The Roles of Intrusive Visual Imagery and Verbal Thoughts in Pre-sleep Arousal of Patients with Insomnia Disorder: A Path Model

[a]Atılım University, Department of Psychology, Ankara, Turkey

[b]Middle East Technical University, Department of Psychology, Ankara, Turkey

[c]Center for Sleep Medicine, Department of Psychiatry, University Hospitals of Geneva, Geneva, Switzerland

[d]Department of Basic Neurosciences, University of Geneva, Geneva, Switzerland

DOI: 10.1007/s10608-023-10442-0

Author footnotes: Correspondence concerning this article should be addressed to Kutlu Kağan Türkarslan, Department of Psychology, Atılım University, Gölbaşı, Ankara, Turkey

E-mail: kutlu.turkarslan@atilim.edu.tr

ORCID ID: 0000-0002-2440-3977

Deniz Canel Çınarbaş, Ph.D.

e-mail: dcanel@metu.edu.tr

ORCID ID: 0000-0002-7259-6822

Lampros Perogamvros, MD, MA, PD.

e-mail: lampros.perogamvros@unige.ch

ORCID ID: 0000-0001-7558-9612

GCRIS

Abstract

Purpose: Researchers have proposed that multiple factors such as hyperarousal, conditioning, worrying, or cortical arousal play roles in the predisposition to, initiation, and perpetuation of insomnia disorder. Previously, only a few studies investigated the differential effects of intrusive visual imagery (IVI) and intrusive verbal thoughts (IVT) on pre-sleep arousal and insomnia severity. The aim of the current cross-sectional study was to examine these effects as well as the moderator role of visual imagery ability (VIA) on the relationship between IVI and pre-sleep arousal.

Methods: A path model comprising the variables of IVI, IVT, pre-sleep arousal, and insomnia severity was tested with 166 of 1444 participants (M_{age} = 25.5, *SD* = 5.26) who were identified as having insomnia disorder based on a 12-question form corresponding to DSM-5 criteria for insomnia disorder and Insomnia Severity Index scores (≥ 8). The moderator role of VIA on the relationship between IVI and pre-sleep arousal was evaluated with a moderation analysis.

Results: It was found that IVI (β = .44, p < .001), but not IVT (β = .15, p = .12), significantly predicted pre-sleep arousal and pre-sleep arousal (β = .44, p < .001) significantly predicted insomnia severity. In addition, the indirect effect of IVI via pre-sleep arousal (IE = .19, p < .001) on insomnia severity was significant. Finally, the moderator role of VIA on the relationship between IVI and pre-sleep arousal (p = .07) was not significant.

Conclusions: IVI may play a more important role in insomnia disorder than IVT. Interventions targeting pre-sleep visual imagery may help poor sleepers alleviate insomnia severity.

Keywords: insomnia, pre-sleep arousal, intrusive visual imagery, intrusive verbal thoughts, visual imagery ability.

Statements and Declarations

Authors' Note: The article was generated from the Ph.D. thesis that the first author produced under the supervision of the second author.

GCRIS

The Roles of Intrusive Visual Imagery and Verbal Thoughts in Pre-sleep Arousal of Patients with Insomnia Disorder: A Path Model

Being one of the most common and bothersome sleep disorders, insomnia disorder is characterized by difficulty falling asleep, an inability to maintain sleep, and early-morning awakenings (Benbir et al., 2015; Cao et al., 2017; Ford et al., 2015; Morin et al., 2015; Ohayon & Hong, 2002). Individuals with insomnia disorder suffer from lower health-related quality of life (LeBlanc et al., 2007), impaired daytime functioning (Rosekind & Gregory, 2010), impaired cognitive skills (Fortier-Brochu et al., 2012), reduced work performance (Léger & Bayon, 2010), higher absenteeism (Godet-Cayré et al., 2006), increased treatment expenditures for non-insomnia disorders (Stoller, 1994), and higher risk for developing mental disorders (Hertenstein et al., 2019; Pigeon et al., 2017). The literature yielded that emotional (Baglioni et al., 2010; Perogamvros et al., 2020), behavioral (Bootzin, 1972), cognitive (Harvey, 2002), neurocognitive (Perlis et al., 1997), and neurobiological factors (Buysse et al., 2011) contribute to predisposition to, initiation, and perpetuation of insomnia disorder (Perlis et al., 2016). Being one of the cognitive factors pertaining to sleep problems, intrusive thoughts in the pre-sleep period are experienced by many insomnia patients (Harvey, 2005). Borkovec stated that "a large number of insomnias are due to intrusive, relatively uncontrollable, cognitive activity." (1982, p. 892). It has been argued that the ability of these patients to fall asleep is prevented by intrusive thoughts in the pre-sleep period, which impair the automatic inhibition of wakefulness (Baglioni et al., 2010; Pillai & Drake, 2015). Previous research has established that intrusive thoughts and pre-sleep cognitive activity were associated with shorter sleep length (Kelly, 2002; Nota & Coles, 2015), increased sleep-onset latency (Nicassio et al., 1985; Nota & Coles, 2015; Wicklow & Espie, 2000), and decreased sleep quality (Baker et al., 2015; Hall et al., 2000). The content analysis studies by Harvey (2002), Watts et al. (1994), and Wicklow and Espie (2000) showed that the themes of intrusive thoughts in the pre-sleep period are related to

rehearsals, problem-solving attempts, long-term concerns, anxiety about sleep deprivation and its consequences, bodily preoccupations, arousal level, and focusing on external noises and time.

Even though the concept of intrusive thoughts may appear to refer to a single construct, an intrusive thought may be a verbal thought, an image, or an impulse (Rachman & de Silva, 1978), each of which may have different impacts on a person's bodily and psychological processes (Hagenaars et al., 2010). In the Bio-informational theory, Lang (1979) argues that "…a mental imagery representation of an emotionally charged stimulus (e.g., a spider) activates an associative network of stored information that overlaps with that activated during actual experience of the stimulus in reality (e.g., encountering a live spider)…" (Ji et al., 2016, p. 703). Elaborating on Lang's bio-informational theory, Hagenaars et al. (2010) underlined the significance of distinguishing the effects of intrusive visual imagery and verbal thoughts on emotions and physiological arousal. Previous studies examining the differences between visual imagery and verbal processing indicated that visual imagery, by activating the visual cortex and inducing fear conditioning (Holmes et al., 2008; Holmes & Mathews, 2005; Ji et al., 2016; Mertens et al., 2020; Vrana et al., 1986), may have a more intense effect on emotions and physiological arousal compared to verbal processing. These findings suggest that intrusive visual imagery may play a role in the etiology of various psychopathologies (Brewin et al., 2010; Hagenaars & Holmes, 2012), including insomnia disorder. Moreover, brain imagining studies found that there were significant associations between the self-reported vividness of imagery and the level of activation in higher-order visual cortices (Fulford et al., 2018). Therefore, it could be asserted that visual imagery ability, referring to a person's ability to form visual mental images (Hall et al., 1985), which also comprises the vividness of visual mental

imagery (Richardson, 1994), may be a cognitive factor exacerbating the effects of intrusive visual imagery.

Unfortunately, few studies have investigated the role of intrusive visual imagery and visual imagery ability in insomnia disorder. In one of the preliminary studies, Harvey (2000) found that the visual imagery of insomnia patients was more distressing and arousing compared to good sleepers' visual imagery. Moreover, about 66% of participants reported experiencing images during the pre-sleep period. To test the premise that thinking in images promotes the emotional processing of worry more than verbal thinking (Borkovec et al., 1998), Nelson and Harvey (2002) compared two groups of insomnia patients who were instructed to think about a 5-minute speech that they would deliver the next day, in images (n = 14) or verbal thoughts (n = 17) before sleep. The results showed that the imagery thinking group reported higher distress and arousal and had shorter subjective sleep-onset latency compared to the verbal thinking group. However, there were no significant differences between the objective sleep-onset latency of the two groups. Moreover, the imagery thinking group was less anxious and rated their speech-related thoughts less uncomfortable the following morning than the verbal thinking group. These results suggested a more successful emotional processing for the imagery thinking group in the long term. In a follow-up study, Nelson and Harvey (2003b) examined the relationship between unpleasant images experienced during the pre-sleep period and sleep-onset latency in insomnia patients (n = 20) and healthy sleepers (n = 20). It was found that insomnia patients had more unpleasant images and less pleasant images than good sleepers, even after controlling for sleep-onset latency. Finally, Nelson and Harvey (2003a) investigated the pre-sleep images and verbal thoughts before an afternoon nap in sleep-onset insomnia patients (n = 34) and good sleepers (n = 38). The participants in the insomnia group reported significantly more negative images than positive images compared to good sleepers, and all

participants rated negative images as less controllable than negative verbal thoughts. In terms of the vividness of visual imagery, there were no significant differences between the vividness of visual imagery scores of insomnia patients and good sleepers in these studies (Harvey, 2000; Nelson & Harvey, 2002, 2003b, 2003a).

We argued here that cognitive and somatic arousal induced by intrusive visual imagery and verbal thoughts in the pre-sleep period contribute to pre-sleep arousal, which has been previously regarded as an important predictor of insomnia severity. Despite being cross-sectional, the current study had an a priori hypothesis for the directionality (A→ B) between intrusive thoughts/images (A) and insomnia severity (B) for two reasons: 1) clinical evidence shows that insomnia complaints in many patients are due to intrusive thoughts and images (Harvey, 2000; Nelson & Harvey, 2002, 2003b, 2003a), and 2) that modification of these unwanted thoughts and images via cognitive therapy can alleviate insomnia severity (Harvey & Payne, 2002; Molen et al., 2013; Schmid & Steil, 2019; Sheikh, 1976; Woolfolk & McNulty, 1983). Moreover, a great deal of research yielded that insomnia patients had higher pre-sleep cognitive and somatic arousal scores than normal sleepers, and higher pre-sleep arousal was associated with longer sleep-onset latency, decreased total sleep time, more frequent middle-of-night and early morning awakenings, lower sleep quality, greater daytime impairment, and higher insomnia severity (Broman & Hetta, 1994; Jansson-Fröjmark & Norell-Clarke, 2012; Marques et al., 2015; Nicassio et al., 1985; Palagini et al., 2016, 2017; Puzino et al., 2019; Ruivo Marques et al., 2018; Yeh et al., 2015).

The purpose of the current study was to investigate the differential effects of intrusive visual imagery and verbal thoughts on pre-sleep arousal and insomnia severity and to test whether visual imagery ability moderates the relationship between intrusive thoughts and pre-sleep

arousal in a sample of people who met the DSM-V criteria for insomnia disorder. More specifically, we hypothesized that higher intrusive visual imagery (Hypothesis 1) and verbal thoughts (Hypothesis 2) would predict higher pre-sleep arousal. Regarding the predictive power, the effect size of the path from intrusive visual imagery to pre-sleep arousal would be higher than the effect size of the path from intrusive verbal thoughts (Hypothesis 3). Moreover, pre-sleep arousal would predict higher insomnia severity (Hypothesis 4). Finally, the visual imagery ability would moderate the relationship between intrusive visual imagery and pre-sleep arousal (Hypothesis 5).

Method

Participants

The data was collected from 1444 participants who were recruited via social media and the internet. To detect the participants with insomnia disorder, a self-report form with 12 questions corresponding to DSM-5 criteria of insomnia disorder (American Psychiatric Association, 2013) and Insomnia Severity Index scores were used. Participants were excluded from the analysis if they reported having: (1) no insomnia symptoms (difficulty falling asleep, difficulty staying asleep, or early morning awakenings); (2) no significant distress and impairment due to sleep problems; (3) no insomnia symptoms three and more days in a week; (4) no sleep problems more than three months; (5) no sleep difficulties even if they have the adequate opportunity for sleep; (6) any sleep-wake disorders; (7) any mental, medical, and neurological disorders that may cause insomnia symptoms; (8) any substance or medication use that may cause insomnia symptoms, and (9) sleep medications use. The list of mental, medical, and neurological disorders, substances, and medications that may cause insomnia symptoms was derived from the guidelines of Schutte-Rodin Sharon et al. (2008) and Riemann et al. (2017). After the first exclusion according to DSM-5 criteria of insomnia disorder, the

participants with Insomnia Severity Index scores lower than eight (the threshold for clinical insomnia) were also excluded (Bastien et al., 2001). As a result of the exclusion process, 168 participants met the criteria for insomnia disorder. The steps of the exclusion procedure and the demographics of the participants can be seen in Figure 1 and Table 1, respectively. Finally, two multiple outliers were detected by Mahalanobis distance and excluded from further analyses. The final sample included 166 participants.

Figure 1

The exclusion chart

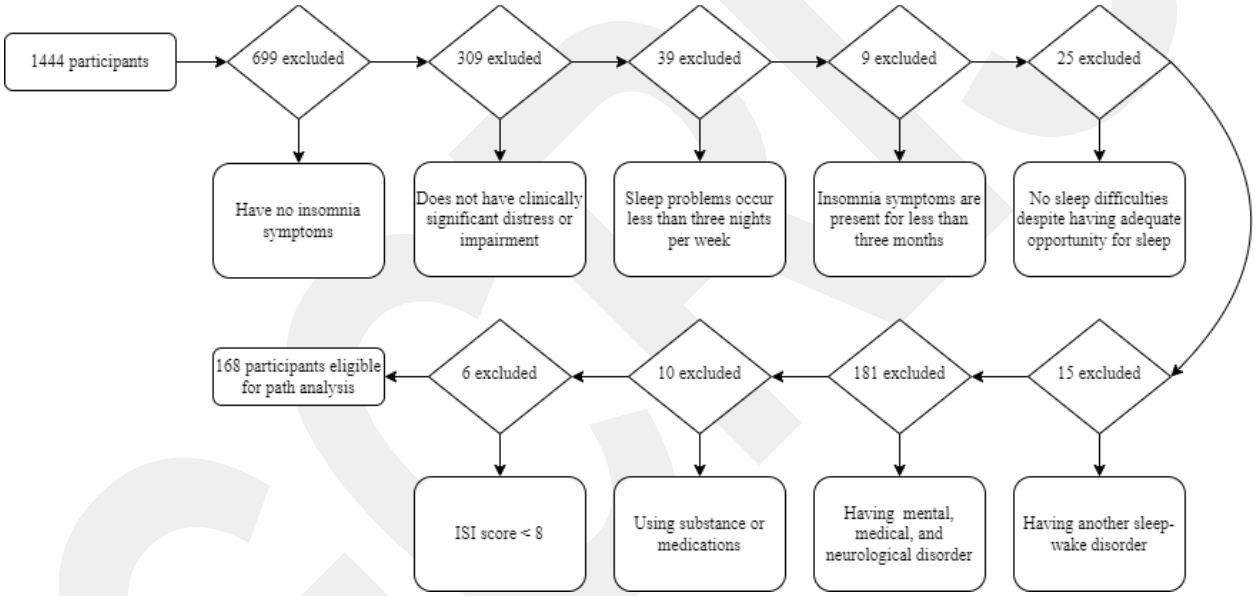


Table 1

Demographics and sleep statistics of the sample

	M	*SD*
Age	25.55	5.26
Frequency of insomnia symptoms (days in a week)	5.16	1.52
Duration of insomnia symptoms (years)	4.11	3.54
	N	%
Gender		
Female	126	75.00
Male	42	25.00
Education		
University	84	50.00
Graduate	84	50.00

Employment		
No	109	64.88
Yes	59	35.12
Marital Status		
Single	147	87.50
Married	19	11.31
Divorced	2	1.19
Socioeconomic Status		
Very Low	32	19.05
Low	46	27.38
Middle	80	47.62
High	9	5.35
Very High	1	.60
Insomnia Symptoms		
Difficulty falling asleep	150	89.29
Difficulty staying asleep	45	73.21
Waking up too early	36	21.43

Instruments

Demographic Information Form

The participants were asked about their age, gender, education level, employment status, marital status, and socioeconomic status. There were also several additional questions adapted from the study of Benbir et al. **(**2015**)** addressing smoking, daily screen time, amount of black tea or coffee intake in the evening, exercise frequency and duration, and pre-sleep screen time.

Diagnostic Questions for DSM-5 Insomnia Disorder

To identify individuals with insomnia disorder, 12 self-report questions corresponding to the eight DSM-5 diagnostic criteria for insomnia disorder were used (see Supplementary Materials). The questions were prepared by the authors under the supervision of a senior psychiatrist who evaluated the face validity of the questions. Participants were asked to report

the type of their sleep complaints, the presence of significant distress and impairment due to insomnia symptoms, the weekly frequency of their sleep problems, the duration of their sleep difficulty, the presence of adequate opportunity for sleep, the presence of other sleep-wake disorders, mental disorders, medical disorders, or neurological disorders, the presence of substance abuse, and their medication use.

Intrusive Visual Imagery and Verbal Thought Questionnaires

McCarthy-Jones et al. (2012) formed the Intrusive Visual Imagery and Verbal Thought Questionnaires (IVIVTQ) to measure intrusive thoughts in the forms of visual imagery and verbal thoughts. Each questionnaire has ten items chosen and adapted from the White Bear Suppression Inventory (Wegner & Zanakos, 1994) and the Thought Control Ability Questionnaire (Luciano et al., 2005). The items are scored on a Likert scale ranging from 1 (Strongly disagree) to 5 (Strongly agree). Higher scores imply higher intrusive thinking. The Turkish adaptation of the scales was conducted by Türkarslan and Çınarbaş (2022). The results of exploratory and confirmatory factor analyses yielded that the Turkish form had a two-factor structure similar to the original scale. Internal consistency coefficients for visual imagery and verbal thoughts questionnaires were .93 and .94, respectively. The three-week test-retest reliability intra-class correlations were .71 for visual imagery and .83 for verbal thoughts questionnaires. In the current study, the IVIVTQ was used to measure intrusive visual imagery and verbal thoughts.

Pre-Sleep Arousal Scale

Nicassio et al. (1985) developed the Pre-sleep Arousal Scale (PSAS) to assess the level of arousal before sleep. Sixteen items are rated on a 5-point Likert scale, ranging from 1 (not at

all) to 5 (extremely). PSAS-16 consists of two factors, each with eight items measuring cognitive (PSAS-C) and somatic (PSAS-S) arousal in the pre-sleep interval. Türkarslan et al. (2022) adapted the PSAS to Turkish. Exploratory and confirmatory factor analyses indicated that the Turkish form with 16 items had a two-factor structure, as found in the original study. The Cronbach alpha value of the Turkish PSAS, PSAS-C, and PSAS-S were .92, .91, and .86, respectively. The intra-class correlation coefficients between baseline and three-week follow-up scores were found as .82, .82, and .71 for Turkish forms of PSAS, PSAS-C, and PSAS-S, respectively. In the current study, the PSAS was used to measure pre-sleep arousal.

The Object–Spatial Imagery and Verbal Questionnaire

Blazhenkova and Kozhevnikov (2009) developed the Object-Spatial Imagery and Verbal Questionnaire (OSIVQ) to measure object imagery, spatial imagery, and verbal cognitive styles. The OSIVQ comprises 45 items with a three-factor structure (object imagery, spatial imagery, and verbal). There are 15 items per subscale. The OSIVQ is scored on a 5-point Likert scale ranging from 1 (disagree) to 5 (agree). Nuhoğlu and Akkoyunlu (2012) adapted the OSIVQ to Turkish. Like the original scale, the confirmatory factor analysis found a three-factor structure. In the current study, the object imagery subscale of OSIVQ (OSIVQ-Visual) was used to assess visual imagery ability.

Insomnia Severity Index

Bastien et al. (2001) developed the Insomnia Severity Index (ISI) as a short screening measure of insomnia severity. The ISI consists of 7 items that assess insomnia symptoms, satisfaction with current sleep, impairment in daily functioning, observable impairment attributed to the sleep problem by others, and general level of distress caused by the sleep problems. Subjects

rate the ISI on a 5-point scale. Higher scores indicate a more severe case of insomnia. The ISI has a three-factor structure consisting of subscales for impact, severity, and satisfaction. Boysan et al. (2010) adapted the ISI to Turkish. The exploratory and confirmatory factor analyses showed that the Turkish version of the ISI comprised two factors which were daily functioning and sleep quality. The internal consistency coefficient of the Turkish form was .79. In the current study; the ISI was used to measure insomnia severity.

Procedure

Middle East Technical University's Human Subjects Ethics Committee granted ethical permission for the current study. The questionnaire package was delivered online to participants in a counterbalanced sequence via the Qualtrics Survey system. All participants were informed of the goal of the study, confidentiality protocols, and their ability to decline or discontinue participation in the survey at any moment during the course of the study. The online questionnaire took roughly 25 minutes to complete.

Statistical Analysis

The data analysis was conducted via SPSS 24.0 and JASP 0.17.3. There were no missing cases in the data. The assumptions of linearity, univariate and multivariate normality, homoscedasticity, and multicollinearity were evaluated by examining scatter plots, skewness (2.0) and kurtosis (7.0) values, and Mardia's test, residuals versus predicted plot, and tolerance (> .01) and VIF (< 10) values, respectively. The sample sizes exceeded the recommended sample size of 160, which was equivalent to 20 cases for each of the eight parameters estimated in the path model (Kline, 2015). A hypothesized path model was formed with intrusive visual

imagery and verbal thoughts as exogenous predictor variables and pre-sleep arousal and insomnia severity as endogenous variables. Using PROCESS Macro in SPSS (Hayes, 2017), the moderation analysis was conducted. A non-significant $\chi 2$ test, SRMR values lower than .08, RMSEA values lower than .10, and TLI and CFI values higher than .90 suggest an adequate model fit (Brown, 2015; Hair et al., 2019; Hu & Bentler, 1999; Schermelleh-Engel et al., 2003). Mediational roles of pre-sleep arousal were examined by testing the significance of indirect effects of intrusive visual imagery and verbal thoughts via pre-sleep arousal on insomnia severity. All path coefficients and indirect effects that are reported represent standardized values. We used the ".005" value as the threshold for statistical significance (Benjamin et al., 2018).

Results

Descriptive Statistics and Correlations Among the Variables

Descriptive statistics and Pearson correlations between the study variables can be seen in Table 2. Multiple outliers were examined via Mahalanobis distance. Two outliers were detected and excluded from further analyses. The total sample included 166 participants. In terms of experiencing difficulty falling asleep due to intrusive thoughts, 69 (41.57%) and 118 (70.48%) reported that they agree (4 on the scale) or strongly agree (5 on the scale) with Item 5 of intrusive visual imagery questionnaire ("I find it hard to sleep as images keep coming into my head") and Item 5 of intrusive verbal thoughts questionnaire ("I find it hard to sleep as verbal thoughts keep coming into my head"), respectively. The results of the correlation analysis yielded that pre-sleep arousal was significantly associated with intrusive visual imagery ($r = .54$, $p < .001$), intrusive verbal thoughts ($r = .45$, $p < .001$), visual imagery ability ($r = .25$, $p < .01$), and

insomnia severity (r = .44, p < .001). Moreover, visual imagery ability had a significant correlation with intrusive visual imagery. (r = .37, p < .001).

Table 2

The descriptive statistics and Pearson correlations among the variables of the model and internal consistency coefficients of the measures

Variables	1	2	3	4	*M*	*SD*	*Min*	*Max*	*α*
1. Intrusive Visual Imagery	-				33.30	9.92	10.00	50.00	.94
2. Intrusive Verbal Thoughts	.69***	-			36.96	8.87	10.00	50.00	.93
3. Visual Imagery Ability	.37***	.31***	-		51.60	12.52	19.00	75.00	.91
4. Pre-sleep Arousal	.54***	.45***	.25**	-	48.51	10.78	20.00	80.00	.88
5. Insomnia Severity	.35***	.28***	.16*	.44***	15.36	4.31	8.00	26.00	.66

Note. * p < .05, ** p < .01, *** p < .001.

Path Analysis

A multivariable path model linking intrusive visual imagery and intrusive verbal thoughts to pre-sleep arousal and pre-sleep arousal to insomnia severity was formed (see Figure 2). Data were screened for linearity, univariate and multivariate normality, homoscedasticity, and multicollinearity. All assumptions of the path analysis were met. Therefore, the path model was estimated using the maximum likelihood parameter estimates with standard error calculation. The path model had good fit values ($\chi^2(2)$ = 3.77, p = .15, SRMR = .05, RMSEA = .08, 90% CI = [.00,.19], TLI = .98, CFI = .98). The direct associations in the model indicated that intrusive visual imagery (β = .44, p < .001), but not intrusive verbal thoughts (β = .15, p = .07), significantly predicted pre-sleep arousal and that pre-sleep arousal (β = .44, p < .001) significantly predicted insomnia severity. Intrusive visual imagery and intrusive verbal thoughts

explained 29.90% of the variance in pre-sleep arousal, and the overall model was responsible for 19.30% of the variance in insomnia severity. In addition, the indirect effect of intrusive visual imagery via pre-sleep arousal on insomnia severity was significant (IE = .19, p < .001), while the indirect effect of intrusive verbal thoughts via pre-sleep arousal on insomnia severity was not significant (IE = .06, p = .08). The results indicated that Hypotheses 1, 3, and 4 were supported, while Hypothesis 2 was not supported.

A further path analysis was conducted by controlling age, gender, marital status, weekly exercise frequency, consuming black tea and coffee in the evening, smoking status, daily screen time, and pre-sleep screen time. No control variables significantly predicted pre-sleep arousal. The direct associations indicated that intrusive visual imagery (β = .39, p < .001), but not intrusive verbal thoughts (β = .15, p = .13), significantly predicted pre-sleep arousal and pre-sleep arousal (β = .44, p < .001) significantly predicted insomnia severity. The indirect effect of intrusive visual imagery via pre-sleep arousal on insomnia severity was significant (IE = .17, p =.002), while the indirect effect of intrusive verbal thoughts via pre-sleep arousal on insomnia severity was not significant (IE = .07, p = .14).

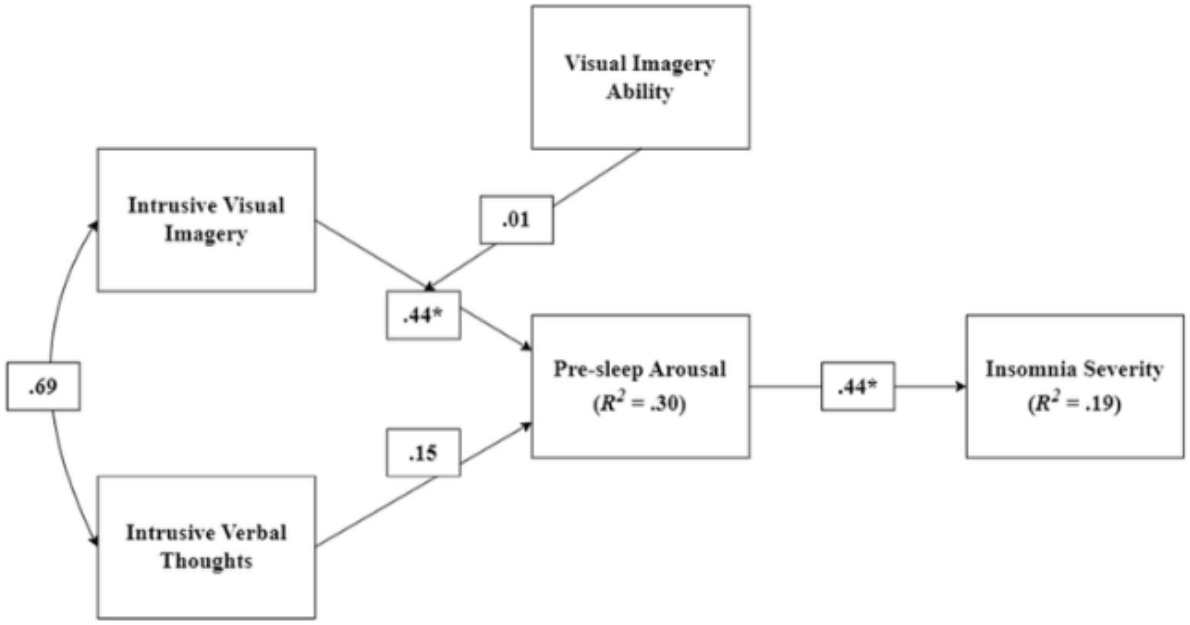
Moderation Analysis

A moderation analysis was conducted to examine whether visual imagery ability moderates the relationship between intrusive visual imagery and pre-sleep arousal. The model comprised intrusive visual imagery, visual imagery ability, the interaction of intrusive visual imagery, and visual imagery ability. The results yielded that visual imagery ability did not significantly moderate the relationship between intrusive visual imagery and pre-sleep arousal R^2 = .01, F

(1, 162) = 3.25, p = .07. Therefore, Hypothesis 5 was not supported. The overall path model, including moderation, can be seen in Figure 2.

Figure 2

The path model with moderation



Discussion

The current study tested five hypotheses regarding a model linking intrusive visual imagery, intrusive verbal thoughts, pre-sleep arousal, and insomnia severity. The results yielded that intrusive visual imagery, but not intrusive verbal thoughts, significantly predicted pre-sleep arousal, and pre-sleep arousal predicted insomnia severity. In addition, the moderator role of visual imagery ability on the relationship between intrusive visual imagery and pre-sleep arousal was not significant. Although previous studies investigated the relationship between intrusive thoughts and pre-sleep arousal (Tousignant et al., 2019; Yeh et al., 2015), none of the studies compared the predictive powers of intrusive visual imagery and intrusive verbal thoughts on insomnia severity via pre-sleep arousal in a clinical sample. The results of the path

analysis indicated that intrusive visual imagery, but not intrusive verbal thoughts, significantly predicted pre-sleep arousal. Intrusive visual imagery and intrusive verbal thoughts accounted for 29.90% of the variance in pre-sleep arousal. Moreover, the indirect effect of intrusive visual imagery on insomnia severity via pre-sleep arousal was also significant. Finally, the effect size of the path coefficient from intrusive visual imagery to pre-sleep arousal was higher than the effect size of the path coefficient from intrusive verbal thoughts to pre-sleep arousal. These findings are in line with previous studies (Cuthbert et al., 2003; Holmes et al., 2008; Holmes & Mathews, 2005; Lang, 1979; Vrana et al., 1986)**,** which showed that visual imagery conceives a more powerful effect on emotions and arousal levels than verbal processing.

One main finding of the current study was the differential effects of intrusive visual imagery and verbal thoughts on pre-sleep arousal. Previous studies yielded that visual imagery activates brain areas such as the frontal cortex, hippocampus, primary visual cortex, superior parietal lobule, the supplementary and cingulate eye fields, and the frontal eye fields (Dijkstra et al., 2017; Pearson, 2019; Winlove et al., 2018), while verbal thoughts were related with the left inferior frontal gyrus (Broca's area) and the cingulate cortex activities (Hurlburt et al., 2016; Kühn et al., 2013). It may be argued that activating several different brain regions pertaining to visual perception, visual imagery may incite a more realistic and potent simulation of anxiety-provoking events, leading to more substantial psychophysiological responses than verbal processing (Ji et al., 2016). Furthermore, the non-significant result regarding intrusive verbal thoughts may be due to the utilization of a scale measuring trait intrusive verbal thoughts rather than pre-sleep intrusive verbal thoughts or sample size (Lantz, 2013). These findings imply that intrusive visual imagery may have a more significant role in the exacerbation of insomnia severity by evoking stronger pre-sleep arousal compared to intrusive verbal thoughts.

The path analysis also showed that pre-sleep arousal significantly predicted insomnia severity. Unsurprisingly, this finding further supported the significant role that has been assigned to pre-sleep arousal in insomnia disorder (Buysse et al., 2011; Harvey, 2002; Lundh & Broman, 2000; Morin, 1993; Perogamvros et al., 2020; Spielman et al., 1987) and the studies showing that higher pre-sleep arousal was associated with higher insomnia severity (Broman & Hetta, 1994; Marques et al., 2016; Puzino et al., 2019; Ruivo Marques et al., 2018; Tousignant et al., 2019; Yeh et al., 2015). Sleep initiation entails the execution of cognitive and somatic dearousal processes, such as inhibition of cortical activity, a reduction in heart rate, a fall of core body temperature, and an increase of distal and proximal skin temperature (Lack et al., 2008; Perlis et al., 1997; Wuyts et al., 2012). Pre-sleep arousal prevents the automatic and involuntary transition from wakefulness to sleep by either evoking arousal or inhibiting dearousal processes (Espie, 2002).

In terms of the moderator role of visual imagery ability, the results indicated that visual imagery ability was not a significant moderator of the relationship between intrusive visual imagery and pre-sleep arousal. Several factors could explain this finding. In a previous fMRI study, the self-report vividness of imagery was significantly associated with the activation of the visual cortex (r = -.73) (Cui et al., 2007). In the current study, the construct of visual imagery ability was utilized instead of the vividness of imagery (Richardson, 1994). Visual imagery ability not only includes vividness of imagery but also predispositions to use visual imagery cognitive style. Only six items in OSIVQ-Visual are directly related to the vividness of imagery .That was the reason we hypothesized that visual imagery ability may also moderate the relationship between intrusive visual imagery and pre-sleep arousal. It could be argued that the interaction effect may not have been represented by the total score of visual imagery ability in the current study. Another possible explanation for this finding may be the existence of a ceiling effect regarding

visual imagery ability scores. In the current study, the lowest visual imagery ability score was 19. Considering that the lowest score of OSIVQ-Visual one can get is 15, we argued that the interaction effect may be present for extremely low visual imagery ability scores ranging from 15-18, which were absent in the current study. Finally, in a recent imagery extinction study in which the participants were asked to visually imagine the conditioned stimulus, which was previously associated with an electric shock, the researchers failed to find a significant moderator role for the vividness of imagery (Hoppe et al., 2022).. This finding may suggest that people with the low vividness of imagery could be affected by both positive (fear extinction) and negative (fear learning) outcomes of visual imagery as much as people with high vividness of imagery, meaning the vividness of imagery does not moderate the effects of visual imagery. This may also be true for visual imagery ability, a construct that comprises the vividness of the visual imagery.

We argue that the role of intrusive visual imagery in the initiation and perpetuation of insomnia disorder can be understood in the framework of the evolutionary-emotional hypothesis of insomnia. Perogamvros et al. (2020) hypothesized that acute insomnia was advantageous in the evolutionary past for fear-eliciting ancestral threats, which were frequently real and actual. However, threats in modern life are typically associated with anticipated threats and are experienced in the form of anxiety. Independently of the nature of the stressor (real or perceived), acute insomnia, which is characterized by hyperarousal and heightened alertness, may serve as an adaptive response to these stressors by activation of the "fight or flight" response (McNamara & Auerbach, 2001; Perogamvros et al., 2020). Several lines of research indicate that acute insomnia may have adaptive functions that help mammals deal with short-term evolutionary threats (Capellini et al., 2010; Haig, 2014; Hill et al., 2016; Lesku et al., 2008; Perlis et al., 2020; Vargas et al., 2020). On the other hand, it seems that chronic insomnia

is characterized by the failure of such functions, as it would reflect a pathological process where hyperarousal has become self-perpetuating (via conditioning), even in the absence of the initial threat (Perogamvros et al., 2020).

In the framework of the evolutionary-emotional hypothesis, Perogamvros et al. (2020) asserted that hyperarousal and wakefulness in an acute insomnia period, which is perpetuated by fear conditioning of sleep-related stimuli with arousal, could develop into chronic insomnia due to the failure of fear extinction even after the threat disperses. Recent studies found that patients with insomnia disorder have heightened fear conditioning (Wassing et al., 2019) and a delay or failure of fear extinction (Seo et al., 2018), supporting the evolutionary-emotional hypothesis. Thus, conditioned stimuli (CS), such as the bed, bedroom, or nighttime, can induce arousal and wakefulness (CR, conditioned response) in these patients because of fear conditioning. These associations are retained in these patients due to the regular presence of an unconditioned aversive stimulus while in bed.

We argue that pre-sleep intrusive visual imagery of past and future threats simulates fearful situations and may maintain the fear response in chronic insomnia. More specifically, past and future threats can be anticipated or remembered in the form of intrusive visual imagery, which corresponds to the simulation of these threats (Ji et al., 2016). Therefore, in cases of chronic insomnia, several initially neutral sleep-related stimuli (e.g., sleep, bed, bedtime, bedroom) are associated with pre-sleep intrusive visual imagery (US) in bed and become conditioned (CS) (Mertens et al., 2020). Following the formation of fear conditioning, sleep-related stimuli (CS) can readily induce arousal and wakefulness (CR). Ultimately, the prolonged and unresolved fear responses activate a psychophysiological survival model characterized by hyperarousal and chronic insomnia symptoms. Moreover, intrusive visual imagery (US) regularly occurring in

the pre-sleep period may maintain fear learning and contribute to the delay and failure of fear extinction.

Our hypothesis regarding intrusive visual imagery having an important role in chronic insomnia is based on three assumptions. First, intrusive visual imagery may create an experience that mimics visual perception. Second, mental imagery of a stimulus can serve as a substitute for real-life unconditioned stimulus in fear conditioning. Third, intrusive visual imagery is usually present in cases of insomnia disorder. Overall, evidence indicated that all these three assumptions have been supported by previous studies. Brain imagining studies yielded that visual imagery and visual perception utilize similar brain areas (Kosslyn et al., 1997), processes (Ganis, 2013), and produce closely related patterns of brain activities (Albers et al., 2013; Lee et al., 2012). As a result, visual mental imagery of a stimulus is able to evoke psychophysiological arousal, such as increased heart rate, elevated skin conductance, elevated startle blink reflex, and acceleration of respiratory rate (Ji et al., 2016). Moreover, a great deal of previous research has shown that visual imagery of CS, US, or CS-US contingency can function similarly to the real-life administration of CS, US, or CS-US contingency in fear conditioning (Dadds et al., 1997; Mertens et al., 2020), meaning that the visual imagery of US or CS-US substitutes the real-life administrations of US or CS (Joos et al., 2012; Krypotos et al., 2019; Mueller et al., 2019). Finally, previous studies by Nelson and Harvey (2002, 2003b, 2003a) found that insomnia patients reported more pre-sleep negative visual imagery than normal sleepers. To sum up, considering the overall evidence, it is reasonable to argue that intrusive visual imagery of past and future threats in the pre-sleep period may both evoke cognitive and somatic arousal and also contribute to the formation of fear conditioning that associates sleep-related stimuli with cognitive and somatic arousal.

The current study has a number of potential clinical implications. According to the findings, interventions or techniques that may alleviate specifically intrusive visual imagery may improve the sleep quality patients with insomnia disorder. Several methods were proposed to manage pre-sleep intrusive thoughts, such as mindfulness meditation and expressive writing (Harvey, 2005). These interventions led to promising improvements in several sleep parameters (Gong et al., 2016; Harvey & Farrell, 2003; Mooney et al., 2009). Moreover, previous studies investigated the effects of imagery interventions on sleep and showed that these techniques (e.g., imagery rescripting) resulted in fewer awakenings (Morin & Azrin, 1987; Woolfolk & McNulty, 1983), shorter sleep-onset latency (Harvey & Payne, 2002), and lower cognitive and somatic pre-sleep arousal compared to control groups (Molen et al., 2013). Finally, several studies have indicated that visuospatial tasks seizing visual working memory may interrupt IVI (Casement & Swanson, 2012; Schwartz et al., 2022). Future studies are needed to investigate the effects of imagery techniques and visuospatial tasks on pre-sleep intrusive thoughts, arousal, and insomnia symptoms.

The current study has certain limitations. First of all, path analysis can only refute a causal model (Streiner, 2005) despite the common misconception that its usage implies causality. Since the study was a cross-sectional one, further experimental and longitudinal studies are required to replicate the findings and examine the causal relationship between the variables of the current study. Second, we identified people with insomnia disorder by using self-report questionnaires and the ISI scores. The identification of people with insomnia disorder may be executed more accurately by face-to-face clinical interviews. Third, the participants were recruited via social media and the Internet. Moreover, the majority of the study sample (75%) comprised young female college students. These aspects limit the findings' generalizability. Therefore, future research utilizing more representative in terms of gender, age, and degree of

education is needed. In the current study, the subscales utilized to evaluate intrusive visual imagery and intrusive verbal thoughts were trait measures. Using measures that directly assess pre-sleep intrusive visual imagery and pre-sleep intrusive verbal thoughts may be a much more accurate method to examine the association between intrusive visual imagery, intrusive verbal thinking, pre-sleep arousal, and insomnia severity. There are currently no such scales in use. Therefore, there is a need to develop measures specifically assessing pre-sleep intrusive visual imagery and intrusive verbal thoughts.

To conclude, we tested a path model comprising intrusive visual imagery, intrusive verbal thoughts, pre-sleep arousal, and insomnia severity in a sample of participants who met the DSM-5 criteria for insomnia disorder. We also assessed the moderator role of visual imagery ability on the relationship between intrusive visual imagery and pre-sleep arousal. The results indicated that intrusive visual imagery may be a significant factor in exacerbating insomnia severity by inducing pre-sleep arousal. In addition, the level of visual imagery ability did not moderate the effects of intrusive visual imagery on pre-sleep arousal, suggesting that both individuals with low and high imagery ability may be vulnerable to the adverse effects of intrusive visual imagery.

References

Agren, T., Hoppe, J. M., Singh, L., Holmes, E. A., & Rosén, J. (2021). The neural basis of Tetris gameplay: Implicating the role of visuospatial processing. *Current Psychology*. https://doi.org/10.1007/s12144-021-02081-z

Albers, A. M., Kok, P., Toni, I., Dijkerman, H. C., & de Lange, F. P. (2013). Shared Representations for Working Memory and Mental Imagery in Early Visual Cortex. *Current Biology*, *23*(15), 1427–1431. https://doi.org/10.1016/j.cub.2013.05.065

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). American Psychiatric Association.

Baglioni, C., Spiegelhalder, K., Lombardo, C., & Riemann, D. (2010). Sleep and emotions: A focus on insomnia. *Sleep Medicine Reviews*, *14*(4), 227–238. https://doi.org/10.1016/j.smrv.2009.10.007

Baker, L. D., Baldwin, D. S., & Garner, M. (2015). Daytime intrusive thoughts and subjective insomnia symptoms. *Psychiatry Research*, *229*(3), 1038–1042. https://doi.org/10.1016/j.psychres.2015.02.022

Bastien, C. H., Vallières, A., & Morin, C. M. (2001). Validation of the Insomnia Severity Index as an outcome measure for insomnia research. *Sleep Medicine*, *2*(4), 297–307. https://doi.org/10.1016/S1389-9457(00)00065-4

Benbir, G., Demir, A. U., Aksu, M., Ardic, S., Firat, H., Itil, O., Ozgen, F., Yılmaz, H., & Karadeniz, D. (2015). Prevalence of insomnia and its clinical correlates in a general population in Turkey. *Psychiatry and Clinical Neurosciences*, *69*(9), 543–552. https://doi.org/10.1111/pcn.12252

Benjamin, D. J., Berger, J. O., Johannesson, M., Nosek, B. A., Wagenmakers, E.-J., Berk, R., Bollen, K. A., Brembs, B., Brown, L., Camerer, C., Cesarini, D., Chambers, C. D.,

Clyde, M., Cook, T. D., De Boeck, P., Dienes, Z., Dreber, A., Easwaran, K., Efferson, C., … Johnson, V. E. (2018). Redefine statistical significance. *Nature Human Behaviour*, *2*(1), Article 1. https://doi.org/10.1038/s41562-017-0189-z

Blazhenkova, O., & Kozhevnikov, M. (2009). The new object-spatial-verbal cognitive style model: Theory and measurement. *Applied Cognitive Psychology*, *23*(5), 638–663. https://doi.org/10.1002/acp.1473

Bootzin, R. R. (1972). Stimulus Control Treatment for Insomnia: [Data set]. In *Proceedings of the American Psychological Association* (Vol. 7, pp. 395–396). https://doi.org/10.1037/e465522008-198

Borkovec, T. D. (1982). Insomnia. *Journal of Consulting and Clinical Psychology*, *50*(6), 880–895. https://doi.org/10.1037/0022-006X.50.6.880

Borkovec, T. D., Ray, W. J., & Stöber, J. (1998). Worry: A cognitive phenomenon intimately linked to affective, physiological, and interpersonal behavioral processes. *Cognitive Therapy and Research*, *22*(6), 561–576. https://doi.org/10.1023/A:1018790003416

Brewin, C. R., Gregory, J. D., Lipton, M., & Burgess, N. (2010). Intrusive Images in Psychological Disorders. *Psychological Review*, *117*(1), 210–232. https://doi.org/10.1037/a0018113

Broman, J.-E., & Hetta, J. (1994). Perceived pre-sleep arousal in patients with persistent psychophysiologic and psychiatric insomnia. *Nordic Journal of Psychiatry*, *48*(3), 203–207.

Brown, T. A. (2015). *Confirmatory Factor Analysis for Applied Research, Second Edition*. Guilford Publications.

Buysse, D. J., Germain, A., Hall, M., Monk, T. H., & Nofzinger, E. A. (2011). A neurobiological model of insomnia. *Drug Discovery Today: Disease Models*, *8*(4), 129–137. https://doi.org/10.1016/j.ddmod.2011.07.002

Cao, X.-L., Wang, S.-B., Zhong, B.-L., Zhang, L., Ungvari, G. S., Ng, C. H., Li, L., Chiu, H. F. K., Lok, G. K. I., Lu, J.-P., Jia, F.-J., & Xiang, Y.-T. (2017). The prevalence of insomnia in the general population in China: A meta-analysis. *PLOS ONE*, *12*(2), e0170772. https://doi.org/10.1371/journal.pone.0170772

Capellini, I., Preston, B. T., McNamara, P., Barton, R. A., & Nunn, C. L. (2010). Ecological constraints on mammalian sleep architecture. In *Evolution of sleep: Phylogenetic and functional perspectives* (pp. 12–33). Cambridge University Press.

Casement, M. D., & Swanson, L. M. (2012). A meta-analysis of imagery rehearsal for post-trauma nightmares: Effects on nightmare frequency, sleep quality, and posttraumatic stress. *Clinical Psychology Review*, *32*(6), 566–574. https://doi.org/10.1016/j.cpr.2012.06.002

Cui, X., Jeter, C. B., Yang, D., Montague, P. R., & Eagleman, D. M. (2007). Vividness of mental imagery: Individual variability can be measured objectively. *Vision Research*, *47*(4), 474–478. https://doi.org/10.1016/j.visres.2006.11.013

Cuthbert, B. N., Lang, P. J., Strauss, C., Drobes, D., Patrick, C. J., & Bradley, M. M. (2003). The psychophysiology of anxiety disorder: Fear memory imagery. *Psychophysiology*, *40*(3), 407–422. https://doi.org/10.1111/1469-8986.00043

Dadds, M. R., Bovbjerg, D. H., Redd, W. H., & Cutmore, T. R. H. (1997). Imagery in human classical conditioning. *Psychological Bulletin*, *122*(1), 89–103. https://doi.org/10.1037/0033-2909.122.1.89

Dijkstra, N., Bosch, S. E., & Gerven, M. A. J. van. (2017). Vividness of Visual Imagery Depends on the Neural Overlap with Perception in Visual Areas. *Journal of Neuroscience*, *37*(5), 1367–1373. https://doi.org/10.1523/JNEUROSCI.3022-16.2016

Espie, C. A. (2002). Insomnia: Conceptual Issues in the Development, Persistence, and Treatment of Sleep Disorder in Adults. *Annual Review of Psychology*, *53*(1), 215–243. https://doi.org/10.1146/annurev.psych.53.100901.135243

Ford, E. S., Cunningham, T. J., Giles, W. H., & Croft, J. B. (2015). Trends in insomnia and excessive daytime sleepiness among US adults from 2002 to 2012. *Sleep Medicine*, *16*(3), 372–378. https://doi.org/10.1016/j.sleep.2014.12.008

Fortier-Brochu, É., Beaulieu-Bonneau, S., Ivers, H., & Morin, C. M. (2012). Insomnia and daytime cognitive performance: A meta-analysis. *Sleep Medicine Reviews*, *16*(1), 83–94. https://doi.org/10.1016/j.smrv.2011.03.008

Fulford, J., Milton, F., Salas, D., Smith, A., Simler, A., Winlove, C., & Zeman, A. (2018). The neural correlates of visual imagery vividness – An fMRI study and literature review. *Cortex*, *105*, 26–40. https://doi.org/10.1016/j.cortex.2017.09.014

Ganis, G. (2013). Visual Mental Imagery. In S. Lacey & R. Lawson (Eds.), *Multisensory Imagery* (pp. 9–28). Springer. https://doi.org/10.1007/978-1-4614-5879-1_2

Godet-Cayré, V., Pelletier-Fleury, N., Le Vaillant, M., Dinet, J., Massuel, M.-A., & Léger, D. (2006). Insomnia and Absenteeism at Work. Who Pays the Cost? *Sleep*, *29*(2), 179–184. https://doi.org/10.1093/sleep/29.2.179

Gong, H., Ni, C.-X., Liu, Y.-Z., Zhang, Y., Su, W.-J., Lian, Y.-J., Peng, W., & Jiang, C.-L. (2016). Mindfulness meditation for insomnia: A meta-analysis of randomized controlled trials. *Journal of Psychosomatic Research*, *89*, 1–6. https://doi.org/10.1016/j.jpsychores.2016.07.016

Grégoire, L., & Greening, S. G. (2019). Opening the reconsolidation window using the mind's eye: Extinction training during reconsolidation disrupts fear memory expression following mental imagery reactivation. *Cognition*, *183*, 277–281. https://doi.org/10.1016/j.cognition.2018.12.001

Hagenaars, M. A., Brewin, C. R., van Minnen, A., Holmes, E. A., & Hoogduin, K. A. L. (2010). Intrusive images and intrusive thoughts as different phenomena: Two experimental studies. *Memory*, *18*(1), 76–84. https://doi.org/10.1080/09658210903476522

Hagenaars, M. A., & Holmes, E. A. (2012). Mental Imagery in Psychopathology: Another Step; Editorial for the special issue of Journal of Experimental Psychopathology. *Journal of Experimental Psychopathology*, *3*(2), 121–126. https://doi.org/10.1177/204380871200300201

Haig, D. (2014). Troubled sleepNight waking, breastfeeding and parent–offspring conflict. *Evolution, Medicine, and Public Health*, *2014*(1), 32–39. https://doi.org/10.1093/emph/eou005

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate data analysis*. Cengage Learning.

Hall, C., Pongrac, J., & Buckholz, E. (1985). The measurement of imagery ability. *Human Movement Science*, *4*(2), 107–118.

Hall, M., Buysse, D. J., Nowell, P. D., Nofzinger, E. A., Houck, P., Reynolds, C. F. I., & Kupfer, D. J. (2000). Symptoms of Stress and Depression as Correlates of Sleep in Primary Insomnia. *Psychosomatic Medicine*, *62*(2), 227–230.

Harvey, A. G. (2000). Pre-sleep cognitive activity: A comparison of sleep-onset insomniacs and good sleepers. *The British Journal of Clinical Psychology*, *39*(3), 275–286. https://doi.org/10.1348/014466500163284

Harvey, A. G. (2002). A cognitive model of insomnia. *Behaviour Research and Therapy*, *40*(8), 869–893. https://doi.org/10.1016/S0005-7967(01)00061-4

Harvey, A. G. (2005). Unwanted Intrusive Thoughts in Insomnia. In *Intrusive thoughts in clinical disorders: Theory, research, and treatment* (pp. 86–118). Guilford Press.

Harvey, A. G., & Farrell, C. (2003). The Efficacy of a Pennebaker-Like Writing Intervention for Poor Sleepers. *Behavioral Sleep Medicine*, *1*(2), 115–124. https://doi.org/10.1207/S15402010BSM0102_4

Harvey, A. G., & Payne, S. (2002). The management of unwanted pre-sleep thoughts in insomnia: Distraction with imagery versus general distraction. *Behaviour Research and Therapy*, *40*(3), 267–277.

Hayes, A. F. (2017). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford publications.

Hertenstein, E., Feige, B., Gmeiner, T., Kienzler, C., Spiegelhalder, K., Johann, A., Jansson-Fröjmark, M., Palagini, L., Rücker, G., Riemann, D., & Baglioni, C. (2019). Insomnia as a predictor of mental disorders: A systematic review and meta-analysis. *Sleep Medicine Reviews*, *43*, 96–105. https://doi.org/10.1016/j.smrv.2018.10.006

Hill, T. D., Trinh, H. N., Wen, M., & Hale, L. (2016). Perceived neighborhood safety and sleep quality: A global analysis of six countries. *Sleep Medicine*, *18*, 56–60. https://doi.org/10.1016/j.sleep.2014.12.003

Holmes, E. A., & Mathews, A. (2005). Mental imagery and emotion: A special relationship? *Emotion (Washington, D.C.)*, *5*(4), 489–497. https://doi.org/10.1037/1528-3542.5.4.489

Holmes, E. A., Mathews, A., Mackintosh, B., & Dalgleish, T. (2008). The causal effect of mental imagery on emotion assessed using picture-word cues. *Emotion*, *8*(3), 395–409. https://doi.org/10.1037/1528-3542.8.3.395

Hoppe, J. M., Holmes, E. A., & Agren, T. (2022). Imaginal extinction and the vividness of mental imagery: Exploring the reduction of fear within the mind's eye. *Behavioural Brain Research*, *418*, 113632. https://doi.org/10.1016/j.bbr.2021.113632

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Hurlburt, R. T., Alderson-Day, B., Kühn, S., & Fernyhough, C. (2016). Exploring the Ecological Validity of Thinking on Demand: Neural Correlates of Elicited vs. Spontaneously Occurring Inner Speech. *PLOS ONE*, *11*(2), e0147932. https://doi.org/10.1371/journal.pone.0147932

Jansson-Fröjmark, M., & Norell-Clarke, A. (2012). Psychometric properties of the Pre-Sleep Arousal Scale in a large community sample. *Journal of Psychosomatic Research*, *72*(2), 103–110. https://doi.org/10.1016/j.jpsychores.2011.10.005

Ji, J. L., Heyes, S. B., MacLeod, C., & Holmes, E. A. (2016). Emotional Mental Imagery as Simulation of Reality: Fear and Beyond—A Tribute to Peter Lang. *Behavior Therapy*, *47*(5), 702–719. https://doi.org/10.1016/j.beth.2015.11.004

Joos, E., Vansteenwegen, D., & Hermans, D. (2012). Post-acquisition repetitive thought in fear conditioning: An experimental investigation of the effect of CS-US-rehearsal.

Journal of Behavior Therapy and Experimental Psychiatry, *43*(2), 737–744. https://doi.org/10.1016/j.jbtep.2011.10.011

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

Kline, R. B. (2015). *Principles and Practice of Structural Equation Modeling, Fourth Edition*. Guilford Publications.

Kosslyn, S. M., Thompson, W. L., & Alpert, N. M. (1997). Neural Systems Shared by Visual Imagery and Visual Perception: A Positron Emission Tomography Study. *NeuroImage*, *6*(4), 320–334. https://doi.org/10.1006/nimg.1997.0295

Krypotos, A.-M., Mertens, G., Leer, A., & Engelhard, I. (2019). *Imagine avoidance: Induction of conditioned avoidance via mental imagery*. PsyArXiv. https://doi.org/10.31234/osf.io/ad2gf

Kühn, S., Schmiedek, F., Brose, A., Schott, B. H., Lindenberger, U., & Lövden, M. (2013). The neural representation of intrusive thoughts. *Social Cognitive and Affective Neuroscience*, *8*(6), 688–693. https://doi.org/10.1093/scan/nss047

Lack, L. C., Gradisar, M., Van Someren, E. J. W., Wright, H. R., & Lushington, K. (2008). The relationship between insomnia and body temperatures. *Sleep Medicine Reviews*, *12*(4), 307–317. https://doi.org/10.1016/j.smrv.2008.02.003

Lang, P. J. (1979). A Bio-Informational Theory of Emotional Imagery. *Psychophysiology*, *16*(6), 495–512. https://doi.org/10.1111/j.1469-8986.1979.tb01511.x

Lantz, B. (2013). The large sample size fallacy. *Scandinavian Journal of Caring Sciences*, *27*(2), 487–492. https://doi.org/10.1111/j.1471-6712.2012.01052.x

LeBlanc, M., Beaulieu-Bonneau, S., Mérette, C., Savard, J., Ivers, H., & Morin, C. M. (2007). Psychological and health-related quality of life factors associated with insomnia in a population-based sample. *Journal of Psychosomatic Research*, *63*(2), 157–166. https://doi.org/10.1016/j.jpsychores.2007.03.004

Lee, S.-H., Kravitz, D. J., & Baker, C. I. (2012). Disentangling visual imagery and perception of real-world objects. *NeuroImage*, *59*(4), 4064–4073. https://doi.org/10.1016/j.neuroimage.2011.10.055

Léger, D., & Bayon, V. (2010). Societal costs of insomnia. *Sleep Medicine Reviews*, *14*(6), 379–389. https://doi.org/10.1016/j.smrv.2010.01.003

Lesku, J. A., Roth, T. C., Rattenborg, N. C., Amlaner, C. J., & Lima, S. L. (2008). Phylogenetics and the correlates of mammalian sleep: A reappraisal. *Sleep Medicine Reviews*, *12*(3), 229–244. https://doi.org/10.1016/j.smrv.2007.10.003

Luciano, J. V., Algarabel, S., Tomás, J. M., & Martínez, J. L. (2005). Development and validation of the thought control ability questionnaire. *Personality and Individual Differences*, *38*(5), 997–1008. https://doi.org/10.1016/j.paid.2004.06.020

Lundh, L.-G., & Broman, J.-E. (2000). Insomnia as an interaction between sleep-interfering and sleep-interpreting processes. *Journal of Psychosomatic Research*, *49*(5), 299–310. https://doi.org/10.1016/S0022-3999(00)00150-1

Marques, D. R., Allen Gomes, A., Clemente, V., Santos, J. M., & Castelo-Branco, M. (2015). Hyperarousal and failure to inhibit wakefulness in primary insomnia: “Birds of a feather”?: Processes in insomnia. *Sleep and Biological Rhythms*, *13*(3), 219–228. https://doi.org/10.1111/sbr.12115

Marques, D. R., Gomes, A. A., Ferreira, M. F., & de Azevedo, M. H. P. (2016). Don't worry, sleep well: Predictors of sleep loss over worry. *Sleep and Biological Rhythms*, *14*(3), 309–318. https://doi.org/10.1007/s41105-016-0060-z

McCarthy-Jones, S., Knowles, R., & Rowse, G. (2012). More than words? Hypomanic personality traits, visual imagery and verbal thought in young adults. *Consciousness and Cognition*, *21*(3), 1375–1381. https://doi.org/10.1016/j.concog.2012.07.004

McNamara, P., & Auerbach, S. (2001). Evolutionary medicine of sleep disorders: Toward a science of sleep duration. In P. McNamara, R. A. Barton, & C. L. Nunn (Eds.), *Evolution of Sleep* (1st ed., pp. 107–122). Cambridge University Press. https://doi.org/10.1017/CBO9780511642074.006

Mertens, G., Krypotos, A.-M., & Engelhard, I. M. (2020). A review on mental imagery in fear conditioning research 100 years since the 'Little Albert' study. *Behaviour Research and Therapy*, *126*, 103556. https://doi.org/10.1016/j.brat.2020.103556

Molen, Y., Santos, G., Carvalho, L., Prado, L., & Prado, G. (2013). Pre-sleep worry decrease by adding reading and guided imagery to insomnia treatment. *Sleep Medicine*, *14*, e210–e211. https://doi.org/10.1016/j.sleep.2013.11.504

Mooney, P., Espie, C. A., & Broomfield, N. M. (2009). An Experimental Assessment of a Pennebaker Writing Intervention in Primary Insomnia. *Behavioral Sleep Medicine*, *7*(2), 99–105. https://doi.org/10.1080/15402000902762386

Morin, C. M. (1993). *Insomnia: Psychological assessment and management* (pp. xvii, 238). Guilford Press.

Morin, C. M., & Azrin, N. H. (1987). Stimulus control and imagery training in treating sleep-maintenance insomnia. *Journal of Consulting and Clinical Psychology*, *55*(2), 260.

Morin, C. M., Drake, C. L., Harvey, A. G., Krystal, A. D., Manber, R., Riemann, D., & Spiegelhalder, K. (2015). Insomnia disorder. *Nature Reviews. Disease Primers*, *1*, 15026. https://doi.org/10.1038/nrdp.2015.26

Mueller, E. M., Sperl, M. F. J., & Panitz, C. (2019). Aversive Imagery Causes De Novo Fear Conditioning. *Psychological Science*, *30*(7), 1001–1015. https://doi.org/10.1177/0956797619842261

Nelson, J., & Harvey, A. G. (2002). The differential functions of imagery and verbal thought in insomnia. *Journal of Abnormal Psychology*, *111*(4), 665–669. https://doi.org/10.1037/0021-843X.111.4.665

Nelson, J., & Harvey, A. G. (2003a). An exploration of pre-sleep cognitive activity in insomnia: Imagery and verbal thought. *British Journal of Clinical Psychology*, *42*(3), 271–288. https://doi.org/10.1348/01446650360703384

Nelson, J., & Harvey, A. G. (2003b). Pre-sleep imagery under the microscope: A comparison of patients with insomnia and good sleepers. *Behaviour Research and Therapy*, *41*(3), 273–284. https://doi.org/10.1016/S0005-7967(02)00010-4

Nicassio, P. M., Mendlowitz, D. R., Fussell, J. J., & Petras, L. (1985). The phenomenology of the pre-sleep state: The development of the pre-sleep arousal scale. *Behaviour Research and Therapy*, *23*(3), 263–271. https://doi.org/10.1016/0005-7967(85)90004-X

Nota, J. A., & Coles, M. E. (2015). Duration and Timing of Sleep are Associated with Repetitive Negative Thinking. *Cognitive Therapy and Research*, *39*(2), 253–261. https://doi.org/10.1007/s10608-014-9651-7

Nuhoğlu, P., & Akkoyunlu, B. (2012). Nesnesel—Uzamsal İmgeleme Ve Sözel Bilişsel Stil Ölçeği'nin Türkçe'ye Uyarlanma Çalışması. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 42,* 299–309.

Ohayon, M. M., & Hong, S.-C. (2002). Prevalence of insomnia and associated factors in South Korea. *Journal of Psychosomatic Research*, *53*(1), 593–600. https://doi.org/10.1016/S0022-3999(02)00449-X

Palagini, L., Mauri, M., Dell'Osso, L., Riemann, D., & Drake, C. L. (2016). Trait- and pre-sleep-state-dependent arousal in insomnia disorders: What role may sleep reactivity and sleep-related metacognitions play? A pilot study. *Sleep Medicine, 25,* 42–48. https://doi.org/10.1016/j.sleep.2016.07.020

Palagini, L., Moretto, U., Dell'Osso, L., & Carney, C. (2017). Sleep-related cognitive processes, arousal, and emotion dysregulation in insomnia disorder: The role of insomnia-specific rumination. *Sleep Medicine, 30*, 97–104. https://doi.org/10.1016/j.sleep.2016.11.004

Pearson, J. (2019). The human imagination: The cognitive neuroscience of visual mental imagery. *Nature Reviews Neuroscience, 20*(10), 624–634. https://doi.org/10.1038/s41583-019-0202-9

Perlis, M. L., Ellis, J. G., Kloss, J. D., & Dieter, W. R. (2016). Etiology and Pathophysiology of Insomnia. In *Principles and Practice of Sleep Medicine* (6th ed., pp. 769–784). Elsevier.

Perlis, M. L., Giles, D. E., Mendelson, W. B., Bootzin, R. R., & Wyatt, J. K. (1997). Psychophysiological insomnia: The behavioural model and a neurocognitive perspective. *Journal of Sleep Research*, *6*(3), 179–188. https://doi.org/10.1046/j.1365-2869.1997.00045.x

Perlis, M. L., Vargas, I., Ellis, J. G., Grandner, M. A., Morales, K. H., Gencarelli, A., Khader, W., Kloss, J. D., Gooneratne, N. S., & Thase, M. E. (2020). The Natural History of Insomnia: The incidence of acute insomnia and subsequent progression to chronic insomnia or recovery in good sleeper subjects. *Sleep*, *43*(6), zsz299. https://doi.org/10.1093/sleep/zsz299

Perogamvros, L., Castelnovo, A., Samson, D., & Dang-Vu, T. T. (2020). Failure of fear extinction in insomnia: An evolutionary perspective. *Sleep Medicine Reviews*, *51*, 101277. https://doi.org/10.1016/j.smrv.2020.101277

Pigeon, W. R., Bishop, T. M., & Krueger, K. M. (2017). Insomnia as a Precipitating Factor in New Onset Mental Illness: A Systematic Review of Recent Findings. *Current Psychiatry Reports*, *19*(8), 44. https://doi.org/10.1007/s11920-017-0802-x

Pillai, V., & Drake, C. L. (2015). Sleep and Repetitive Thought. In *Sleep and Affect* (pp. 201–225). Elsevier. https://doi.org/10.1016/B978-0-12-417188-6.00010-4

Puzino, K., Amatrudo, G., Sullivan, A., Vgontzas, A. N., & Fernandez-Mendoza, J. (2019). Clinical Significance and Cut-Off Scores for the Pre-Sleep Arousal Scale in Chronic Insomnia Disorder: A Replication in a Clinical Sample. *Behavioral Sleep Medicine*, *18*(6), 705–718. https://doi.org/10.1080/15402002.2019.1669604

Rachman, S., & de Silva, P. (1978). Abnormal and normal obsessions. *Behaviour Research and Therapy*, *16*(4), 233–248. https://doi.org/10.1016/0005-7967(78)90022-0

Reddan, M. C., Wager, T. D., & Schiller, D. (2018). Attenuating Neural Threat Expression with Imagination. *Neuron*, *100*(4), 994-1005.e4. https://doi.org/10.1016/j.neuron.2018.10.047

Richardson, A. (1994). *Individual defferences in imaging: Their measurement, origins, and consequences*. Baywood Publishing Company.

https://eds.s.ebscohost.com/eds/detail/detail?vid=0&sid=ed9c53fa-b2ce-4df0-a815-7855c50fe3d8%40redis&bdata=JkF1dGhUeXBlPWlwJnNpdGU9ZWRzLWxpdmU%3d#AN=16262959&db=asn

Riemann, D., Baglioni, C., Bassetti, C., Bjorvatn, B., Groselj, L. D., Ellis, J. G., Espie, C. A., Garcia-Borreguero, D., Gjerstad, M., Gonçalves, M., Hertenstein, E., Jansson-Fröjmark, M., Jennum, P. J., Leger, D., Nissen, C., Parrino, L., Paunio, T., Pevernagie, D., Verbraecken, J., … Spiegelhalder, K. (2017). European guideline for the diagnosis and treatment of insomnia. *Journal of Sleep Research*, *26*(6), 675–700. https://doi.org/10.1111/jsr.12594

Rosekind, M. R., & Gregory, K. B. (2010). Insomnia risks and costs: Health, safety, and quality of life. *The American Journal of Managed Care*, *16*(8), 617–626.

Ruivo Marques, D., Allen Gomes, A., Nicassio, P. M., & Azevedo, M. H. P. de. (2018). Pre-Sleep Arousal Scale (PSAS): Psychometric study of a European Portuguese version. *Sleep Medicine*, *43*, 60–65. https://doi.org/10.1016/j.sleep.2017.10.014

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research Online*, *8*(2), 23–74.

Schmid, C., & Steil, R. (2019). Cognitive restructuring and imagery modification in insomnia disorder: A feasibility study. *Sleep and Hypnosis - International Journal*, 233–241. https://doi.org/10.5350/Sleep.Hypn.2019.21.0191

Schutte-Rodin Sharon, Broch Lauren, Buysse Daniel, Dorsey Cynthia, & Sateia Michael. (2008). Clinical Guideline for the Evaluation and Management of Chronic Insomnia in Adults. *Journal of Clinical Sleep Medicine*, *04*(05), 487–504. https://doi.org/10.5664/jcsm.27286

Schwartz, S., Clerget, A., & Perogamvros, L. (2022). Enhancing imagery rehearsal therapy for nightmares with targeted memory reactivation. *Current Biology: CB*, *32*(22), 4808-4816.e4. https://doi.org/10.1016/j.cub.2022.09.032

Seo, J., Moore, K. N., Gazecki, S., Bottary, R. M., Milad, M. R., Song, H., & Pace-Schott, E. F. (2018). Delayed fear extinction in individuals with insomnia disorder. *Sleep*, *41*(8). https://doi.org/10.1093/sleep/zsy095

Sheikh, A. A. (1976). Treatment of Insomnia through Eidetic Imagery: A New Technique. *Perceptual and Motor Skills*, *43*(3), 994–994. https://doi.org/10.2466/pms.1976.43.3.994

Spielman, A. J., Caruso, L. S., & Glovinsky, P. B. (1987). A Behavioral Perspective on Insomnia Treatment. *Psychiatric Clinics of North America*, *10*(4), 541–553. https://doi.org/10.1016/S0193-953X(18)30532-X

Stoller, M. K. (1994). Economic effects of insomnia. *Clinical Therapeutics: The International Peer-Reviewed Journal of Drug Therapy*, *16*(5), 873–897.

Streiner, D. L. (2005). Finding Our Way: An Introduction to Path Analysis. *Can J Psychiatry*, *50*(2), 8.

Tousignant, O. H., Taylor, N. D., Suvak, M. K., & Fireman, G. D. (2019). Effects of Rumination and Worry on Sleep. *Behavior Therapy*, *50*(3), 558–570. https://doi.org/10.1016/j.beth.2018.09.005

Türkarslan, K. K., & Çınarbaş, D. C. (2022). *The Examination of Reliability and Validity of the Turkish Intrusive Visual Imagery and Verbal Thought Questionnaires*. PsyArXiv. https://doi.org/10.31234/osf.io/6rqmw

Türkarslan, K. K., Çınarbaş, D. C., & Nicassio, P. M. (2022). *The Psychometric Properties of the Pre-sleep Arousal Scale in a Turkish Sample*. PsyArXiv. https://doi.org/10.31234/osf.io/2tx5s

Vargas, I., Nguyen, A. M., Muench, A., Bastien, C. H., Ellis, J. G., & Perlis, M. L. (2020). Acute and Chronic Insomnia: What Has Time and/or Hyperarousal Got to Do with It? *Brain Sciences*, *10*(2), 71. https://doi.org/10.3390/brainsci10020071

Vrana, S. R., Cuthbert, B. N., & Lang, P. J. (1986). Fear Imagery and Text Processing. *Psychophysiology*, *23*(3), 247–253. https://doi.org/10.1111/j.1469-8986.1986.tb00626.x

Wassing, R., Schalkwijk, F., Lakbila-Kamal, O., Ramautar, J. R., Stoffers, D., Mutsaerts, H. J. M. M., Talamini, L. M., & Van Someren, E. J. W. (2019). Haunted by the past: Old emotions remain salient in insomnia disorder. *Brain*, *142*(6), 1783–1796. https://doi.org/10.1093/brain/awz089

Watts, F. N., Coyle, K., & East, M. P. (1994). The contribution of worry to insomnia. *British Journal of Clinical Psychology*, *33*(2), 211–220.

Wegner, D. M., & Zanakos, S. (1994). Chronic Thought Suppression. *Journal of Personality*, *62*(4), 615–640. https://doi.org/10.1111/j.1467-6494.1994.tb00311.x

Wicklow, A., & Espie, C. A. (2000). Intrusive thoughts and their relationship to actigraphic measurement of sleep: Towards a cognitive model of insomnia. *Behaviour Research and Therapy*, *38*(7), 679–693. https://doi.org/10.1016/S0005-7967(99)00136-9

Winlove, C. I. P., Milton, F., Ranson, J., Fulford, J., MacKisack, M., Macpherson, F., & Zeman, A. (2018). The neural correlates of visual imagery: A co-ordinate-based meta-analysis. *Cortex*, *105*, 4–25. https://doi.org/10.1016/j.cortex.2017.12.014

Woolfolk, R. L., & McNulty, T. F. (1983). Relaxation treatment for insomnia: A component analysis. *Journal of Consulting and Clinical Psychology*, *51*, 495–503. https://doi.org/10.1037/0022-006X.51.4.495

Wuyts, J., De Valck, E., Vandekerckhove, M., Pattyn, N., Bulckaert, A., Berckmans, D., Haex, B., Verbraecken, J., & Cluydts, R. (2012). The influence of pre-sleep cognitive arousal on sleep onset processes. *International Journal of Psychophysiology*, *83*(1), 8–15.

Yeh, Z.-T., Wung, S.-K., & Lin, C.-M. (2015). Pre-sleep Arousal as a Mediator of Relationships Among Worry, Rumination, and Sleep Quality. *International Journal of Cognitive Therapy*, *8*(1), 21–34. https://doi.org/10.1521/ijct.2015.8.1.21

GCRIS