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

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ORIGINAL ARTICLE

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

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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 or 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 ($\beta = 0.44$, $p < .001$), but not IVT ($\beta = 0.15$, $p = .12$), significantly predicted pre-sleep arousal and pre-sleep arousal ($\beta = 0.44$, $p < .001$) significantly predicted insomnia severity. In addition, the indirect effect of IVI via pre-sleep arousal (IE = 0.19, $p < .001$) 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 can help poor sleepers alleviate insomnia severity.

Keywords Insomnia · Pre-sleep arousal · Intrusive visual imagery · Intrusive verbal thoughts · Visual imagery ability

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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 (1982) stated that "a large number of insomnias are due to intrusive, relatively uncontrollable, cognitive activity." (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 showed 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 exacerbate 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 intrusive 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 visual imagery and pre-sleep arousal in a sample of individuals 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 medication 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 ≤ 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 Fig. 1; Table 1, respectively.

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 1, 2). 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
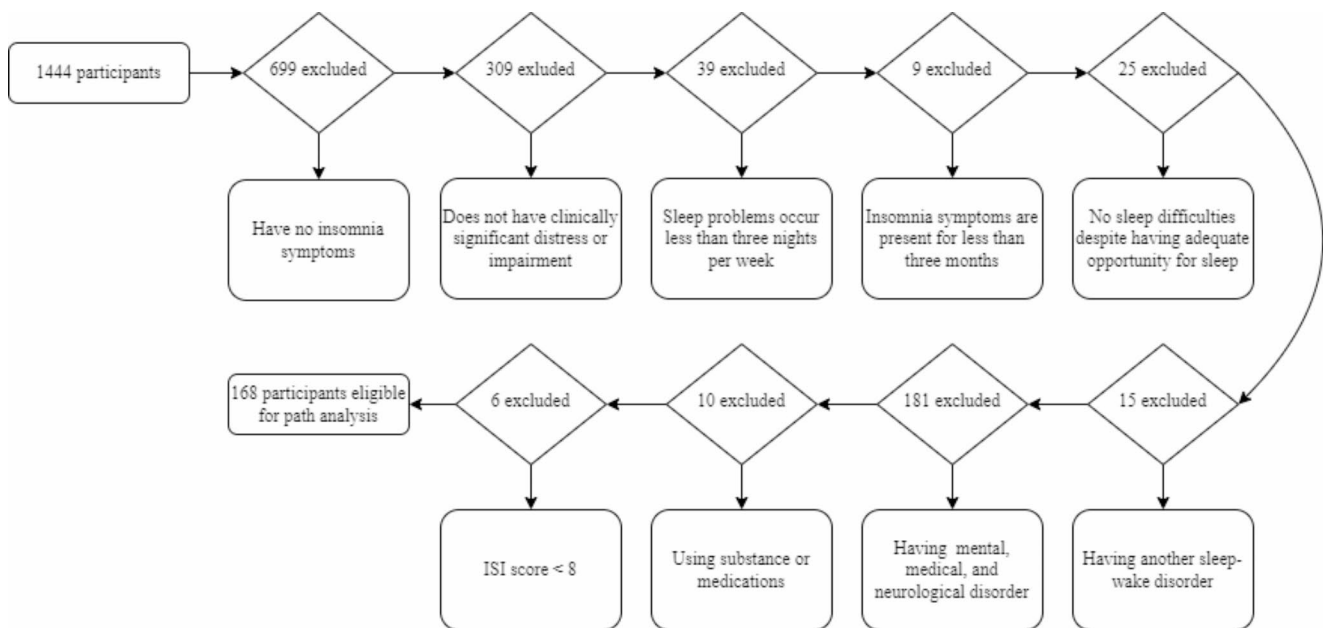
Fig. 1 The exclusion chart

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	0.60
Insomnia Symptoms		
Difficulty falling asleep	150	89.29
Difficulty staying asleep	45	26.79
Waking up too early	36	21.43

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 5-point 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 0.93 and 0.94, respectively. The three-week test-retest reliability intra-class correlations were 0.71 for visual imagery and 0.83 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 phase. Türkarslan et al. (2023) adapted the PSAS to Turkish. Confirmatory factor analysis validated the Turkish form with 16 items and two-factors, as found in the original study. The Cronbach alpha value of the Turkish PSAS, PSAS-C, and PSAS-S were 0.92, 0.91, and 0.86, respectively. The

intra-class correlation coefficients between baseline and three-week follow-up scores were found as 0.82, 0.82, and 0.71 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. The confirmatory factor analysis validated the three-factor structure of the original questionnaire. 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 0.79. 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 right to decline or discontinue participation in the survey at any moment during the course of the study. The online questionnaire took roughly 25 min 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 (> 0.01) and VIF (< 10) values, respectively. The sample size 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 ≤ 0.08, RMSEA values ≤ 0.10, and TLI and CFI values ≥ 0.90 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 117 (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 ($r = .25$, $p < .001$), and insomnia severity ($r = .44$, $p < .001$). Moreover, visual

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	0.94
2. Intrusive Verbal Thoughts	0.69***				36.96	8.87	10.00	50.00	0.93
3. Visual Imagery Ability	0.37***	0.31***			51.60	12.52	19.00	75.00	0.91
4. Pre-sleep Arousal	0.54***	0.45***	0.25**		48.51	10.78	20.00	80.00	0.88
5. Insomnia Severity	0.35***	0.28***	0.16*	0.44***	15.36	4.31	8.00	26.00	0.66

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

imagery ability had a significant correlation with intrusive visual imagery. ($r = .37$, $p < .001$).

Path Analysis

A multivariable path model linking intrusive visual imagery and verbal thoughts to pre-sleep arousal and pre-sleep arousal to insomnia severity was formed (see Fig. 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 $= 0.05$, RMSEA $= 0.08$, 90% CI $= [0.00, 0.19]$, TLI $= 0.98$, CFI $= 0.98$). The direct associations in the model indicated that intrusive visual imagery ($\beta = 0.44$, $p < .001$), but not intrusive verbal thoughts ($\beta = 0.15$, $p = .12$), significantly predicted pre-sleep arousal and that pre-sleep arousal ($\beta = 0.44$, $p < .001$) 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 ($IE = 0.19$, $p < .001$), while the indirect effect of intrusive verbal thoughts via pre-sleep arousal on insomnia severity was not significant ($IE = 0.06$, $p = .12$). The results showed 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 ($\beta = 0.39$, $p < .001$), but not intrusive verbal thoughts ($\beta = 0.15$, $p = .13$), significantly predicted pre-sleep arousal and pre-sleep arousal ($\beta = 0.44$, $p < .001$) significantly predicted insomnia severity. The indirect effect of intrusive visual imagery via pre-sleep arousal on insomnia severity was significant ($IE = 0.17$, $p = .002$), while the indirect effect of intrusive verbal thoughts via pre-sleep arousal on insomnia severity was not significant ($IE = 0.07$, $p = .14$).

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

Fig. 2 The path model with moderation. *Note 1 * p < .001. Note 2* Standardized path coefficients among variables are presented. .10 = small effect, .30 = medium effect, and .50 = large effect (Cohen, 1992)
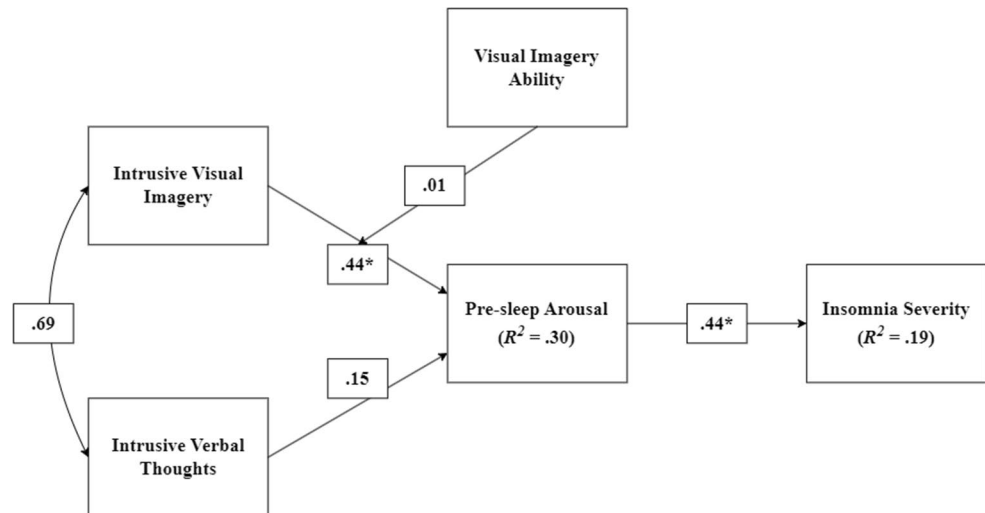
imagery ability. The results yielded that visual imagery ability did not significantly moderate the relationship between intrusive visual imagery and pre-sleep arousal, $\Delta R^2 = 0.01$, $F(1, 162) = 3.25$, $p = .07$. Therefore, Hypothesis 5 was not supported. The overall path model, including moderation, can be seen in Fig. 2.

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 showed 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 the sample size of the current study (Lantz, 2013). Altogether, 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 showed 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 to 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 individuals 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 individuals 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 specifically alleviate intrusive visual imagery may improve the sleep quality patients with insomnia disorder. In the past, 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), better sleep quality (Casement & Swanson, 2012; Schwartz et al., 2022), and lower cognitive and somatic pre-sleep arousal compared to control groups (Molen et al., 2013). Future studies are certainly needed to investigate the effects of imagery techniques on pre-sleep intrusive images, arousal, and insomnia symptoms.

The current study has several 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 individuals with insomnia disorder by using self-report questionnaires and the ISI scores. The identification of individuals 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 may limit the generalizability of the findings. Therefore, future research utilizing more representative samples in terms of gender, age, and degree of education is needed. In the current study, the subscales used 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 associations 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 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.

Data Availability The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Conflict of Interest The authors declare that they have no conflicts of interest.

Ethics Approval This research meets the ethical guidelines, including adherence to the legal requirements of the study country. Ethical committee approval was sought where necessary and is acknowledged within the text of the submitted manuscript.

Consent to Participate Informed consent was obtained from all participants included in the study.

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