruption as well as to cognitive and emotional disturbances. Of note, the top-down and the bottom-up processes are not in contradiction. Indeed, as transitory insomnia is a common experience for many persons, it seems plausible that only those individuals genetically predisposed to sustained psychophysiological hyperarousal are prone to develop a disorder of chronic insomnia.

Emotion dysregulation in insomnia has been described by two patterns of subjective experience of emotions. The cognitive model of insomnia[14] described the heightened cognitive activity as excessively negative toned in this patient group. The psychobiological model of insomnia[15] suggests that insomnia is characterized by both strong positive and negative emotions.

A summary of the interplay between the different types of arousal in insomnia, as described by the present aetiological theories of insomnia, is schematized in Fig. 1.

Research methods

Studies were identified via literature searches using PUBMED, MEDLINE, PsycINFO, and PsycArticles. Key search terms included: "emotions" paired with "sleep" and "insomnia".

We grouped the identified articles in the following categories:

1) Insomnia or poor sleep and emotional reactivity: relations with other psychological diseases and implications for treatment: a) sleep length and vulnerability to stress; b) insomnia and depression and anxiety; c) efficacy of strategies dealing with emotional processes in CBT-I;
2) The developmental perspective;
3) Does sleep predict affective states?: a) sleep deprivation and positive and negative emotions; b) naps and positive and negative emotions; c) quality of sleep and positive and negative emotions; d) insomnia: the emotional valence of cognitive activity;
4) Do affective states predict sleep quality?: a) loneliness; b) complicated grief and bereavement; c) hostility, impulsivity, aggression and anger; d) romantic love.

As we focussed on the role of emotionality and its valence in insomnia and poor sleep in humans, we excluded articles dealing with issues not directly related to it, namely: 1) dreams; 2) sleep disorders other than insomnia; 3) pharmacological treatment effects; 4) sleep and emotional memory; 5) the effects of sleep deprivation treatment on depressive mood; 6) insomnia and burnout; and 7) insomnia and the emotional component of pain. Additionally, non-English articles were excluded. Following these criteria, we identified 72 publications which were estimated to be of interest and warranted closer inspection.

Insomnia or poor sleep and emotional reactivity: relations with other psychological diseases and implications for treatment

Sleep length and vulnerability to stress

Short sleep duration (<6 h) has been linked to specific personality traits that are known to predispose to psychiatric conditions.[17–19] Kumar and Vayda[19] collected information about anxiety levels in 25 long and 25 short sleepers, and found that short sleep length was associated with high levels of anxiety. In another study,[18] worry was found to be negatively correlated with habitual sleep length in a sample of 222 undergraduate and graduate students. Thus, people who slept less tended to worry more often. In a very large sample of 5877 participants aged between 15 and 54 years, neuroticism, extraversion, openness to experiences, self-criticism, and interpersonal dependency were assessed, as well as information about sleep duration.[17] In this study, neuroticism and self-criticism were negatively related to sleep length, even after controlling for depression and anxiety. Based on these results, reduced quantity of sleep seems to be associated with difficulties in coping with stressful life events. However, as all of these studies were cross-sectional, no conclusions can be drawn about cause–effect relationships.

Insomnia and depression and anxiety: directionality studies and a possible modulation role of emotionality

Historically, insomnia has been conceptualized as a symptom of psychopathology, especially in relation to mood disorders.[20] More recently, insomnia has been considered as a primary disorder if it is present without the co-existence of clinically relevant psychiatric diseases, and as a secondary symptom of psychopathology when a clinical diagnosis for another mental disorder is present. However, at least with respect to the link to depression, chronic insomnia can also exist years before the first onset of an episode of depression. Accordingly, it has been suggested that "comorbid" insomnia may be a more appropriate term than "secondary".[21–23] Riemann and Voderholzer[24] summarised the findings on the link between insomnia and depression, and reported that insomnia symptoms for a period of more than two weeks predict an increased risk for developing depression within the following three years. Indeed, a number of longitudinal studies indicate that insomnia or poor sleep are risk factors for major depression (Table 1). Of the 21[25–45] studies that we identified, only two failed to find that symptoms of insomnia predict an increased risk for future depression.[31,45] Two studies found this result only in women.[35,43] Two investigations reported that insomnia had a higher predictive value for future depression than anxiety.[27,28] Eight of the 21 studies also investigated anxiety[27–29,31,33,39,44,45]: five of them found insomnia to predict anxiety[28,29,31,33,44] and one that insomnia predicts panic attacks.[39] In turn, one study found anxiety to be predictive for subsequent insomnia.[27] Of note, one study did not find any effect.[45]

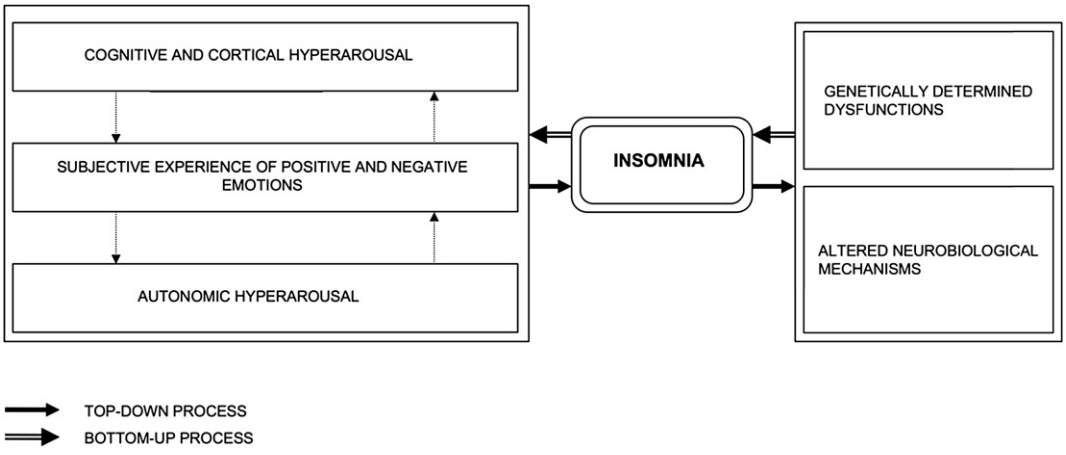

Fig. 1. The interaction between cortical, cognitive, emotional and autonomic hyperarousal in insomnia is maintained through two parallel routes: a top-down process (hyperarousal determining and maintaining insomnia) and a bottom-up process (dysfunctions in sleep–wake circuitres determining and maintaining emotional and cognitive alterations).

Table 1
Longitudinal and test–retest studies on the directionality between insomnia and depression and anxiety.

Study	Distance between BSL and FU	Age range at BSL	Number	% Female	Measures of Insomnia	Measures of Depression or/ and Anxiety	Brief summary of the Results
Gregory et al., 2009	2 yrs	8 yrs and 2 months–8 yrs and 11 months	300 twin pairs	57.0	Child Sleep Habits Questionnaire (CSHQ)	Children's Depression Inventory (CDI)	Unidirectional relationship: sleep problems at BSL predicted symptoms of depression at 10 yrs, but not the other way round. (OR not computable).
Buysse et al., 2008	20 yrs	19–20 yrs	591	50.6	The Structured Psychopathological Interview and Rating of Social Consequences of Psychic Disturbances for Epidemiology (SPIKE)	SPIKE	Insomnia with a duration >2 weeks predicted major depression episodes (OR = 1.60)
Jansson-Fröjmark & Lindblom 2008	12 months	20–60 yrs	1.498	55.0	Basic Nordic Sleep Questionnaire + Uppsala Sleep Inventory	HADS to assess anxiety and depression	Anxiety indicative of a greater risk for insomnia (OR = 4.27). Insomnia indicative of a greater risk for depression (OR = 3.51)
Morphy et al., 2007	12 months	≥18 yrs	2.363	55.9	Jenkins Sleep Scale	HADS to assess anxiety and depression	Bidirectional relationship between anxiety and depression on one side and insomnia on the other side (insomnia indicative of future anxiety OR = 2.28 and of future depression OR = 2.71)
Neckelmann et al., 2007	11 yrs	20–69 yrs	25.130	48.1	Questions about the presence of DIS (difficulties initiating sleep) and/or DMS (difficulties maintaining sleep)	HADS to assess anxiety and depression	Insomnia: risk factor for depression (OR = 1.10) and anxiety (OR = 1.60)
Perlis et al., 2006	12 months	60–94 yrs	147	56.5	Hamilton Rating Scale for Depression (HAMD) sleep items	SCID + HAMD	Persistent insomnia was approximately 6 times more likely to be associated with a first episode of major depression compared to no insomnia (OR = 6.86)
Gregory et al., 2005	2–7–16–21 yrs	5 yrs	943	48.0	Parent reports on children sleep: responses to questions scored on a binary scale (0 = no sign of a problem, 1 = sign of a problem)	Diagnostic Interview Schedule to assess anxiety and depression at 21 and 26 yrs	46% of children with persistent sleep problems at age 5, 7 and 9 had anxiety in adulthood (OR = 1.60). No significant effect with respect to depression (OR = 0.99)
Hein et al., 2003	5 yrs	≥55 yrs	664	59.3	Composite International Diagnostic Interview (CIDI)	CIDI	Difficulty falling asleep indicative of a greater risk of future depression (OR = 2.40)
Gregory & O' Connor 2002	9–10–11 yrs	4 yrs	490	46.0	Children Behaviour Checklist (CBCL)	CBCL	Sleep problems at 4 years significantly predicted depression/anxiety in mid-adolescence. (OR not computable)
Roberts et al., 2002	12 months	11–17 yrs	4.175	49.0	Questions on sleep in the past 4 weeks based on DSM-IV	Module on major depressive episodes from the Diagnostic Interview Schedule for Children (DISC-IV)	High insomnia at BSL increased the subsequent risk of depression (OR = 1.92)
Mallon et al., 2000	12 yrs	45–65 yrs	1.244	53.0	Uppsala Sleep Inventory	"Do you feel depressed" dicotomic question at baseline and HADS at follow up	Insomnia is indicative of a greater risk of future depression only in women (OR = 2.70)
Roberts et al., 2000	12 months	50–95 yrs	2.370	56.4	1 item from the DSM-12 D*: trouble falling asleep or staying asleep	*DSM-12D (12 items for the diagnosis of depression based on the DSM-IV)	2.6% of people with no sleep complaints at BSL was classified as depressed at FU, whereas 71.9% of people with sleep complaints at BSL was classified as depressed at FU (OR = 4.85)

Table 1 (*continued*)

Study	Distance between BSL and FU	Age range at BSL	Number	% Female	Measures of Insomnia	Measures of Depression or/ and Anxiety	Brief summary of the Results
Foley et al., 1999	3 yrs	≥65 yrs	6.899	63.3	Insomnia questionnaire (self-reported difficulty falling asleep or early morning arousal)	Center for Epidemiologic Studies Depression Scale (CES-D)	People with insomnia were more likely to report depression at FU compared to people without insomnia (OR = 3.09)
Chang et al., 1997	34 yrs	Mean of 26 yrs	1.024	All males	Habit Survey Questionnaire	Checklists + medical reports + self-reports reviewed by 5 physicians basing on DSM-IV	Insomnia is indicative of a greater risk for subsequent depression (OR = 2.00)
Weissman et al., 1997	12 months	≥18 yrs	7.113	60.4	"Have you ever had a period of 2 weeks or more when you had trouble falling asleep, staying asleep or waking up too early" + further information about physical illness, medication, or drug or alcohol use for exclusion criteria	Diagnostic Interview Schedule (DIS) based on the DSM-III diagnoses	Insomnia is associated with increased risk of subsequent first onset of major depression and panic disorder (OR = 5.40)
Breslau et al., 1996	3 yrs	21–30 yrs	1.007	61.7	National Institute of Mental Health (NIMH) Diagnostic Interview Schedule sleep items: insomnia is defined as a period of at least 2 weeks of trouble falling asleep, staying asleep or waking up too early nearly every day	*The NIHM Diagnostic Interview Schedule revised to cover the DSM-III-R diagnoses (DIS-III-R)	Complaints of 2 weeks or more of insomnia nearly every night as a marker of subsequent onset of major depression (OR = 3.95)
Brabbins et al., 1993	3 yrs	≥65 yrs	1.070	60.8	Geriatric Mental State (GMS) introductory question ("Have you had any problems sleeping recently" + further information about symptoms and causes in the previous 4 weeks	Geriatric Mental State (GMS)	Insomnia enhanced the risk for depression (OR = 1.39).
Livingston et al., 1993	3 yrs	≥65 yrs	705	63.4	The Sleep Disturbance Scale for assessing the presence of the insomnia symptoms	Semi-structured interview	People with chronic insomnia were significantly more likely to present depression at FU than those without insomnia (OR = 3.22)
Dryman & Eaton 1991	12 months	≥18 yrs	133	71.4	Diagnostic Interview Schedule's specifications of DSM-III criteria for major depression	Diagnostic Interview Schedule's specifications of DSM-III criteria for major depression	Sleep disturbance among women and fatigue among males were significantly associated with experiencing an onset of major depression (OR = 5.02)
Ford & Kamerow 1989	12 months	≥18 yrs	7.954	59.8	Questions about sleep disturbances on the DIS + further information about symptom duration (and about physical illness, medication, or drug or alcohol use for exclusion criteria)	Diagnostic Interview Schedule (DIS) based on the DSM-III diagnoses	People with chronic insomnia were nearly 40 times more likely to have major depression (OR = 39.80), and over 6 times more likely to have an anxiety disorder (OR = 6.3) compared to those without insomnia
Vollarath et al., 1989	2–7 yrs	≥21 yrs	591	51.2	Three groups of insomnia were identified: continuous insomnia (>2weeks); repeated brief insomnia (<2weeks); occasional insomnia (occasional symptoms)	Psychiatric interview based on the DSM-III diagnoses	Insomnia at baseline did not predict subsequent onsets of depressive disorders (OR = 2.16) or anxiety disorders (OR = not computable)

SCID = Structural clinical interview; HADS = Hospital Anxiety and Depression Scale; BSL = baseline; FU = follow up; OR = odd ratios.

These studies clearly show that insomnia predicts the onset of depression, especially in women. That being said, whether the relationship is unidirectional or not, awaits further assessment, as the majority of the studies aforementioned focussed specifically on the effect of insomnia on depression. Additionally, insomnia and anxiety seem to be linked through a bidirectional relationship. Koffel and Watson[46] conducted an interesting study investigating the association between nighttime and daytime symptoms of insomnia and anxiety/depression. Nighttime symptoms were defined as poor sleep quality, long sleep latency, and minutes awake at night; daytime symptoms were conceptualised as fatigue and sleepiness. This association was tested in three different samples: 349 college students, 213 older adults, and 266 patients. Both nighttime and daytime symptoms of insomnia were found to be significantly related to depression and anxiety (panic attacks, post-traumatic stress disorder, social

phobia, and generalized anxiety disorder). However, daytime symptoms were more strongly related to depression and anxiety, when compared with nighttime symptoms. Moreover, daytime impairments showed a stronger relationship to depression than to anxiety in all three samples. Additionally, daytime symptoms were associated with a higher negative emotionality and a lower positive emotionality, as measured by the PANAS, in all three samples. Thus, heightened negative emotionality and diminished positive emotionality might be the psychological mechanism through which insomnia, and especially the daytime component of insomnia, acts as a risk factor for depression. It appears of utmost importance to investigate whether specific daytime impairments have a stronger relation to psychopathology than others (e.g., fatigue or daytime sleepiness or mood disturbances/irritability) or whether the link is explained by the combination of different forms of impairment.

Cognitive–behavioural treatment for insomnia (CBT-I): could the inclusion of strategies dealing with emotional processes enhance the efficacy?

CBT-I is a multi-component treatment that features behavioural, cognitive and educational components.[47] The efficacy of CBT-I for primary insomnia has been clearly demonstrated.[48–50] Moreover, CBT-I is also efficacious in patients with insomnia in the context of other psychiatric disorders.[51,52] This treatment does not only seem to ameliorate sleep parameters, but also the general condition of the patients. Thus, treating insomnia could be important for preventing the development of subsequent disorders. Concerning heightened emotionality in those with insomnia, two studies have used the Pennebaker writing intervention as a method to specifically target emotional processes.[53,54] This intervention consists of the instruction to write down thoughts, worries and emotions. It is proposed that writing about emotional experiences is a method to facilitate emotional processes. Harvey and Farrel[54] found in 44 poor sleepers that those who underwent a 3-nights Pennebaker writing intervention reported shorter sleep-onset latencies compared to a no-writing group. Mooney, Espie and Broomfield[53] found that a Pennebaker writing group reported significantly reduced pre-sleep arousal compared to a control group. However, they did not find an effect of the intervention on sleep-onset latencies. The standard CBT-I protocol already includes some strategies which influence the emotional system, as for example the cognitive control strategy. In the latter, the patient is instructed to sit comfortably in an armchair and write down a list of worries and a list of what to do the next day. The rationale of this strategy is to prevent emotionally-loaded intrusive thoughts during the sleep-onset period, as all worries have been "already" processed before going to bed.

A deeper understanding of the mechanisms through which insomnia leads to an increased risk for psychopathology is of great relevance; perhaps leading to the enhancement of existing effective treatments, as well as a more complete understanding of the role of intervention in the prevention of psychopathology development. If heightened negative emotionality characterises insomnia and modulates its relationship with psychiatric conditions, additional strategies dealing with emotional processes could enhance the efficacy of the treatment.

Sleep quality, insomnia and emotions: a developmental perspective

The investigation of the relationship between insomnia and other psychological diseases is of particular interest in children because improvements in the efficacy of treatments might stop the progression to serious and enduring problems in adulthood. Sleep problems in childhood are bidirectionally related to emotional and behavioural problems (e.g.,[55,56]). Reid et al.[55] investigated how child, parent, and family factors contribute to sleep problems and internalising (emotional) and externalising (behavioural) problems. Sleep problems were more strongly related to internalising problems than to externalising problems.[55] As illustrated in Table 1, four studies evaluated the relationship between insomnia and depression/anxiety in children or adolescents and found similar results as those studies that were conducted in adults.[25,31,33,34] Like in adults, dysfunctional emotionality might modulate the relationship between insomnia and emotional disorders. Consistent with this hypothesis, short sleep duration in children was found to be associated with heightened emotional instability.[57] Moreover, high negative affect was linked to resistance to having a nap in the afternoon in a sample of 38 children with a mean age of 3.8 years.[58] El-Sheikh and Buckhalt[59] investigated physiological and subjective measures of emotion regulation in 23 boys and 18 girls aged between 6 and 12 years. Decreased levels of vagal suppression, which were considered indices of poorer emotion regulation, were found to be associated with sleep problems. Moreover, higher levels of emotional intensity, defined as the frequency and the intensity of the child's expression of emotions, were linked to reduced amounts of sleep and increased nocturnal activity. The same group showed that disrupted sleep in children was a moderating variable between emotional insecurity in the family and school performance.[60] In this study, emotional insecurity was evaluated by a scale measuring emotional arousal (e.g., feeling sad, scared and angry), behavioural dysregulation (e.g., throwing things), and destructive family representations (e.g., worrying about what the parents will do next).

Does sleep predict affective states?

Sleep deprivation and positive and negative affective states

Recent literature on sleep deprivation supports an exciting role for sleep in regulating emotional experience.[61] Dahl[56] indicated that the interaction between sleep and affect regulatory systems is modulated and integrated in regions of the prefrontal cortex (PFC). Sleep deprivation induces alterations in goal-directed behaviours by weakening the PFC influence over other brain regions. This results in a reduced modulation of emotions, drives, and impulses.[56] Consistent with this, the cognitive-energy model proposed by Zohar et al.[62] indicates that sleep loss affects cognitive-energy resources required for coping with goal-obstructing events or for capitalizing on new opportunities offered by goal-enhancing events. The availability of cognitive energy resources influences the perception of the progression toward a valued goal. When enough cognitive resources to reach a goal are anticipated, positive emotions are promoted; when a lack of resources is perceived, negative emotions are enhanced. According to this model, sleep deprivation affects cognitive-energy resources resulting in the perception that the goal is obstructed. Two studies have evaluated subjective emotional responses in sleep deprivation.[63,64] Wagner et al.[63] investigated the effect of selective first-half and second-half nocturnal sleep deprivation on subjective ratings of a set of pictures taken from the International Affective Picture System (IAPS[65]). The IAPS is a large database of pictures validated for the dimensions of valence and arousal, based on the dimensional approach to emotions. Twenty-four participants (all males, age range 18–30) were investigated. Second-half nocturnal sleep deprivation resulted in increased emotional responses to negative pictures. As REM sleep is prevalent in the second-half of the night, and as increased REM density and REM time is frequently found in patients with depression, the authors interpreted this finding in terms of

enhancement of emotional reactivity after periods rich in REM sleep. Leotta et al.[64] showed 10 positive, 10 negative and 10 neutral pictures to 15 healthy adolescents (60% girls, age range 10–15) after a night of "optimized" sleep (in which participants were allowed to sleep up to 10 h) and after a night of restricted sleep (in which participants were woken up after 4 h). After viewing the pictures, participants had to rate the dimensions of valence and arousal and the intensity of self-experienced anger, sadness, fear, disgust, happiness, and interest. After sleep restriction, they reported higher rates of anger, sadness and fear, but no difference was found between conditions with respect to valence and arousal.

Physiological responses to visual emotional stimulation have been investigated in three sleep deprivation studies.[66–68] All these studies used visual stimuli selected from the IAPS. In the two studies conducted by Franzen et al.[66,67] pupillary responses were obtained to measure the magnitude and the time-course of emotional information processing. The pupil dilates in response to emotional stimulation. High arousing negative and positive, and low-arousing neutral pictures were presented. In the first study,[67] 29 participants were investigated (52% women); and, in the second study,[66] 30 participants (50% women). In both studies the age range was between 21 and 30 years. In the sleep deprivation group, pupillary responses to negative emotional pictures were larger than in the control group,[66] and positively correlated with self-reported sleepiness.[67] Moreover, the sleep-deprived participants showed an anticipatory pupillary reactivity during blocks of negative pictures.[66] No group difference was found with respect to positive stimuli. However, in the PANAS, the sleep deprived group reported lower positive emotions, but no group difference was found with respect to negative emotions.[67] Yoo et al.[68] investigated the neural correlates of emotions in a sleep deprivation group through functional magnetic resonance imaging (fMRI). Twenty-six participants (50% women, age range 18–30) were asked to watch 100 pictures ordered from emotionally neutral (neutral valence, low arousal) to increasingly aversive (negative valence, high arousal). The sleep deprivation group ($n = 14$) displayed enhanced activity in the amygdala and reduced functional connectivity between the amygdala and the medial PFC. These results were interpreted as an increased neurobiological response to emotional stimuli and a reduced inhibitory influence of the PFC on emotional reactivity after sleep deprivation.

Naps and positive and negative affective states

Short naps have been reported to have a positive effect on mood. In a study by Kaida et al.[69] the mood of 16 healthy female participants (age range 33–43) was assessed by self-rating scales before and after a short nap or a natural bright light condition of 30 min. Both the conditions were efficacious in improving positive mood, defined as pleasantness, satisfaction, and relaxation. However, while the light condition improved only pleasantness, the short nap had a significant effect on all three dimensions. Pre- and post-nap emotional levels were also examined in a study by Luo and Inoué.[70] Eight participants (50% women, age range 27–30) were requested to take a nap in the laboratory between 13:00 and 14:00 for three consecutive days. Results showed an increase in joy and relaxation from the pre- to the post-nap period. However, perhaps less expected, anger levels were also enhanced after the nap.

Quality of sleep and positive and negative affective states

It is a common belief that a night of good quality sleep enhances positive emotions and well-being during the day and that a night of bad quality sleep increases irritability and negative emotions. However, only few studies have investigated the relationship between poor sleep and positive and negative emotions. Berry and Webb[71,72] used PSG recordings and showed that increased sleep efficiency and total sleep time were associated with positive affective states as measured by mood scales, at least in elderly women. Additionally, increased wake time after sleep-onset was related to negative affective states.

To the best of our knowledge, three studies used the PANAS to investigate these effects (Table 2).[73–75] The results of these studies are consistent with the assumption that poor sleep quality is linked to increased negative emotions and decreased positive emotions. However, many questions remain unanswered. Only one study[73] used an objective measure of sleep, actigraphy, and found no

Table 2
Sleep quality/insomnia and negative (NE) and positive (PE) emotions evaluated through the PANAS.

Study	Number	% Female (% F) and age	Measures of Sleep Quality/Insomnia	Other measures	Procedure	Results
McCrae et al. 2008	103 participants with no severe psychiatric condition or other sleep disorder than insomnia, and no medication intake	% F: not reported Age range: >60	14-days sleep diaries + actigraph	-	Completion of sleep diaries and PANAS every morning + actigraph for 2 weeks	Higher self-report sleep quality and less wake time: higher PE. Lower self-report sleep quality and higher wake time: higher NE and lower PE. No effect was found with respect to the data taken with the actigraph
Scott & Judge 2006	45 employees	% F: ~71.0 Mean age ± sd: 34.9 ± 11.8	Jenkins Sleep Problems Scale	Job satisfaction scale	Participants completed the surveys every working day for a period of 3 weeks	Insomnia the previous night had a contributory effect on negative emotions at work (hostility and fatigue), as well as a dampening effect on positive emotions (joviality and attentiveness), especially in women
Norlander et al. 2005	50 healthy subjects and 41patients with stress-related problems	% F: 81.0 Age range: 10.0%: <30 61.5%: 31–50 28.5%: >50	11 Sleep Quality questions (e.g., *How often do you feel you did not get enough sleep?*)	1) Stress-Energy Scale; 2) Hospital Anxiety Depression Scale; 3) Life Orientation Test (a measure of optimism); 4) Diurnal Type Scale (a measure of circadian preference)	Battery of questionnaire to fill in	High PE and low NE associated with the best sleep quality. Low PE and high NE associated with worst sleep quality. High PE and high NE associated with high levels of anxiety, stress, as well as of optimism, energy, and good sleep quality.

associations between objectively determined sleep and self-reported emotionality. Additionally, Scott and Judge[74] found that the relationship between emotional dysregulation and poor sleep quality was stronger in women as compared to men, while no gender differences were reported by McCrae et al.[73] However, with respect to the latter point, Scott and Judge[74] did not control for psychiatric disorders, which might be related to gender, and McCrae et al.[73] did not report the gender distribution. Finally, the finding by Norlander et al.[75] that reporting both strong negative and positive emotions in the PANAS is linked to high stress and anxiety as well as to high self-reported sleep quality should be further investigated.

Three studies investigated positive and negative emotions in insomnia for several times per day using self-report measures other than the PANAS.[76–78] Steptoe et al.[76] found in 736 participants aged 58–72 years that positive emotions were associated with good sleep quality independently of age, gender, household income, employment status, and self-rated health. Levitt et al.[78] reported from a study of 7 insomnia patients and 8 healthy controls (87% women, age range 20–30) that people with insomnia exhibited a higher variability in mood compared to good sleepers. In another study, it was found that negative and positive mood had different time courses in 47 people with primary insomnia compared to 18 good sleepers (62% women, age range 20–50).[77] Specifically, with respect to negative mood, those with insomnia showed higher overall values than good sleepers. The groups presented similar values in the morning, however, in the evening, people with insomnia showed an increase of negative mood, while good sleepers showed a decrease. With respect to positive mood, good sleepers presented higher overall values. Concerning the daily time course, good sleepers presented an increase of positive emotions both in the morning and in the evening. Those with insomnia presented, instead, a roughly stable pattern.

Only few studies have reported physiological indices of emotional reactivity in insomnia; with the majority using electrodermal activity as the dependent measure. Waters et al.[79] investigated orienting response and emotional stress elicitation in 27 people with insomnia and 13 healthy controls (73% women, undergraduates) using measures of skin conductance, vasomotor response and heart rate. In this study, an increased electrodermal activity has been found to be associated with poor sleep. Additionally, the results support the assumption of an increased emotional reactivity during encoding of new stimuli in insomnia patients as measured by physiological indices. Similar results were reported by Broman and Hetta[80] who also measured electrodermal activity in an orienting and habituation task. In this study, 40 insomnia patients were compared with 20 healthy controls (80% women, age range 31–69). Results showed that electrodermal activity was again higher in the patient group. Within the insomnia patients, a reduced total sleep time was associated with a slower habituation to new stimuli which was interpreted as an indicator of increased daytime arousal. This is, however, one of the major limitations of the aforementioned work: skin conductance and electrodermical activity have been described as sensitive predominantly to the arousal dimension of emotional responses.[7] Moreover, autonomic activity is not only related to emotional reactivity, but also to cognitive processes. So far no study has been published investigating specific physiological indices of the valence dimension of emotional response in poor sleep or clinical insomnia.

Insomnia: the emotional valence of cognitive activity

Patients with insomnia frequently experience intrusive thoughts in the sleep-onset period which interfere with their ability to fall asleep. They describe this cognitive activity as worrisome and negatively toned.[81] Indeed, affect-laden cognitions are more likely to interfere with sleep.[15] Negative thoughts at bedtime were found to be positively associated with longer sleep-onset periods.[82] A qualitative analysis revealed three types of typical cognitions in insomnia: problem solving, analysis of the context of the sleep-onset period, and thoughts about sleep and the consequences of sleep loss.[83] According to Carney et al.,[84] intrusive thoughts have two components: rumination and worry. While rumination is associated with dysphoric mood and is often focussed on the causes of this mood state, worry is linked to anxious mood and involves catastrophizing about future stressful events.[84] Considering rumination, it was found that people with insomnia are more prone to ruminate than good sleepers and that the rumination is predominantly symptom-focused.[84] Concerning worry, Watts et al.[85] found that people with insomnia and low worry report predominantly thoughts about sleep and the consequences of sleep loss, while people with insomnia and high worry report more heterogeneous thoughts both about sleep and other issues like work and social relations.

Do affective states predict sleep quality?

Loneliness

The construct of loneliness refers to the discrepancy between an individual's desired and actual relationships. Cacioppo et al.[86] investigated the relationship between loneliness and sleep quality in 54 undergraduates (39% women) who reported non-clinical scores of depression. Participants were classified in three groups with respect to the measure of loneliness: "lonely", "middling", and "non-lonely". Total sleep time, sleep efficiency, sleep duration, number of awakenings, and wake time after sleep-onset were evaluated through polysomnographic recordings. Lonely individuals had a lower sleep efficiency and higher wake time after sleep-onset, compared to the other two groups. A study by Mahon[87] investigated self-reported sleep disturbances in 106 early adolescents (age range 12–14), 111 middle adolescents (age range 15–17), and 113 late adolescents (age range 18–21). Sleep disturbances were positively associated with higher scores of loneliness only in the early and middle adolescents, but not in the late adolescents.

Complicated grief and bereavement

Grief refers to feelings, thoughts, and behaviours following the loss of a loved one. Complicated grief (CG) is characterized by the following: intrusive emotional feelings of pain due to the associated loss; persistent yearning and longing for the deceased; intrusive thoughts of death; and avoidance of reminders of the lost individual (e.g.,[88]). The Pittsburgh sleep group conducted a number of studies on the impact of CG on sleep. Considering these studies, it has to be noted that CG, although being an independent construct, is closely connected to depression. In one study, polysomonographically determined sleep impairments were only found in those participants with both CG and depression, but not in those without depression.[89] In other studies, only mild impairments in subjective or objective sleep parameters were reported in CG without depression.[88,90,91,92] The relationship between CG and sleep was also investigated in 508 bereaved and 307 non-bereaved college students using questionnaires.[93] Bereavement was found to be positively associated with the number of awakenings during the night. However, no measure of depression was taken in this study. Furthermore, sleep disturbances were found to modulate the relationship between CG and bipolar disorder.[94]

Hostility, impulsivity, aggression and anger

Brissette and Cohen[95] found that hostility is linked to heightened negative emotionality and subsequently with increased sleep disruption. In a 2-year longitudinal study by Granö et al.,[96] 5433 hospital employees (89% women, age range 19–62) filled in questionnaire surveys about hostility, insomnia and sleep duration. Participants with trait hostility were compared on the sleep measures to participants with transient hostility. Transient hostility, but not trait hostility, was associated with shorter sleep duration, even after statistical adjustment for psychiatric disorders. In another study, impulsivity, aggression and anger, and their relationship with total sleep time, number of awakenings, and sleep-onset latency were investigated in a sample of 184 incarcerated male offenders (age range 14–20).[97] Only the hostility sub-scale of the aggression questionnaire predicted both sleep quality and sleep quantity. However, comorbid psychiatric conditions were not controlled in this study. Another investigation evaluated the relationship between impulsivity and insomnia in 223 participants (75% women, age range 18–49).[98] The urgency dimension of impulsivity, defined as engaging in impulsive/rapid behaviours in order to alleviate negative emotions, without considering harmful long-term consequences, was associated with increased insomnia severity and daytime impairments.

Romantic Love

A recent study by Brand et al.[99] evaluated the effect of early stage intense romantic love on sleep quality in 113 adolescents (64% girls, mean age $\pm$ sd: 17.8 $\pm$ 1.3). Three groups were evaluated: adolescents that reported recently falling in love; adolescents reporting being in a long-term relationship; and adolescents reporting being single and not in love. Love-related depressive states and psychopathologies were ruled out by interview. Self-reported daily sleepiness, relaxation, daily concentration, and mood were assessed in the evening. Self-reported sleep quality, sleep-onset latency, total sleep time, relaxation, and mood were acquired in the morning. With respect to the evening ratings, adolescents in love reported significantly less daily sleepiness, higher daily concentration, more physical activity, and better mood, compared to the other 2 groups. With respect to the morning ratings, they reported significantly shorter sleep duration, better sleep quality and mood, and a greater feeling of being relaxed. Thus, intense love in adolescents is comparable with a hypo-maniac state, which involves for example increased energy and arousal, loss of appetite and decreased need for sleep, mood swings, irritability, and accelerated thinking.[99] According to this, intense positive emotions could disturb sleep quantity through the presence of heightened psychophysiological arousal, while improving perceived sleep quality and daytime activity. However, the reduction of sleep duration could be linked with increased slow wave sleep, which would indicate a beneficial effect of strong positive emotions on sleep. PSG studies are needed to understand the effects of intense positive emotions on sleep.

Synthesis

Heightened emotional reactivity is considered as a maintaining factor for insomnia, however, to date, the exact mechanism through which it intervenes in perpetuating insomnia has received little attention. Kales et al.[11] proposed that emotional hyperarousal, provoked by a predisposition to internalise psychological conflicts, increases autonomic activity and leads to sleep difficulties. Noteworthy, studies in children and adolescents, as well as studies on the effect of negative affective states (such as hostility) on sleep, highlight relations between insomnia and externalising problems. Importantly, however, it appears that, insomnia seems to be more strongly related to internalising problems (depression, anxiety) than to externalising ones (acting out, aggression), as shown also by the study of Reid et al.[55] Recent aetiological theories of insomnia suggest that it is more generally linked to a dysregulation of emotional reactivity. Considering the psychobiological model of insomnia by Espie,[15] insomnia is maintained by the interaction between cognitive and autonomic processes. This interaction is mediated by heightened emotionality.[15] Moreover, dysfunction in sleep–wake regulating neural circuitries leads to alteration in emotional reactivity.[13] From a neurobiological point of view, emotional stimuli interact with the basic homeostatic and circadian drives for sleep through the interaction between affect-related regions, such as the infralimbic cortex or the central nucleus of the amygdala, and regions that control sleep and wake, in particular the ventrolateral preoptic nucleus (VLPO).[100] Additionally, neuroimaging studies have shown significant elevations in activity in affect-related regions (e.g., amygdala, hippocampus, anterior cingulate cortex) during REM sleep. Specifically, during REM sleep, due to the increased limbic activation, the emotional event would be first reactivated and then associated to previous events and processed.[101] Indeed, it is known that insomnia and alterations of REM sleep are present in most psychological diseases. In order to further our understanding of the interaction between sleep and emotions, studies integrating the three domains of clinical psychology of emotions (low and high emotional reactivity), insomnia, and neurobiology of emotions and insomnia (including imaging approaches) are necessary. From a psychological point of view, the association between insomnia and psychiatric disorders could be modulated by a difficulty in regulating emotions which results in high negative and low positive emotionality. This hypothesis has been supported by the study of Koffel and Watson,[46] who found that a trait of high negative and low positive emotions modulated the link between daytime symptoms of insomnia and anxiety or depression. Furthermore, with respect to a developmental perspective, poor sleep has been found to be linked with emotional dysregulation as measured by physiological indices, and reports of expression variables and intensity of emotions.[59]

Considering the impact of sleep on emotions, studies on sleep deprivation showed enhanced emotional physiological responses to negative stimuli both by measuring pupillary responses[66,67] and brain activity[68] following experimental sleep loss. Overall, the findings of these studies suggest that sleep is relevant for maintaining adaptive emotional regulation and reactivity, but more research is needed to more profoundly understand this relationship. For example, referring to the dimensional approach to emotions, as in the study by Yoo et al.[68] pleasant stimuli were not used; it could be possible that the increase of brain activity found could not reflect specifically the negative experience related to the view of the stimulus, but also the arousal dimension of the emotional response. Additionally, pupillary responses measured in the studies conducted by Franzen et al.[66,67] are not specific indices of the valence dimension of emotional responses. We think that it would be of interest to further investigate the dimensions of valence and arousal and the relationships of each dimension with sleep deprivation studies. As sleep deprivation seems to increase negative emotionality, it could be expected that good sleep would promote the reduction of the experience of negative emotions. However, Luo and Inoué[70] showed that taking a nap enhances anger, as well as positive emotions such as joy. This suggests that good sleep does not simply decrease negative emotions and enhance positive emotions. Sleep could be important to promote those emotional states which are necessary to reach valued goals.

Negative affective states, such as loneliness, grief or hostility, are related with increased mild or relevant sleep impairments. Little is

known, though, about the effect of specific strong positive affective states on sleep. Intense love was found to be associated with decreased sleep duration, and enhanced subjective sleep quality.[99] However, so far, we have no information about the effects of love or other intense positive affective states on objective sleep quality.

Emotionality has been found to be negatively toned in insomnia and poor sleep. Good sleep quality, instead, seems to be linked with positive emotionality. However, the link between sleep and valence of emotions seems to be neither clear nor simple. While both high negative emotions and low positive emotions seem related to a bad night of sleep, low negative emotions do not seem to be essential for good sleep. Norlander et al.[75] found good sleep quality even in those with both high negative and positive emotionality. This could mean that positive emotions have a protecting value for sleep, specifically for the subjective perception of it. Further investigations are needed. It appears important and relevant to investigate the time course of positive and negative emotions during the day in people with insomnia and in good sleepers, as recent studies have done.[77,78] Heightened negative emotionality could be linked to sleep processes and being more enhanced during times of the day close to sleep (for example, the sleep onset period). Moreover high variability of mood in people with insomnia[78] could be linked with the high variability in night sleep quality characteristic of this group.

Finally, of note, there is a lack of studies using physiological measures of emotions and emotional valence in insomnia.

Limitation

The reviewed literature on the relationship between sleep and emotions includes a number of limitations, which should be taken into account in further research. Many studies aforementioned used small samples. In order to obtain a clear picture of the topic, it is important to conduct further studies which include a large number of participants. Additionally, some of these studies have been conducted exclusively on undergraduate samples. The reported findings from these samples may, therefore not generalize to other populations, such as children, adolescents and elderly adults. Finally, the constructs of mood, emotions, and affects are often confused in the available reviewed literature. So far, we are not able to affirm which is the specific effect of sleep on the different affective states (e.g., moods or emotions). This important caveat, concerning the specificity of measurement, should be addressed in future investigations in order to further elucidate the relationship between sleep and emotions.

Practice points

1) Heightened levels of emotional arousal act as a maintaining factor in insomnia by mediating the interaction between cognitive and physiological hyperarousal. Moreover, dysfunction in sleep–wake regulating neural circuitries leads to emotional disturbances.
2) The relationship between insomnia and anxiety and depression seems to be explained by referring to two pathways: 1) insomnia and anxiety are related through a bidirectional relationship; 2) insomnia, and especially daytime symptoms of insomnia, predicts the onset of depression. These directional relationships might be modulated by heightened negative emotionality and diminished positive emotionality.
3) Negative emotionality is enhanced by sleep deprivation.
4) Poor sleep quality seems to be linked with high negative and low positive emotions. This link could be enhanced in times of day close to sleep. Good sleep seems to be associated with high positive emotions, regardless of the intensity of negative emotions.

Research agenda

1) The modulatory role of heightened negative and lowered positive emotionality in the relationship between insomnia and depression and anxiety should be evaluated. Longitudinal studies, both observational and interventional, to describe the sequences are necessary.
2) Studies investigating physiological indices of emotions and specifically of the valence dimension of emotions in insomnia should be conducted through different methods, such as neuroimaging techniques or facial EMG.
3) The role of positive and negative emotions in insomnia as well as good sleep requires more thorough investigation. Increased emphasis in distinguishing the relationships of different affective states (e.g., moods vs emotions) in insomnia should be considered a research priority.
4) In terms of insomnia treatment, the efficacy of strategies dealing with emotional processes should be evaluated.

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