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Multiple phenotypes of resting-state cognition are altered in insomnia disorder

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ABSTRACT

Background: Research has supported the role of cognitive processes in the development and maintenance of insomnia, yet a standardized characterization of mind-wandering experiences in insomniacs is lacking.
Objectives: The aim was to understand the quantitative nature of thoughts and feelings during mind wandering in insomniacs and healthy controls and their relationship with sleep-related parameters.
Methods: We used the 5-minute eyes-closed wakeful rest as an experimental model condition of mind wandering. Forty-seven individuals with insomnia disorder according to the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (48.66 ± 15.62 years; 31 women) and 29 healthy controls (50.66 ± 15.14 years; 17 women) participated in the experiments and completed the Amsterdam Resting-State Questionnaire (ARSQ) immediately after the resting session. Participants also completed the Insomnia Severity Index (ISI), the Pittsburgh Sleep Quality Index (PSQI), the Dysfunctional Beliefs and Attitudes About Sleep Scale (DBAS). Statistical analyses included multiple regression to elucidate the independent determinants of ARSQ phenotypes.
Results: Participants with insomnia presented higher ISI, PSQI, and DBAS scores than did healthy controls. Insomniacs had strikingly different scores on most dimensions of the ARSQ, in particular Discontinuity of Mind, Self, Sleepiness, and Health Concern, that correlated positively with ISI and DBAS. Multiple regressions highlighted that for insomniacs, ISI was the best predictor of both Discontinuity of Mind and Health Concern.
Conclusions: Resting-state activity in insomnia is altered and it seems to be related to unhelpful beliefs and insomnia severity. Resting-state neuroimaging in combination with the ARSQ could reveal important associations between these aberrant cognitive scores and their underlying systems-level brain mechanisms.

Introduction

Chronic insomnia is a highly prevalent health problem worldwide, affecting almost one-third of the adult population.[1] It is related to a wide spectrum of sequelae and cormorbid conditions, which include psychiatric, neurodegenerative disorders, neuroendocrine, and cardiovascular diseases.[2–4] Moreover, insomnia is involved in the development of cognitive impairment,[5,6] it is an independent risk factor for work disability and reduced work performance,[7] and it is associated with high direct and indirect costs for the health care system and society.[8] Understanding the mechanisms involved in the development and maintenance of insomnia may thus be particularly useful for the design of prevention and treatment strategies for insomnia and its comorbid conditions.

Research has supported the role of cognitive processes in the development and maintenance of insomnia. Previous studies have consistently shown that participants with insomnia have more unhelpful sleep-related thoughts than good sleepers.[9,10] According to Harvey's Cognitive Model of Insomnia,[9] those with sleep difficulties can suffer from repetitive thinking throughout the 24-hour period. This mental activity has been described to focus on unhelpful beliefs and attitude about sleep, worries about sleep, or daytime rumination on the possible consequences of insomnia, which may interfere with sleep, thus contributing to perpetuating insomnia.[9,10] Previous studies have also shown that participants with insomnia have more

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unhelpful sleep-related thoughts on a metacognitive level compared with good sleepers and participants with other sleep disorders.[11]

Spontaneous cognition, that is, the activity of the brain during a "rest" period with no ongoing task to perform, has been associated with the activation of a specific brain network called "default mode network" (DMN[12]). The DMN is purported to maintain the most basic cognitive activities of the human brain in a condition of "resting state," including perceiving the outside world and monitoring mental conditions.[13] From a cognitive perspective, the resting state may be viewed as a model system for states in which attention drifts away from any task at hand toward inner mentation—also referred to as stimulus-independent thought,[14] daydreaming, or mind wandering.[15,16] Estimates suggest that the human brain engages in mind wandering for approximately half of its waking day, thereby generating thoughts and feelings unrelated to current external demands.[15,16] Altered connectivity between regions of the DMN has been associated with a variety of mental disorders including depressive and anxiety disorders.[12,13,15,17-19] In particular, overactivity of the DMN has been related to rumination in depression.[19] Recent studies have also suggested that structural abnormalities in insomnia may be linked to alterations in the DMN.[20-22]

In this view, a self-report tool, the Amsterdam Resting-State Questionnaire (ARSQ[23,24]), has been developed to quantify thoughts and feelings during wakeful rest along different dimensions. The ARSQ consists of 50 statements on thoughts and feelings that one may experience at rest, and this questionnaire has been validated with data gathered from studies measuring resting-state functional magnetic resonance imaging ([25,26]) and electroencephalography,[23,27] and with measures of mental health such as depression, anxiety, and sleep quality.[23-25] At least 10 cognitive phenotypes have been labeled such as Discontinuity of Mind, Theory of Mind, Self, Planning, Sleepiness, Comfort, Somatic Awareness, Health Concern, Visual Thought, and Verbal Thought.[24,25]

The primary objective of this study was to evaluate the mind-wandering activity during wakeful rest in individuals suffering from insomnia and in healthy controls. Based on previous literature showing higher level of daytime rumination in insomniacs (see Palagini et al[28]), as well as on studies showing a positive association between frequency of mind-wondering episodes and poorer sleep quality,[29,30] we hypothesized that insomniacs would present higher scores relative to controls in resting-state phonotypes associated with sleep (ie, Sleepiness), health (ie, Health Concern), and cognitive and somatic arousal (ie, Discontinuity of Mind and Somatic Awareness). The second aim was to explore the possible associations between mind-wandering activity during the resting state and other aspects that may contribute to the development and maintenance of insomnia such as unhelpful beliefs and attitude about sleep. We hypothesized that resting-state phenotypes that are altered in insomniacs would also be predictive of sleep-related cognitions as scored by established scales such as the Pittsburgh Sleep Quality Index (PSQI), the Insomnia Severity Index (ISI), the Dysfunctional Beliefs and Attitudes About Sleep Scale (DBAS), the Zung Self-Rating Anxiety Scale (SAS), and the Beck Depression Inventory (BDI). To the best of our knowledge, this is the first report using the ASRQ to characterize the aberrant content and quality of thoughts and feelings in a clinical cohort.

Methods

Participants enrollment and psychometric questionnaire administration

From January 2014 to January 2015, consecutive outpatients attending the Sleep Center of the Psychiatry Unit II, University of Pisa, Italy, who met the diagnostic criteria for insomnia disorder according to the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition*[1] were included in the study.

All participants underwent a face-to-face evaluation conducted by a medical doctor with an expertise in the sleep field (L.P.). Sleep disorders were assessed by clinical evaluation coupled with sleep questionnaires following the recommendations for a standard research assessment of insomnia.[31] Inclusion criteria for participants with insomnia disorder were as follows: (i) difficulty in initiating and/or maintaining sleep and/or early morning awakening, (ii) the sleep disturbance causes clinically significant distress or impairment in important areas of functioning, (iii) for at least 3 months, and (iv) without a sleep disruptive medical/psychiatric condition, substance abuse, and/or other sleep disorder.[1] Only individuals who reported sleep difficulties for at least 3 nights per week were enrolled in the study.[1]

Exclusion criteria for individuals with insomnia disorder were the presence of cognitive disorders, previous or present diagnosis of psychiatric disorders, and other sleep disorders (eg, obstructive sleep apnea syndrome, restless legs syndrome). In particular, participants with a score of 1 or more on item 10 of the PSQI[32] regarding self-reported symptoms or symptoms reported by the patient's roommate that were compatible with other sleep disorders (eg, sleep apnea) were excluded according to the *International Classification of Sleep Disorders–Third Edition* guidelines.[1]

Healthy individuals were recruited from the hospital and the university personnel. Participants underwent a face-to-face assessment and completed the same set of questionnaires used for the potential insomniacs. Inclusion criteria of the healthy participants were less than 30 minutes of sleep onset latency or wake time after sleep onset in usual nocturnal sleep.[33] The exclusion criteria were the following: (i) previously or currently diagnosed as having cognitive impairment, sleep disorders, or psychiatric diseases; (ii) habitual use of hypnotics or bedtime alcohol; (iii) engaged in shift work; and (iv) failed to complete the questionnaires.

For each participant, the presence of previous or current diagnosis of psychiatric disorders was assessed by means of the Structured Clinical Interview for *DSM IV-TR* Axis I Disorders.[34]

The study conformed to the Declaration of Helsinki. All participants provided written informed consent prior to entering the study.

Resting-state cognition assessment

Resting-state cognition was evaluated using the ARSQ.[23,24] The ARSQ is a self-report questionnaire consisting of 50 Likert-type statements relating to thoughts and feelings that may be experienced during rest. Participants were seated in a quiet and isolated room of the laboratory and asked to find a comfortable position and relax with the eyes closed for 5 minutes. Laboratory personnel took care that they were not interrupted or disturbed during the resting state period. Participants were instructed that an acoustic "beep" would notify the end of the rest session. Afterwards, participants were instructed to fill out the ARSQ. Specifically, they were asked to report their level of agreement to all the ARSQ statements, which refer to the feelings and thoughts participants may have experienced during the 5-minute resting state. The level of agreement of all statements in the questionnaire was scored on a 5-point ordinal scale with the labels "Completely Disagree," "Disagree," "Neither Agree nor Disagree," "Agree," and "Completely Agree" corresponding to scores of 1 to 5, respectively. Ten cognitive phenotypes were computed using the mean score of the 3 items belonging to each cognitive phenotype.[24,25] The 10 dimensions and example items are Discontinuity of Mind ("I had busy thoughts," "I had difficulty holding on to my thoughts"), Theory of Mind ("I thought about other," "I thought about people I like"), Self (eg, "I thought about my behavior," "I thought about myself"), Planning ("I thought about my work/study," "I thought about solving

problems"), Sleepiness ("I felt tired," "I felt sleepy"), Comfort ("I felt comfortable," "I felt relaxed"), Somatic Awareness ("I was conscious of my body," "I thought about my heartbeat"), Health Concern ("I felt ill," "I thought about my health"), Visual Thought ("I pictured events," "I pictured places,"), and Verbal Thought ("I had silent conversations," "I imagined talking to myself"). For each phenotype, higher scores indicate that the cognitive phenotype was experienced more prominently during the resting state. The overall internal consistency of the ARSQ, estimated by Cronbach α, was .85, with each scale ranging from .82 to .86.

Sleep scales

The severity of insomnia symptoms was evaluated with the ISI. The ISI is a 7-item questionnaire for self-assessment of insomnia in the previous 2 weeks. It is a reliable and valid instrument to detect cases of insomnia and to estimate insomnia severity.[10] The sum yields a global score ranging from 0 to 28. For the purposes of this study, according to the ISI authors' recommendations, the presence of insomnia symptoms was defined by an ISI score of 8 or higher.[10] The Cronbach α observed was .82.

Sleep quality was evaluated using the PSQI.[32] The PSQI is a widely used self-report questionnaire that assessed sleep quality experienced by individuals during the previous month. The 19 questions are grouped into 7 component scores whose sum yields a global PSQI score ranging from 0 to 21. Poor sleep quality was defined, according to the PSQI authors' recommendations, when the PSQI sum score was higher than 5.[32,35] The questionnaire showed a Cronbach α of .88.

The DBAS scale was used to evaluate unhelpful cognitions about sleep.[36] It consists of 16 statements exploring various sleep/insomnia-related cognitions (eg, beliefs, attitudes, expectations, appraisals, attributions). The nature of these beliefs clustered around 5 conceptually derived themes: (*a*) misconceptions about the causes of insomnia (eg, "I believe insomnia is essentially the result of a chemical imbalance"); (*b*) misattribution or amplification of its consequences (eg, "I am concerned that chronic insomnia may have serious consequences on my physical health"); (*c*) unrealistic sleep expectations (eg, "I must get 8 hours of sleep to feel refreshed and function well the next day"); (*d*) diminished perception of control and predictability of sleep (eg, "When I sleep poorly on one night, I know it will disturb my sleep schedule for the whole week"); and (*e*) faulty beliefs about sleep-promoting practices (eg, "When I have trouble sleeping, I should stay in bed and try harder"). The participant indicates his or her level of agreement to each statement on a visual analog scale, scoring between 1 ("strongly disagrees") and 10 ("strongly agree"). Items are summed up to yield a total score (maximum possible score of 160). High scores on the DBAS are indicative of pronounced unhelpful beliefs about sleep.[36] The Cronbach α in the current sample was .95.

Psychiatric scales

Depressive symptoms were assessed using BDI.[37] The Beck Depression Inventory is a 21-question inventory used to assess the severity of depression. The total score ranges from 0 to 63. According to the BDI authors' recommendations, a BDI score higher than 9 is indicative of depressive symptoms.[37,38] The internal consistency observed was .87.

Anxiety symptoms were assessed with SAS.[3] The Self-Rating Anxiety Scale is a 20-item self-report scale with questions related to cognitive, autonomic, motor, and central nervous system symptoms. Each question is scored on a Likert-type scale ranging from 1 to 4. The total score ranges from 0 to 80. The presence of clinically relevant anxiety symptoms is defined by SAS scores higher than 44.[38,39] The Cronbach α observed was .93.

Statistical analysis

Because the variables were not normally distributed (as determined by Shapiro-Wilk *W* tests), we used the Mann-Whitney *U* test to compare demographics, psychiatric, sleep, and resting-state variables between groups. Differences in sex distribution were assessed by Pearson χ^2.

A series of univariate regression analyses between ARSQ phenotypes, as a dependent variable, and each of the global scores obtained from the questionnaires administered were performed both in the insomniac and control groups. Subsequently, variables significantly associated with ARSQ phenotypes in the univariate analysis were inserted in the corresponding multiple-regression model in order to elucidate independent predictors of each ARSQ phenotype.

Results

Insomniacs have altered thoughts and feelings during rest

Demographic and clinical characteristics of the samples are shown in Table 1. Among the 60 participants enrolled in the insomnia group, those with self-reported (or reported by roommate) sleep apneas, snoring, and leg restlessness (n = 8) or with incomplete data (n = 5) were excluded. The final analysis was performed on 47 participants with insomnia (mean age, 48.66 ± 15.14 years; 31 women; Table 1) and 29 healthy controls (mean age, 50.66 ± 15.62 years; 17 women).

Participants with insomnia and healthy controls did not differ regarding sex distribution ($\chi^2(1,n = 76) = 0.28$; $P = .60$) and mean age ($Z_{76} = 1.05$; $P = .29$). As expected, participants with insomnia showed higher scores in all sleep scales (ie, PSQI, ISI, and DBAS had $P < .001$) and psychiatric scales (BDI and SAS had $P < .01$) compared with healthy control (Table 1). In the insomnia group, depressive

Table 1
Demographic and psychometric variables.

	Individuals with insomnia (n = 47)	Healthy controls (n = 29)	*Z*(74)	*P*
Age (y)	48.66 ± 15.62	50.66 ± 15.14	−1.05	.292
Sleep scales				
PSQI	14.11 ± 2.91	2.34 ± 3.91	7.29	<.001
ISI	16.81 ± 4.44	2.66 ± 4.44	7.30	<.001
DBAS	78.3 ± 33.39	5.76 ± 33.39	7.12	<.001
Psychiatric scales				
SAS	29.66 ± 9.6	12.31 ± 9.6	6.98	<.001
BDI	10.13 ± 7.98	5.34 ± 7.98	2.90	.004
ARSQ scales				
ARSQ DoM	2.59 ± 1.06	1.1 ± 1.06	6.36	<.001
ARSQ ToM	1.23 ± 0.47	1.02 ± 0.47	2.45	.014
ARSQ S	2.71 ± 1.08	1.68 ± 1.08	3.55	<.001
ARSQ C	1.63 ± 0.62	3.82 ± 0.62	−6.42	<.001
ARSQ P	1.67 ± 0.95	1.36 ± 0.95	0.72	.472
ARSQ SLP	2.77 ± 1.08	1.15 ± 1.08	6.01	<.001
ARSQ SA	2.47 ± 1.14	1.34 ± 1.14	4.79	<.001
ARSQ HC	2.69 ± 1.16	1.03 ± 1.16	6.16	<.001
ARSQ VT	1.76 ± 1.14	1.07 ± 1.14	2.84	.005
ARSQ VERBT	2.31 ± 2.06	1.44 ± 2.06	1.30	.195

Data are reported as mean ± SD.
PSQI, Pittsburgh Sleep Quality Index; ISI, Insomnia Severity Index; DBAS, Dysfunctional Beliefs and Attitudes About Sleep Scale; SAS, Zung Self-Rating Anxiety Scale; BDI, Beck Depression Inventory; ARSQ, Amsterdam Resting-State Questionnaire; DoM, Discontinuity of Mind; ToM, Theory of Mind; C, Comfort; S, Self; P, Planning; SLP, Sleepiness; SA, Self Awareness; HC, Health Concern; VT, Visual Thought; VERBT, Verbal Thought.

symptoms were present in 13 individuals, whereas symptoms of anxiety were present in 12 individuals. Interestingly, insomniacs also presented with pronounced changes in thoughts and feelings during the 5-minute resting-state session. In particular, insomniacs scored lower on Comfort and higher on Discontinuity of Mind and Health Concern. Insomniacs also scored higher than healthy controls on Self, Theory of Mind, Sleepiness, Somatic Awareness, and Visual Thought. Only the scores on Planning and Verbal Thought were not affected (Table 1 and Figure 1).

Determinants of resting-state phenotypes in individuals with insomnia

Univariate analysis in the insomnia participants showed that Discontinuity of Mind was positively correlated with insomnia severity ($r = 0.43$, $P = .003$), and with unhelpful beliefs about sleep ($r = 0.33$, $P = .022$; Table 2).

The multiple regression model including the score on Discontinuity of Mind as the dependent variable, and ISI and DBAS as independent variables, was significant ($F_{2,\ 44} = 5.30, P = .009$) and explained 16% of the variance. The ISI was the only variable significantly related to Discontinuity of Mind ($\beta = 0.35, P = .039$; Figure 2), indicating that individuals with more severe insomnia symptoms were more likely to present a more prevalent Discontinuity of Mind resting-state phenotype. Thus, for every 1-SD increase in insomnia severity, Discontinuity of Mind scores increase by 0.35 SD.

The ARSQ scores on Self were positively correlated with ISI ($r = 0.33$, $P = .024$) and DBAS ($r = 0.31$, $P = .033$). The model including Self score as the dependent variable, and ISI and DBAS as independent variables, was significant ($F_{2,44} = 3.30, P = .046$) explaining 9% of the variance in the phenotype. No specific determinants of this ARSQ phenotype were observed (Table 2), indicating that Self cannot be predicted by a specific sleep parameter alone.

Sleepiness was positively correlated with ISI ($r = 0.37$, $P = .011$) and DBAS ($r = 0.38$, $P = .009$). The a multiple regression model including the Sleepiness score as the dependent variable, and ISI and DBAS as the independent variables, was significant ($F_{2,44} = 4.65$, $P = .015$) explaining 14% of the variance. However, the analysis reveals no specific predictor of Sleepiness, indicating that single sleep parameters cannot predict the level of this phenotype (Table 2).

Health Concern was positively correlated with ISI ($r = 44$, $P = .002$) and DBAS ($r = 0.37$, $P = .012$; Table 2). The multiple regression model including the Health Concern score as the dependent variable, and ISI and DBAS as the independent variables, was significant ($F_{2,44} = 5.88$, $P = .005$), accounting for 18% of the variance of this phenotype. The ISI was significantly associated with Health Concern ($\beta = 0.34$; $P = .009$; Figure 3), indicating that individuals with greater insomnia severity were more likely to present a resting-state phenotype focused on the experience or concern of feeling ill. Thus, for every 1-SD increase in insomnia severity, Health Concern scores increase by 0.34 SD.

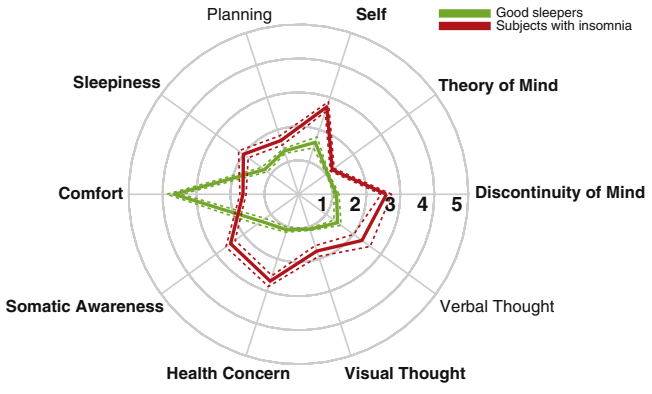

Fig. 1. The pattern of thoughts and feelings during rest is severely altered by insomnia. The spider plot shows the mean plus standard error of mean scores on the 10 dimensions of the ARSQ subjects with insomnia (*red*) and healthy controls (*green*). Dimensions with a significant difference are written in boldface. Note the pronounced differences especially for Comfort, Discontinuity of Mind, Self, and Health Concern.

Determinants of resting-state phenotypes in healthy individuals

In healthy controls, we observed only a negative correlation between Planning phenotype and insomnia severity ($r = -0.40$, $P = .031$). No other significant associations were found between ARSQ phenotypes and demographic, sleep, or psychiatric scales.

Discussion

The present study aimed to investigate the content and quality of thoughts and feelings during the resting state in individuals with Insomnia Disorder, and to explore their possible associations with insomnia severity and sleep-related cognition. We assessed the cognitive resting-state phenotypes of a group of participants with insomnia and a group of healthy controls by administering the ARSQ immediately after a 5-minute resting-state session.[23,24] Results confirmed the hypothesis that subjects with insomnia have profoundly different quality and content in thoughts and feelings while mind wandering compared with healthy participants. In addition, we found that several of these thoughts and feelings experienced during rest were related to insomnia severity and to unhelpful sleep-related beliefs.

Results of the present study revealed that individuals with insomnia may present different levels of resting-state phenotypes compared with healthy controls. Specifically, mind-wandering activity during resting state in participants with insomnia was focused on thoughts and feelings about self, worries about their own thoughts and feelings, concerns about their health, and feeling sleepy. Particularly, this cognitive activity resulted to be related to factors that may contribute to insomnia, such as unhelpful beliefs about sleep, and to the severity of insomnia symptomatology. Although the cross-sectional design of the study did not allow us to establish the cause-effect relationship between variables, one may hypothesize that unhelpful sleep-related beliefs and insomnia severity may drive the mind-wandering activity during the resting state in individuals with insomnia. These results are consistent with the findings of Ottaviani and Couyoumdjian,[29] who reported a positive association between mind-wandering propensity and sleep-onset difficulties. Similarly, a survey-based study found that the frequency of mind-wandering episodes was associated with poorer sleep quality.[30]

As expected by sampling criteria, participants with insomnia showed a poorer sleep quality, greater insomnia severity, and higher level of unhelpful beliefs about sleep than did healthy controls.[9,10] Also, although none of the insomniacs met the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* criteria[1] for anxiety or depressive disorders, the sample showed quite substantial differences compared with healthy participants for both anxiety and depressive symptoms. This result is not surprising because in insomnia, depression and anxiety are highly comorbid.[4,40]

Scoring high on Discontinuity of Mind turned out to be a prevalent resting-state phenotype in insomnia. In particular, statement such as "I had difficulty holding on to my thoughts" and "I had busy thoughts" were frequently rated high the insomniacs. This is in line with previous studies finding strong associations with indicators of mental health problems in normal population samples.[23,24]

Self-focused thoughts grouped under the phenotype "Self" also emerged as a particular characteristic of participants with insomnia, giving high ratings to the statements "I thought about myself," "I

Table 2
Univariate and multivariate regression analyses on resting-state phenotypes in insomnia.

	Discontinuity of Mind		Self		Sleepiness		Health Concern	
	Univariate (r, P)	Multivariate b (std. b, P)	Univariate (r, P)	Multivariate b (std. b, P)	Univariate (r, P)	Multivariate b (std. b, P)	Univariate (r, P)	Multivariate b (std. b, P)
Intercept	–	0.84 (0, .141)	–	1.33 (0, .030)	–	1.23 (0, .015)	–	0.73 (0, .233)
PSQI	0.08, .582	–	0.21, .162	–	0.13, .381	–	0.14, .358	–
ISI	**.43, .003**	**0.08 (0.35, .039)**	**.33, .024**	0.05 (0.22, .202)	**.37, .011**	0.05 (0.22, .191)	**0.44, .002**	**0.09 (0.34, .043)**
DBAS	**0.33, .022**	0.13 (0.01, .447)	**0.31, .033**	0.01 (0.18, .298)	**0.38, .009**	0.01 (0.25, .149)	**0.37, .012**	0.06 (0.16, .317)
BDI	0.04, .777	–	0.06, .695	–	0.07, .621	–	0.04, .796	–
SAS	0.17, .256	–	0.21, .164	–	0.24, .107	–	0.17, .250	–
Model fit	–	$F_{2,44} = 5.30$, $P = .009$		$F_{2,44} = 3.30$, $P = .046$		$F_{2,44} = 4.65$, $P = .015$		$F_{2,44} = 5.88$, $P = .005$
Adj R^2		0.16		0.09		0.14		0.18

Results of the univariate and multivariate regression analyses between Amsterdam Resting-State Questionnaire (ARSQ), Discontinuity of Mind, Self, Sleepiness, Health Concern, and the other psychometric variables in subjects with insomnia. Note that only variables significantly associated with ARSQ in the univariate model were entered as predictors in the respective multivariate model.
PSQI, Pittsburgh Sleep Quality Index; ISI, Insomnia Severity Index; DBAS, Dysfunctional Beliefs and Attitudes About Sleep Scale; SAS, Zung Self-Rating Anxiety Scale; BDI-II, Beck Depression Inventory II.
Significant results are highlighted in bold.

thought about my feelings," and "I thought my behavior." Self-focused thoughts have been associated with maladaptive consequences for mental and physical health in general, and depression and generalized anxiety in particular.[41] Recent research suggests that self-focused thinking at night is also associated with increased physiological arousal and leads to inhibition of de-arousal associated with normal sleep processes, thus contributing to insomnia.[42] Thus, in this light, it is not surprising to find higher scores on Self for insomniacs during rest.

Also, high scores on statements such as "I felt ill" and "I thought about my health," which belong to the resting-state phenotype Health Concern, were more prevalent in insomniacs than in controls. This result indicates that also insomniacs are constantly focused on the experience or concern of feeling ill, similarly to what has been observed in patients with depression or chronic pain.[43] Specifically, this phenotype may reflect worries, beliefs, and rumination that insomniacs usually have about their sleep problems and the consequences of them.[28] In addition, insomniacs experienced high levels of sleepiness in line with observations of a day-time repetitive thought processes about the consequence of the lack of sleep, such as excessive sleepiness and fatigue or lack of concentration.[44] Especially, "I felt tired" and "I felt sleepy" were feelings rated high by the insomniacs in the resting state.

In individuals with insomnia, these resting-state thoughts and feelings were correlated with insomnia severity and unhelpful beliefs about sleep. Interestingly, multiple regression analysis revealed that severity of insomnia symptomatology was the best predictor of the Discontinuity of Mind and Health Concern mind-wandering phenotypes. The relationship between Discontinuity of Mind and insomnia severity is consistent with Diaz and colleagues,[23] who report, in the first validation of the ARSQ, that Discontinuity of Mind scores correlated positively with ISI and PSQI scores in a nonclinical population sample. Here, we report that also Health Concern, a dimension developed later by the same authors but not tested in relation to sleep quality and insomnia symptoms,[24] is also associated with insomnia severity.

As previously mentioned, the cross-sectional design of the current study does not permit to establish a cause-effect relationship between variables. Nevertheless, we may speculate that the mind-wandering activity during resting state in insomnia may depend on unhelpful beliefs about sleep and insomnia severity. The study of thoughts and feelings during the resting state may provide additional information about cognitive and emotional processing that may be present, for example, during the sleep-onset period in insomnia. Thus, it would be interesting to have people with problems falling asleep fill in the ARSQ after lying in bed unsuccessfully trying to fall asleep. Such a study was recently performed in normal sleepers. Interestingly, in this normal cohort, only the Sleepiness ratings were significant predictors of sleep onset latency; however, in insomniacs, this could be different.[27]

The current results should be interpreted in light of several limitations. First, the lack of physiological measures of sleep and arousal limits our results to the subjective experience of participants. Second, the cross-correlational design limits our interpretation of the linear association between symptoms severity and phenotype levels, and longitudinal studies are warranted to deeply assess this relationship.

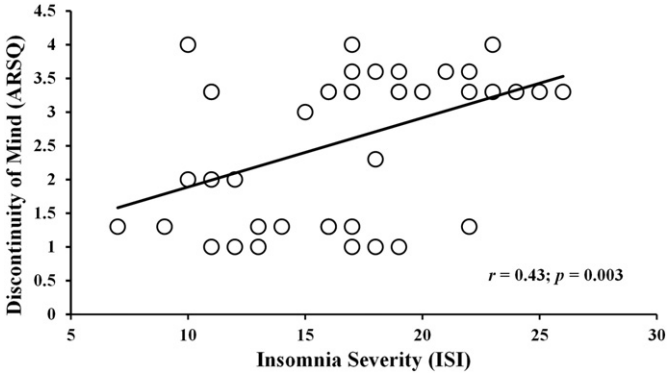

Fig. 2. Discontinuity of Mind correlates positively with insomnia severity. Scatter plots illustrate the positive correlations between the Insomnia Severity Index and Discontinuity of Mind as probed with the ARSQ.

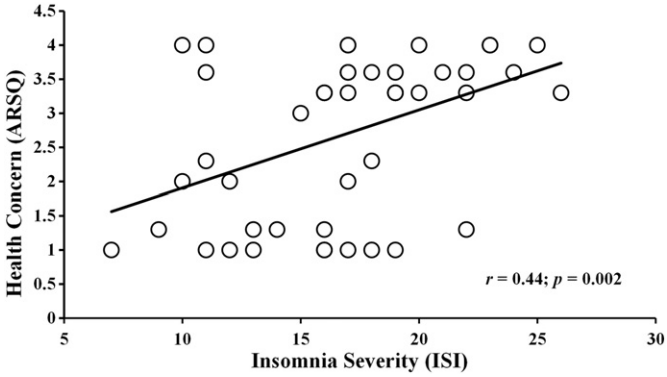

Fig. 3. Health Concern correlates positively with insomnia severity. Scatter plots illustrate the positive correlations between the Insomnia Severity Index and Health Concern as probed with the ARSQ.

Third, although we ruled out that our participants had a history of substance abuse, we cannot completely exclude the possibility that some of them used over-the-counter hypnotics or alcohol to self-medicate, which could also influence the ratings on the ARSQ. Considering that in young healthy individuals, functional connectivity in the DMN, as estimated from resting-state functional magnetic resonance imaging, exhibits positive associations with Sleepiness, Discontinuity of Mind, and Visual Thought, and that neuroimaging studies have reported that DMN seems to be impaired in insomnia, with increased activity observed in regions such as amygdala and thalamus and reduced cortical thickness in prefrontal and anterior cingulate areas,[20-22] future studies could benefit from combining resting-state neuroimaging and the ARSQ to shed light on the brain mechanisms implicated with insomnia.

Conclusions

The current study suggests that the mind-wandering activity of insomnia during wakeful rest is characterized by discontinuity of thoughts, a strong focus on themselves, worries about their health, and the feeling of sleepiness. Furthermore, these experiences may be related to factors that contribute to insomnia, especially to unhelpful sleep-related beliefs, and to insomnia severity. We speculate that the aberrant resting-state experiences in insomnia may reflect altered activity of the DMN previously reported in insomnia. Understanding the mechanisms involved in the development and maintenance of insomnia may be particularly useful for the design of prevention and treatment strategies for insomnia and its comorbid conditions.

Disclosure

The authors disclose no conflicts of interest.

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References

1. American Academy of Sleep Medicine. International Classification of Sleep Disorders. 3rd. Darien, USA: American Academy of Sleep Medicine; 2014.
2. Baglioni C, Battagliese G, Feige B, et al. Insomnia as a predictor of depression: a meta-analytic evaluation of longitudinal epidemiological studies. *J Affect Disord*. 2011;135(1–3):10–19.
3. Palagini L, Bruno R, Gemignani A, Baglioni C, Ghiadoni L, Riemann D. Sleep loss and hypertension: a systematic review. *Curr Pharm Des*. 2013;19(13):2409–2419.
4. Riemann D, Nissen C, Palagini L, Otte A, Perlis M, Spiegelhalder K. The neurobiology, investigation, and treatment of chronic insomnia. *Lancet Neurol*. 2015; 14(5):547–558.
5. Yaffe K, Falvey C, Hoang T. Connections between sleep and cognition in older adults. *Lancet Neurol*. 2014;13(10):1017–1028.
6. Cellini N, de Zambotti M, Covassin N, Sarlo M, Stegagno L. Impaired off-line motor skills consolidation in young primary insomniacs. *Neurobiol Learn Mem*. 2014;114: 141–147.
7. Kucharczyk E, Morgan K, Hall A. The occupational impact of sleep quality and insomnia symptoms. *Sleep Med Rev*. 2012;16(6):547–559.
8. Léger D, Bayon V. Societal costs of insomnia. *Sleep Med Rev*. 2010;14(6):379–389.
9. Harvey AG. A cognitive model of insomnia. *Behav Res Ther*. 2002;40(8):869–893.
10. Morin C. Insomnia: psychological assessment and management. New York: Guilford Press; 1993.
11. Palagini L, Bruno RM, Paolo T, et al. Association between stress-related sleep reactivity and metacognitive beliefs about sleep in insomnia disorder: preliminary results. *Behav Sleep Med*. 2015:1–14.
12. Whitfield-Gabrieli S, Ford JM. Default mode network activity and connectivity in psychopathology. *Annu Rev Clin Psychol*. 2012;8:49–76.
13. Buckner RL, Andrews-Hanna JR, Schacter DL. The brain's default network. *Ann N Y Acad Sci*. 2008;1124(1):1–38.
14. Teasdale JD, Dritschel BH, Taylor MJ, et al. Stimulus-independent thought depends on central executive resources. *Mem Cognit*. 1995;23(5):551–559.
15. Killingsworth MA, Gilbert DT. A wandering mind is an unhappy mind. *Science*. 2010;330(6006):932.
16. Mittner M, Boekel W, Tucker AM, Turner BM, Heathcote A, Forstmann BU. When the brain takes a break: a model-based analysis of mind wandering. *J Neurosci*. 2014;34(49):16286–16295.
17. Mooneyham BW, Schooler JW. The costs and benefits of mind-wandering: a review. *Can J Exp Psychol*. 2013;67(1):11–18.
18. Marchetti I, Van de Putte E, Koster EH. Self-generated thoughts and depression: from daydreaming to depressive symptoms. *Front Hum Neurosci*. 2014;8.
19. Zhu X, Wang X, Xiao J, et al. Evidence of a dissociation pattern in resting-state default mode network connectivity in first-episode, treatment-naive major depression patients. *Biol Psychiatry*. 2012;71(7):611–617.
20. Suh S, Kim H, Dang-Vu T, Joo E, Shin C. Cortical thinning and altered cortico-cortical structural covariance of the default mode network in patients with persistent insomnia symptoms. *Sleep*. 2015;39(1):161–171.
21. Altena E, Vrenken H, Van Der Werf YD, van den Heuvel OA, Van Someren EJ. Reduced orbitofrontal and parietal gray matter in chronic insomnia: a voxel-based morphometric study. *Biol Psychiatry*. 2010;67(2):182–185.
22. Killgore WD, Schwab ZJ, Kipman M, DelDonno SR, Weber M. Insomnia-related complaints correlate with functional connectivity between sensory-motor regions. *Neuroreport*. 2013;24(5):233–240.
23. Diaz BA, Van Der Sluis S, Moens S, et al. The Amsterdam Resting-State Questionnaire reveals multiple phenotypes of resting-state cognition. *Front Hum Neurosci*. 2013;7.
24. Diaz BA, Van Der Sluis S, Benjamins JS, et al. The ARSQ 2.0 reveals age and personality effects on mind-wandering experiences. *Front Psychol*. 2014;5.
25. Marchetti A, Baglio F, Costantini I, et al. Theory of mind and the whole brain functional connectivity: behavioral and neural evidences with the Amsterdam Resting State Questionnaire. *Front Psychol*. 2015;6:1855.
26. Stoffers D, Diaz BA, Chen I, et al. Resting-state fMRI functional connectivity is associated with sleepiness, imagery, and discontinuity of mind. *PLoS One*. 2015;10, e0142014.
27. Diaz BA, Hardstone R, Mansvelder HD, Van Someren EJ, Linkenkaer-Hansen K. Resting-state subjective experience and EEG biomarkers are associated with sleep-onset latency. *Front Psychol*. 2016;7:492.
28. Palagini L, Mauri M, Banfi T, et al. Daytime rumination as a feature of insomnia disorder: sleep related cognition is not merely a problem of the night. *Arch Ital Biol*. 2015;153(2–3):251–259.
29. Ottaviani C, Couyoumdjian A. Pros and cons of a wandering mind: a prospective study. *Front Psychol*. 2013;4.

30. Carciofo R, Du F, Song N, Zhang K. Mind wandering, sleep quality, affect and chronotype: an exploratory study. *PLoS One*. 2014;9(3), e91285.
31. Buysse D, Ancoli-Israel S, Edinger J, Lichstein K, Morin C. Recommendations for a standard research assessment of insomnia. *Sleep*. 2006;29(9):1155–1173.
32. Buysse D, Reynolds III C, Monk T, Berman S, Kupfer D. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28(2):193–213.
33. Lichstein K, Durrence H, Taylor D, Bush A, Riedel B. Quantitative criteria for insomnia. *Behav Res Ther*. 2003;41(4):427–445.
34. First MB. Structured clinical interview for DSM-IV-TR Axis I disorders. patient ed. Biometrics Research Department, Columbia University; 2005.
35. Curcio G, Tempesta D, Scarlata S, et al. Validity of the Italian version of the Pittsburgh Sleep Quality Index (PSQI). *Neurol Sci*. 2013;34(4):511–519.
36. Morin CM, Vallières A, Ivers H. Dysfunctional Beliefs and Attitudes About Sleep (DBAS): validation of a brief version (DBAS-16). *Sleep*. 2007;30(11):1547–1554.
37. Beck AT, Ward C, Mendelson M. Beck Depression Inventory (BDI). *Arch Gen Psychiatry*. 1961;4(6):561–571.
38. Conti L. Repertorio delle Scale di Valutazione in Psichiatria (Psychiatric Assessment Scales Repertory). Florence: SEE Editrice Firenze; 2000.
39. Zung WW. A rating instrument for anxiety disorders. *Psychosomatics*. 1971;12(6):371–379.
40. Baglioni C, Riemann D. Is chronic insomnia a precursor to major depression? Epidemiological and biological findings. *Curr Psychiatry Rep*. 2012;14(5):511.
41. Mor N, Winquist J. Self-focused attention and negative affect: a meta-analysis. *Psychol Bull*. 2002;128(4):638–662.
42. Takano K, Ueno M, Tanno Y. Self-focused thinking predicts nighttime physiological de-arousal. *Biol Psychol*. 2014;97:9–14.
43. Sarnthein J, Stern J, Aufenberg C, Rousson V, Jeanmonod D. Increased EEG power and slowed dominant frequency in patients with neurogenic pain. *Brain*. 2006;129(1):55–64.
44. Carney CE, Harris AL, Falco A, Edinger JD. The relation between insomnia symptoms, mood, and rumination about insomnia symptoms. *J Clin Sleep Med*. 2013;9(6):567–575.