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Title

Associations between exploding head syndrome and measures of sleep quality and experiences, dissociation, and well-being

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Abstract

Exploding head syndrome is a sensory parasomnia characterized by the perception of loud noises and/or a sense of explosion in the head that occurs when transitioning to or from sleep. Despite receiving little attention from both researchers and clinicians, studies suggest approximately 10-15% of individuals have episodes, with significant levels of fear occurring in a subset of cases. Using two independent samples, we examine sleep and well-being variables associated with exploding head syndrome. We focused on insomnia symptoms, life stress, anxiety and depression symptoms, and sleep experiences such as sleep paralysis as potential factors associated with exploding head syndrome. Study 1 consisted of 199 female undergraduate students. We found a lifetime prevalence of 37.19%, with 6.54% experiencing at least one episode a month. All variables were associated with exploding head syndrome in univariate analyses, but only insomnia symptoms and sleep paralysis frequency were significantly associated with exploding head syndrome in multiple logistic regression models. Study 2 was an international sample of 1683 participants (age range 18-82, 53.00% female). Lifetime prevalence was 29.59%, with monthly episodes occurring in 3.89% of participants. The same set of variables were investigated as in Study 1, with dissociative experiences during wakefulness and a larger range of sleep experiences also included. Study 2 replicated the results of Study 1. In addition, dissociative experiences during wakefulness and other sleep experiences such as nightmares were associated with exploding head syndrome in multiple logistic regression models. These studies provide valuable first insights into variables associated with exploding head syndrome.

Keywords

exploding head syndrome, parasomnia, anomalous sleep experience

Clinical trial information: Study 1 constitutes a planned exploratory outcome of a pilot feasibility study conducted to provide information useful for designing a clinical trial: Name: STOP-pilot URL: https://clinicaltrials.gov/ct2/show/NCT03062891?term=NCT03062891&rank=1, Registration: NCT03062891

Statement of significance

Exploding head syndrome, the perception of loud bangs at sleep-wake transitions, has received little attention from researchers and is unknown to the majority of clinicians. In spite of this, it has been found to be relatively common and can lead to significant levels of distress in some cases. Here, two independent datasets were utilized to investigate whether insomnia symptoms, well-being, and other sleep experiences are associated with exploding head syndrome. Insomnia symptoms, dissociative experiences, and unusual sleep experiences such as sleep paralysis predicted the presence of exploding head syndrome in multiple regression models. These results provide some initial information about multiple factors that may contribute to exploding head syndrome, which will be useful in designing future interventions.

Introduction

Exploding head syndrome (or episodic cranial sensory shock [1]) is an anomalous sleep experience characterized by hearing loud noises (e.g. resembling an explosion or gunshot) in one's head at either wake-sleep or sleep-wake transitions [2]. Using a clinical interview to establish diagnosis in 49 individuals, the most frequent associated symptoms are: increased heartrate (reported by 83% of participants), fear (81%), and muscle jerks/twitches (68%) [3]. Interestingly, approximately one third of the sample reported visual phenomena such as flashing lights, whilst physical pain (9%) and headaches were rarely reported (7%) [3]. Whilst not typically associated with physical pain, episodes can result in clinically significant levels of distress/impairment in some cases [3,4]. As such, exploding head syndrome is an important differential diagnostic consideration for nocturnal headache disorders such as hypnic headaches, which involve recurrent headaches occurring exclusively during sleep causing the patient to awaken [5–7].

The study of exploding head syndrome has received relatively little attention from both researchers and clinicians [8]. To our knowledge, only two studies to date have assessed the prevalence of exploding head syndrome. One study with 180 participants found a lifetime prevalence of 11% in healthy individuals; a second study of college students (N = 211) reported an 18% lifetime prevalence rate, with 16.50% experiencing recurrent episodes (defined as more than one lifetime episode) [4,9].

Despite its prevalence, very few individuals report exploding head syndrome episodes to medical professionals, with one study finding just 11% of participants reported episodes to their doctors [3]. Furthermore, of those that reported seeking medical advice, none found that clinicians were familiar with exploding head syndrome [3]. This highlights the importance of further research into this topic so that the phenomenon can be better characterized, allowing increased recognition in the medical community – for example, to prevent misdiagnosis, or simply to inform patients about the condition to reduce anxiety.

An important question concerns factors that are associated with experiencing exploding head syndrome. To date, systematic studies have not been conducted on this topic and current knowledge is based only on small-scale studies. While case studies suggest that variables such as stress and psychopathology make episodes more likely, these conclusions rest on informal patient interviews and have not been tested systematically [10–12]. Large scale investigations on this topic are warranted in order to identify associations between experiencing exploding head syndrome and other variables as a very first stage to establishing risk factors for exploding head syndrome.

A growing body of evidence suggests that anomalous sleep experiences (a broad construct subsuming a variety of nocturnal experiences involving altered states of consciousness [13]) frequently co-occur. For example, exploding head syndrome is more common in individuals reporting sleep paralysis (a period of inability to perform voluntary movements at sleep onset/sleep offset), with the suggestion that exploding head syndrome may temporally precede an episode of sleep paralysis [4,13]. Other work indicates that experiences, such as sleep paralysis, hypnagogic/hypnopompic hallucinations (hallucinations that occur at sleep onset/sleep offset), nightmares, and lucid dreaming (whereby the dreamer becomes aware that they are dreaming) tend to co-occur [14–17]. It is currently unknown whether exploding head syndrome co-occurs with any of these other sleep experiences (except for sleep paralysis).

Individuals who are prone to anomalous waking experiences such as dissociation, which involves depersonalization (feelings of disconnection from oneself) and derealization (feeling disconnected from ongoing reality), are more likely to have anomalous experiences during sleep [18,19]. These associations are thought to reflect a common domain of unusual cognitive and perceptual experiences that manifest across different states of consciousness [20]. It is also possible that poor sleep quality in general, perhaps exacerbated by factors such as stress and anxiety, are risk factors for unusual sleep experiences [21]. This is especially true for sleep paralysis, where factors such as insomnia, stress, and anxiety have been consistently linked to increased prevalence rates [22]. Well-being variables such as stress and anxiety may be directly related to exploding head syndrome. Alternatively, the relationship may be indirect in that experiencing a period of heightened stress may lead to an increase in sleep problems, which may then lead to exploding head syndrome. Such a mechanism has been proposed for other sleep experiences, namely sleep paralysis [23]. However, exploding head syndrome has not yet been investigated in this context, so it is unclear whether it shares similar predictors with other sleep experiences.

The objective of this work was to perform the first systematic investigation of multiple variables potentially associated with exploding head syndrome. Although cross-sectional data are reported here, finding associations will constitute a first step to conducting future research to establish risk factors for EHS and to facilitate the design of intervention methods to help those who suffer most from this experience. We address this objective using two independent samples.

Study 1 employed a female-only sample of UK university students enrolled as part of a larger study on sleep quality and insomnia symptoms [24]. Study 2 used a large international sample from a study of anomalous sleep experiences [14]. We believe this latter study is the largest sample (to date) used to investigate exploding head syndrome. We had the following specific aims:

1) To establish the prevalence of exploding head syndrome in our two samples, to compare with previous estimates in the existing literature.

2) To investigate whether sleep and well-being variables are associated with exploding head syndrome. Based on the previous literature on variables associated with other unusual sleep experiences, insomnia symptoms, stress, and symptoms of anxiety and depression were included in analyses. Study 2 also measured dissociative experiences. As a supplementary post-hoc analysis, we conducted mediation analyses to test whether the association between well-being variables (stress, anxiety, and depression) and exploding head syndrome were mediated by insomnia symptoms. The rationale for this choice was based on the large body of evidence that these well-being factors have been shown in longitudinal designs to be related to insomnia symptoms [25].

3) To examine whether unusual sleep experiences are associated with exploding head syndrome. We sought to replicate the finding that exploding head syndrome is associated with sleep paralysis. Furthermore, in Study 2 (the only sample in which they were measured), we explored whether experiences of other unusual sleep experiences (threatening hypnagogic/hypnopompic hallucinations, nightmares, false awakenings, and lucid dreaming) were associated with the presence of exploding head syndrome.

Study 1

Methods

Participants

A total of 199 participants took part in Study 1 (M_{age} = 20.02, SD = 4.75, range = 18-50, 100% female). Participants were recruited as part of a larger pilot study investigating predictors of treatment outcome to cognitive behavioral therapy for insomnia in university students (the Sleep Treatment Outcome Predictors (STOP) study, see elsewhere for more details and study protocol [23]). Note that the results presented here are a planned exploratory outcome of the STOP study (trial number: NCT03062891). Inclusion criteria were as follows: 1) female; 2) over 18 years of age; and 3) enrolled in a psychology degree program (undergraduate or postgraduate) at one of three UK universities. Only data from the baseline assessment of the STOP study were used, as this was the only session that assessed exploding head syndrome. Data were collected via the online survey platform Qualtrics (Qualtrics, Provo, UT). The study received ethical approval from Goldsmiths, University of London Research Ethics and Integrity sub-committee.

Measures

Exploding head syndrome

Lifetime prevalence of exploding head syndrome was measured using a single item from the Munich parasomnia screening (MUPS) [9]. Participants were asked “Have you ever noticed the following behavior? When falling asleep or waking up, perceiving a loud bang, a sound similar to a bang (e.g. door bang), or having the sensation of an “explosion in the head”. The item was answered on a 5-point scale, ranging from never observed to several times a week. The sensitivity and specificity of the item for detecting exploding head syndrome has been validated against detailed clinical interview [9]. This item has been used in previous research to assess prevalence of exploding head syndrome [9].

Insomnia symptoms: Sleep condition indicator (SCI) [26]

Participants consider a typical night in the last month and rate various aspects of their sleep including onset (“How long does it take you to fall asleep?”); waking during sleep (“If you wake up during the night…how long are you awake for in total?”); perceived sleep quality (“How would you rate your sleep quality?”); the effect of poor sleep on various aspects of life (e.g. “To what extent has poor sleep affected your mood, energy, or relationships?”); and the length of time that sleep problems have been an issue (“How long have you had a problem with your sleep?”). Higher scores are indicative of better sleep, and scores <= 16 indicate insomnia disorder. The SCI is valid, reliable, and sensitive to change in insomnia severity [26]. In the current sample, the measure showed good internal reliability ($\alpha = .85$).

Life stress: Perceived stress scale (PSS) [27]

This 10-item scale was used to measure stress. Participants rated the extent to which they had felt and thought in a certain way over the past month (e.g. “How often have you felt confident about your ability to handle your personal problems”), on a 0-4 scale ranging from never to very often. All items are summed to create an overall score with higher scores indicating a greater level of perceived stress over the past month. A review of articles assessing the psychometric properties of the PSS found the measure to be a reliable and valid measure of life stress [28], and showed good internal reliability in this sample ($\alpha = .83$).

Anxiety symptoms: State trait anxiety index (STAI) [29]

The STAI assesses both state and trait levels of anxiety. Here, only trait anxiety was examined, and was measured using 20 items (e.g. "I feel that difficulties are piling up so I cannot overcome them", "I worry too much over something that really doesn't matter"). Participants rate each item for how they generally feel on a 4-point scale from not at all to very much so. Scores are summed to create a total score. Higher scores are indicative of greater trait anxiety. The STAI has been shown to be a reliable and valid measure of anxiety symptoms [30]. The measure had good reliability in this sample (α = .88).

Depressed mood: Mood and feelings questionnaire *(*MFQ*)* [31]

Depressed mood was measured using the 13-item MFQ. Participants rated the extent to which they had felt or acted in a certain way during the past two weeks (e.g. "I felt miserable and unhappy", "I found it hard to think properly or concentrate") on a 3-point scale (not true, sometimes, true). All items are summed to create to a total score, with a higher score being indicative of a more depressed mood over the last 2 weeks. It has been shown to be a reliable and valid measure of depressed mood [32]. In this sample, the reliability of the measure was good (α = .91).

Sleep paralysis

Frequency of sleep paralysis was assessed with a single item: "Sometimes when falling asleep or when waking from sleep, I experience a brief period during which I am unable to move, even though I am awake and conscious of my surroundings" [33], answered on a 7-point scale ranging from never observed to several times a week. This has been shown to be a reliable and valid measure of sleep paralysis frequency [34], and self-report measures of sleep paralysis have been found to yield similar prevalence rates to interview methods in healthy samples [35].

Statistical analysis

Due to the non-normal distribution of exploding head syndrome prevalence (see **Figure 1**), the variable was dichotomized into exploding head syndrome absent (n = 125, 62.81%) and present (n = 74, 37.19%). Participants who had experienced at least one episode in their lives were categorized as exploding head syndrome present. As such, all results reflect predictors of lifetime exploding head syndrome. Independent samples t-tests were used to investigate sleep and well-being variables associated with exploding head syndrome. Then, multiple logistic regression was used to test which well-being variables were independently associated with exploding head syndrome. Two regression models were run. Model 1 predicted exploding head syndrome from insomnia symptoms, life stress, and anxiety and depression symptoms. The effect of age was controlled for in Model 2.

Bootstrapped mediated regression models (with 5000 repetitions) were performed to test whether the relationships between well-being variables (stress, anxiety and depression symptoms) and exploding head syndrome were mediated by insomnia symptoms. Bootstrapping was used due to the increase in statistical power and does not assume normally distributed data [36]. A total of three mediated regression models were run (one for each well-being variable: life stress, anxiety and depression), with age entered as a co-variate in each model. Note that mediation analyses were performed post-hoc. Furthermore, as the data are cross-sectional, findings should be considered preliminary and interpreted with caution.

To examine the association between exploding head syndrome and sleep paralysis, we conducted t-tests followed up with logistic regression models predicting the presence of exploding head syndrome from sleep paralysis frequency. In Model 1, exploding head syndrome presence was predicted from sleep paralysis frequency. Model 2 controlled for the effect of age. This analysis allowed us to examine whether the odds of experiencing exploding head syndrome increase as the frequency of sleep paralysis episodes increase.

Well-being variables and anomalous sleep experiences (sleep paralysis) were analyzed in separate regression models as they constituted independent hypotheses. We kept to this format for Study 1, despite the lower number of predictor variables (though also lower sample size), to be consistent and allow easier comparisons with Study 2. However, for full transparency and completeness, we also performed an ad hoc separate regression model containing *all* predictors (**Table S1**).

It is possible that experiencing exploding head syndrome less than once per year would differ in terms of its predictors compared to experiencing more frequent episodes. In order to examine this, analyses were also run on a reduced dataset excluding individuals who reported experiencing exploding head syndrome less than once a year. Therefore, these additional analyses only examined those reporting more frequent episodes – at least once/several times a year (**Tables S2-S5**).

Results

Frequency of exploding head syndrome and other descriptives

In the sample, 37.29% of individuals reported at least one lifetime episode of exploding head syndrome. The distribution of prevalence rates is displayed in **Figure 1**. Descriptive statistics for all variables are shown in **Table 1**. Independent samples t-tests showed all variables except age and depressed mood to be significantly related to exploding head syndrome in the expected direction.

Regression models predicting exploding head syndrome from insomnia symptoms, stress, anxiety symptoms, and depression symptoms

The results of the regression models are displayed in **Table 2**. After controlling for the effect of age (see model 2 in **Table 2**), insomnia symptoms were the only independent predictor of exploding head syndrome, OR (CI) = 0.65 (0.44 – 0.94), p = .020. Stress, anxiety symptoms, and depression symptoms were not significantly associated with exploding head syndrome in the multiple logistic regression model. The same pattern of results was obtained with the "Less than once a year" category of the exploding head syndrome variable removed (see **Table S3**).

Supplementary mediation analyses

Bootstrapped mediation models revealed a significant indirect effect of well-being variables on exploding head syndrome, with insomnia symptoms as the mediator: life stress (indirect effect, OR = 1.12, 95% CI = 1.02 – 1.23), anxiety (indirect effect, OR = 1.11, 95% CI = 1.01-1.22), and depression (indirect effect, OR = 1.15, 95% CI = 1.04 – 1.27). In all three cases the direct effect was not significant. Full model results are shown in **Table 3**. Note the mediation analysis was post-hoc, performed after the primary multiple logistic regression analysis.

Exploding head syndrome and sleep paralysis

Using logistic regression, and after controlling for the effect of age (see model 2 in **Table 2**), frequency of sleep paralysis significantly predicted exploding head syndrome, OR (CI) = 1.79 (1.32 – 2.45), $p < .001$. For this analysis, the same pattern of results was obtained with the "Less than once a year" category of the exploding head syndrome variable removed) (see **Table S3).**

When all possible predictors were assessed in the same model (insomnia symptoms, stress, anxiety symptoms, depression symptoms, and sleep paralysis), a similar pattern of results was obtained. Of note, in this model, insomnia symptoms showed only a non-significant trend association with exploding head syndrome, though the co-efficient size remained highly similar (OR (CI) = 0.69 (0.47 – 1.02), $p = .065$). See **Table S1** for full model information.

Study 2

Note that data on the sleep paralysis and lucid dreaming items from this study have been previously published elsewhere [14]. All the analyses presented here are novel, and the data on exploding head syndrome has not been reported before.

Methods

Participants

In total, 1928 participants took part (M_{age} = 34.17, SD = 13.62, range = 18-82 years, 53% female). Participants were invited to take part in an online survey through advertisements on a university mailing list (i.e. aimed at students and staff at a university interested in taking part in research), and on lucid dreaming and sleep paralysis websites and forums (see Acknowledgements). The study was described as an investigation of people's experiences of wakefulness and sleep. Only those who answered the item on exploding head syndrome were included in the analyses (n = 1673). The study received ethical approval from the University of Sheffield Department of Psychology Ethics Committee.

Measures

The following measures used in Study 1 were used in Study 2: SCI (α = .86), PSS (α = .90), STAI (α = .94), and MFQ (α = .90), and all showed good internal reliability in the current study. The same item was used to measure sleep paralysis.

Dissociative experiences: Dissociative experiences scale II (DES-II) [37]

Participants rated the percentage of time occupied by dissociative experiences over the past month (e.g. "Finding yourself in a place and having no idea how you got there") using 100-point sliding scales. For each item, a score of 0 would indicate that experience happens to you 0% of the time, with 100% indicating that experience happens 100% of the time. Scores for each item were summed to create an overall score with possible values from 0-2800; higher scores indicate greater dissociative experiences (α = .93).

Anomalous sleep experiences

Threatening hypnagogic/hypnopompic hallucinations were measured with the item "How often do you experience auditory or visual illusions that accompany falling asleep or waking up in a distressing or threatening manner (e.g. hearing sounds or voices, or seeing people or things that are not in the room?)". Nightmares were measured using the item "How often do you experience frightening dreams or nightmares?". Both items are scored on a 1-5 scale ranging from never observed to several times a week, taken from the MUPS [9]. False awakenings were measured with the item "How often do you experience erroneously believing that you have woken up, only to discover subsequently that the apparent awakenings were part of a dream?". This item was adapted from the Waterloo unusual sleep experiences questionnaire [34], and is measured on the same 1-5 scale as the MUPS [9] items.

Lucid dreaming was measured by the item "Some people experience the phenomenon of lucid dreaming. During a lucid dream, one is – while dreaming – aware of the fact that one is dreaming. It is possible to deliberately wake up or to control the dream action or to observe passively the course of the dream with this awareness. How frequently do you experience lucid dreams?". This item is scored on an 8-point scale ranging from never to several times a week, and has been used previously to measure the frequency of lucid dreaming [38].

Statistical analysis

The same statistical methods as Study 1 were used. The exploding head syndrome variable was dichotomized, n = 1178 (70.41%) were exploding head syndrome absent, and n = 495 (29.59%) were exploding head syndrome present.

For sleep, well-being (insomnia symptoms, stress, depression and anxiety symptoms), and dissociation variables, independent samples t-tests were performed (to test for differences in sex between exploding head syndrome and exploding head absent, chi-square was used), followed by multiple logistic regression. Two logistic regression models were performed. Model 1 predicted exploding head syndrome from insomnia symptoms, stress, anxiety symptoms, depression symptoms, and dissociative experiences. Model two was adjusted for the effects of age and sex.

As in Study 1, three bootstrapped mediated regression models were run to examine the mediating effect of insomnia symptoms on the relationship between well-being variables (stress, anxiety and depression symptoms) and exploding head syndrome. Age and sex were added as co-variates.

To examine associations between exploding head syndrome and other anomalous sleep experiences, independent samples t-tests and logistic regressions were performed. Multiple logistic regression was used to determine which sleep experiences were independently associated with the presence of exploding head syndrome. Model 1 predicted exploding head syndrome from each of the other sleep experiences (sleep paralysis, threatening hypnagogic/hypnopompic hallucinations, nightmares, false awakenings, and lucid dreaming), whilst Model 2 controlled for the effects of age and sex.

Associations between exploding head syndrome and well-being variables, and associations between exploding head syndrome and anomalous sleep experiences were run in separate regression models. As for Study 1, we conducted an additional ad hoc separate regression model containing *all* predictors. We also re-ran the analysis excluding those who only ever reported one lifetime episode of exploding head syndrome.

Results

Frequency of exploding head syndrome and other descriptives

In the sample, 29.59% of individuals reported at least one lifetime episode of exploding head syndrome. The distribution of prevalence rates is displayed in **Figure 1**. Descriptive statistics for all variables from Study 2 are shown in **Table 4**. Independent samples t-tests showed all variables apart from age to be significantly related to exploding head syndrome. Chi-square showed sex was not significantly related to exploding head syndrome.

Regression models predicting exploding head syndrome from insomnia symptoms, stress, anxiety symptoms, depression symptoms, and dissociative experiences

The results of the regression models are displayed in **Table 5**. Insomnia symptoms (OR (CI) = 0.73 (0.63 – 0.85), $p < .001$), and dissociative experiences (OR (CI) = 1.24 (1.08 – 1.43), $p < .001$) were both independently associated with exploding head syndrome. Age, sex, stress, anxiety symptoms, and depression symptoms were not significantly associated with exploding head syndrome in a multiple logistic regression model (all *ps* > .05). The same pattern of results was obtained with the "Less than once a year" category of the exploding head syndrome variable removed. See **Table S5.**

Supplementary mediation analyses

Bootstrapped mediation models revealed that insomnia symptoms mediated the relationship between life stress and exploding head syndrome (indirect effect, OR = 1.08, 95% CI = 1.05 – 1.12), anxiety symptoms and exploding head syndrome (indirect effect, OR = 1.09, 95% CI =

1.05 – 1.13), and depression symptoms and exploding head syndrome (indirect effect, OR = 1.08, 95% CI = 1.04 – 1.12). In all three cases, the direct effect was not significant. Full model results are shown in **Table 3**. As in Study 1, mediation analyses were performed post-hoc.

Regression models predicting exploding head syndrome from other anomalous sleep experiences

After controlling for age and sex (see Model 2 in **Table 5**), multiple logistic regression revealed all anomalous sleep experiences were significantly associated with exploding head syndrome: sleep paralysis, OR (CI) = 1.15 (1.02 – 1.30), $p = .020$; threatening hypnagogic/hypnopompic hallucinations, OR (CI) = 1.55 (1.37 – 1.75), $p < .001$; nightmares, OR (CI) = 1.15 (1.01 – 1.31), $p = .03$; false awakenings, OR (CI) = 1.18 (1.04 – 1.33), $p = .01$; lucid dreaming, OR (CI) = 1.14 (1.01 – 1.29), $p = .03$. When the “Less than once a year” category of the exploding head syndrome variable was removed, false awakenings no longer independently predicted exploding head syndrome. See **Table S5.**

When all possible predictors were included in the same model, broadly similar results were obtained. Dissociative experiences showed only a nonsignificant trend (OR (CI) = 1.15 (0.99 – 1.33), $p = .060$), and false awakenings (OR (CI) = 1.09 (0.94 – 1.27), $p = .26$) and lucid dreaming (OR (CI) = 1.11 (0.96 – 1.29), $p = .15$) were not significant predictors in this model. See **Table S1** for full model information.

Discussion

We examined the prevalence of exploding head syndrome and associations with insomnia symptoms and sleep experiences, well-being measures (stress, anxiety symptoms, depression symptoms), and dissociation. We believe this work to be the first systematic investigation of multiple variables associated with this experience. Lifetime prevalence of exploding head syndrome was 37.19% and 29.59% in our two samples respectively. In both samples symptoms of insomnia was associated with the experience exploding head syndrome in a multiple predictor model. Our second sample found dissociative experiences during wakefulness to also be independently associated in a multiple predictor model. Both samples showed a significant association between the presence of exploding head syndrome and sleep paralysis, replicating previous findings [4]. In Study 2, we extend this by showing that other potentially distressing sleep experiences (threatening hypnagogic/hypnopompic hallucinations and nightmares) are also associated with the presence of exploding head syndrome.

Notably, the prevalence rates obtained in our samples were nearly double those reported in previous studies. Using the same measure as the one used here, Fulda and colleagues reported a prevalence rate of 11% [9]. Using a different measure (clinical interview), a second study reported a lifetime prevalence of 18% [4]. This suggests that exploding head syndrome is perhaps more prevalent than previously thought or that our study possibly over-estimated the prevalence – perhaps reflecting a self-selection bias in our study for example. For instance, although Study 2 represents a far larger and more international sample than previous studies, some participants were recruited from sleep paralysis and lucid dreaming discussion forums, a feature of the study that could have resulted in higher proportions of participants with anomalous sleep experiences compared to the population more generally. The difference in prevalence found in our studies as compared to others may also reflect other differences between the samples such as the entirely female sample used in Study 1, given previous evidence that exploding head syndrome may be more prevalent in females [11,39]. However, we should note that our second study found no sex differences in the experience of exploding head syndrome. Given that our studies were only the third and fourth investigations into lifetime prevalence of exploding head syndrome ever conducted, more studies are needed to firmly establish prevalence rates. However, our results suggest exploding head syndrome may be more common than other unusual sleep experiences such as sleep paralysis and night terrors [35].

In multiple logistic regression models, insomnia symptoms, dissociative experiences, and a range of anomalous sleep experiences were significantly independently associated with exploding head syndrome. Interestingly, a large body of research now suggests an intricate relationship between sleep disruption, dissociation, and anomalous sleep experiences [19]. Specifically, multiple studies have found robust correlations between waking life dissociation and sleep experiences such as hypnagogic/hypnopompic hallucinations [19]. Furthermore, sleep disruption (assessed either through sleep deprivation or subjective report) has been shown to lead to increased levels of dissociative experiences during wakefulness [40–42]. The work reported here suggests that exploding head syndrome is related to a wide variety of other sleep experiences, meaning it should be assessed more regularly in studies of anomalous sleep experiences.

Despite univariate t-tests suggesting a significant relationship between exploding head syndrome and measures of stress, anxiety symptoms, and depression symptoms, none of these variables were significantly associated in multiple logistic regression models. It is possible that these variables are related indirectly, and our post-hoc mediation analyses raises the possibility that insomnia symptoms mediate the relationship. However, this finding should be considered preliminary and treated with caution. Future studies employing longitudinal designs are needed to confirm this possibility. These kinds of designs are needed to fully understand the mechanisms and time course of exploding head syndrome and will facilitate more targeted interventions (e.g., treatment of insomnia, improving well-being).

Limitations of the study should be considered. First, the study was cross-sectional in design meaning that the direction of observed relationships cannot be inferred. For example, do insomnia symptoms increase the risk of exploding head syndrome, or does exploding head syndrome lead to insomnia symptoms by making sleep initiation harder (as exploding head syndrome occurs at sleep-wake transitions), or is there another explanation for these associations (such as a shared genetic risk leading to vulnerability to both)?

Second, only the presence of exploding head syndrome, as measured by a single item, was used. Whilst this item has been well validated against detailed clinical interviews [9], future studies should seek to employ a more detailed assessment of exploding head syndrome that includes associated features and distress levels [3]. Although our method was practically useful, facilitated larger sample sizes, and has been validated against detailed clinical interview [9], it would be important to replicate our findings with samples where exploding head syndrome has been confirmed via detailed interview.

Third, in Study 2, the threatening hypnagogic/hypnopompic hallucinations item shared some overlap with the exploding head syndrome item, in that they both asked about auditory hallucinations at sleep onset/sleep onset periods. Whilst the threatening hypnagogic/hypnopompic hallucinations item also asked about visual experiences, it is possible that this overlap could in part explain the associations found between these two items.

With these limitations in mind, this report represents the largest published sample to date in the study of exploding head syndrome (though we note that our group has now collected an even larger dataset since the submission of this manuscript). Using two independent samples, we found that: 1) approximately one third of individuals experienced at least one episode in their lifetime, 2) insomnia symptoms, and dissociative experiences during wakefulness independently predict the presence of exploding head syndrome, 3) insomnia symptoms mediated the relationship between well-being and exploding head syndrome, and 4) exploding head syndrome is associated with a variety of other anomalous sleep experiences. We hope that more work on exploding head syndrome will be conducted in the future, especially in the context of other anomalous sleep experiences, leading to a greater understanding of this fascinating experience.

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the study design; collection, management, analysis and interpretation of data; writing of this publication; or in the decision to submit any future reports for publication.

Authorship responsibilities

AMG designed study 1. DD, SD, and IB collected the data for Study 1. DD analyzed the data for study 1. DD and GLP designed study 2, collected the data, and analyzed the data. DD led the writing of the manuscript, and GLP and AMG contributed to the writing process.

Disclosure statement

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Non-financial disclosure: AMG has provided guidance and educational content for a freely available educational website (www.babysleep.com) focused on infant sleep. This website is partially supported by Johnson and Johnson, but they do not have any influence over content and do not advertise on it. She has written a book Nodding Off (Bloomsbury Sigma, June, 2018) and has a contract for a second book Sleepy Pebble (Nobrow). She occasionally contributes to BBC Focus magazine and other magazines and newspapers. She is occasionally sent sample products related to sleep (e.g. blue blocking glasses). She has provided a talk on sleep for business. None of the other authors have any disclosures to declare.

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Table 1. Descriptive statistics for variables included in Study 1

Variable	Theoretical range	Overall		EHS present		EHS absent		Sig
		Mean	SD	Mean	SD	Mean	SD	*p*
Exploding head syndrome (EHS)	1 – 5	1.64	0.98	-	-	-	-	-
Age	18 – 50 ±	20.20	4.75	20.64	5.65	19.94	4.13	
Sleep problems (SCI)	0 – 32	19.60	6.99	17.48	7.35	20.85	6.49	**
Life stress (PSS)	5 – 50	20.09	6.22	21.33	5.63	19.36	6.45	*
Trait anxiety (STAI)	20 – 80	49.13	10.28	51.59	10.27	47.69	10.05	**
Depressed mood (MFQ)	0 – 26	9.41	6.35	10.42	6.37	8.82	6.28	
Sleep paralysis	1 – 7	1.98	1.35	2.47	1.51	1.69	1.15	***

Note. SD = standard deviation, sig = independent samples t-tests between exploding head syndrome present and exploding head syndrome absent significance level, * = $p < .05$, ** = $p < .01$, *** = $p < .001$, ± = actual range, not theoretical.
EHS = Exploding Head Syndrome. A higher score indicates more frequent episodes.
SCI = Sleep condition indicator. A higher score indicates better sleep.
PSS = Perceived stress scale. A higher score indicates higher levels of life stress.
STAI = State trait anxiety index (trait). A higher score indicates higher levels of trait anxiety.
MFQ = Mood and feelings questionnaire. A higher score indicates higher levels of depressed mood.
Sleep paralysis. A higher score indicates more frequent episodes of sleep paralysis.

Table 2. Predictors of exploding head syndrome in Study 1

Independent variable [predicting exploding head syndrome]	Model information	
	Model 1	Model 2
Insomnia symptoms and well-being	χ^2 (df = 4) = 13.17, $p < .05$	χ^2 (df = 5) = 13.88, $p < .05$
	OR (95% CI)	OR (95% CI)
Age	-	0.99 (0.93 – 1.07)
Insomnia symptoms	0.65 (0.45 – 0.94) *	0.65 (0.44 – 0.94) *
Life stress	1.20 (0.71 – 2.03)	1.20 (0.71 – 2.03)
Anxiety symptoms	1.33 (0.77 – 2.30)	1.39 (0.80 – 2.41)
Depression symptoms	0.73 (0.44 – 1.22)	0.71 (0.42 – 1.20)
Anomalous sleep experiences	χ^2 (df = 1) = 15.72, $p < .01$	χ^2 (df = 2) = 16.02, $p < .01$
	OR (95% CI)	OR (95% CI)
Age	-	1.02 (0.96 – 1.09)
Sleep paralysis	1.82 (1.33 – 2.47) ***	1.79 (1.32 – 2.45) ***

Note. OR = Odds ratio, CI = Confidence intervals, *** = $p < .001$, * = $p < .05$

Table 3. Mediated regression analyses in Study 1 and Study 2

	Model information	
	Study 1	Study 2
DV: Exploding head syndrome		
MV: Insomnia symptoms		
<u>Life stress</u>		
<u>EHS on life stress</u>	χ^2 (df = 2) = 5.19, p = .07	χ^2 (df = 3) = 9.86, p < .05
	OR (95% CI)	OR (95% CI)
Life stress	1.40 (1.04 – 1.89) *	1.20 (1.07 – 1.36) **
Age	1.02 (0.95 – 1.08)	1.00 (0.99 – 1.01)
Sex	-	0.98 (0.82 – 1.17)
<u>Insomnia symptoms on life stress</u>	F (2, 191) = 36.02, p < .001	F (3, 1395) = 104.86, p < .001
	β (95% CI)	β (95% CI)
Life stress	-0.48 (-0.60 – -0.35) ***	-0.44 (-0.48 – -0.39) ***
Age	-0.05 (-0.08 – 0.02) ***	-0.01 (-0.02 – 0.01)
Sex	-	0.07 (-0.01 – 0.15)
<u>EHS on insomnia symptoms and life stress</u>	χ^2 (df = 3) = 12.02, p < .01	χ^2 (df = 4) = 34.33, p < .001
	OR (95% CI)	OR (95% CI)
Insomnia symptoms	0.66 (0.46 – 0.93) *	0.73 (0.64 – 0.82) ***
Life stress	1.20 (0.84 – 1.69)	1.05 (0.92 – 1.20)
Age	0.99 (0.93 – 1.07)	1.03 (0.99 – 1.05)
Sex	-	1.01 (0.84 – 1.21)
Indirect effect	1.12 (1.02 – 1.23)	1.08 (1.05 – 1.12)
<u>Anxiety symptoms</u>		
<u>EHS on anxiety symptoms</u>	χ^2 (df = 2) = 7.44, p < .05	χ^2 (df = 3) = 10.93, p < .05
	OR (95% CI)	OR (95% CI)
Anxiety symptoms	1.51 (1.11 – 2.04) **	1.22 (1.08 – 1.37) **
Age	1.01 (0.94 – 1.08)	1.01 (0.99 – 1.03)
Sex	-	0.95 (0.79 – 1.14)
<u>Insomnia symptoms on anxiety symptoms</u>	F (2, 191) = 42.86, p < .001	F (3, 1385) = 135.21, p < .001
	β (95% CI)	β (95% CI)

Anxiety symptoms	-0.51 (-0.63 – -0.39) ***	-0.49 (-0.54 – -0.44) ***
Age	-0.05 (-0.07 – -0.02) **	-0.05 (-0.08 – -0.02) **
Sex	-	0.11 (0.02 – 0.18) **
<u>EHS on insomnia symptoms and anxiety symptoms</u>	χ^2 (df = 3) = 12.07, $p < .01$	χ^2 (df = 3) = 9.86, $p < .05$
	OR (95% CI)	OR (95% CI)
Insomnia symptoms	0.69 (0.48 – 0.98) *	0.72 (0.63 – 0.82) ***
Anxiety symptoms	1.26 (0.89 – 1.80)	1.03 (0.90 – 1.18)
Age	0.99 (0.92 – 1.06)	1.04 (0.99 – 1.06)
Sex	-	0.98 (0.82 – 1.19)
Indirect effect	1.11 (1.01 – 1.22)	1.09 (1.05 – 1.13)
<u>Depression symptoms</u>		
<u>EHS on depression symptoms</u>	χ^2 (df = 2) = 4.12, $p = .12$	χ^2 (df = 3) = 13.76, $p < .01$
	OR (95% CI)	OR (95% CI)
Depression symptoms	1.30 (0.97 – 1.73) +	1.25 (1.11 – 1.40) ***
Age	1.03 (0.97 – 1.10)	1.01 (0.99 – 1.02)
Sex	-	0.98 (0.81 – 1.17)
<u>Insomnia symptoms on depression symptoms</u>	F (2, 193) = 45.86, $p < .001$	F (3, 1390) = 119.84, $p < .001$
	β (95% CI)	β (95% CI)
Depression symptoms	-0.52 (-0.64 – -0.41) ***	-0.46 (-0.51 – -0.41) ***
Age	-0.05 (-0.07 – -0.02) ***	-0.04 (-0.08 – -0.01) **
Sex	-	0.09 (0.01 – 0.16) *
<u>EHS on insomnia symptoms and depression symptoms</u>	χ^2 (df = 3) = 11.10, $p < .05$	χ^2 (df = 4) = 35.23, $p < .001$
	OR (95% CI)	OR (95% CI)
Insomnia symptoms	0.61 (0.43 – 0.88) **	0.74 (0.65 – 0.84) ***
Depression symptoms	1.00 (0.71 – 1.42)	1.08 (0.95 – 1.24)
Age	1.01 (0.95 – 1.08)	1.00 (0.99 – 1.01)
Sex	-	1.01 (0.84 – 1.21)
Indirect effect	1.15 (1.04 – 1.27)	1.08 (1.04 – 1.12)

Note. EHS = Exploding head syndrome OR = Odds ratio, CI = Confidence interval *** = $p < .001$, ** = $p < .01$, * = $p < .05$, + = $p < .10$. For all indirect effects, bootstrapped confidence intervals are displayed

Table 4. Descriptive statistics for variables included in Study 2

	Theoretical range	Overall		EHS present		EHS absent		Sig
Variable		Mean	SD	Mean	SD	Mean	SD	*p*
Exploding head syndrome	1 – 5	1.45	0.83	-	-	-	-	-
Age	18 – 82 ±	34.17	13.62	35.27	13.32	34.75	14.05	
Sex[1]		60.46		64.24		60.78		
Sleep problems (SCI)	0 – 32	19.68	7.89	17.74	8.10	20.46	7.72	***
Life stress (PSS)	5 – 50	17.20	7.57	18.13	7.75	16.80	7.46	**
Trait anxiety (STAI)	20 – 80	43.69	12.26	45.15	12.38	43.07	12.17	**
Depressed mood (MFQ)	0 – 26	5.63	4.60	6.24	4.82	5.36	4.47	**
Dissociative experiences (DES)	0 – 2800	459.33	418.70	533.75	473.59	426.80	388.90	***
Sleep paralysis	1 – 7	2.74	1.63	3.14	1.72	2.52	1.57	***
Threatening hypnagogic/hypnopompic hallucinations	1 – 5	2.03	1.29	2.59	1.40	1.80	1.17	***
Nightmares	1 – 5	2.94	1.23	3.21	1.19	2.82	1.23	***
False awakenings	1 – 5	2.46	1.23	2.79	1.26	2.32	1.19	***
Lucid dreaming	0 – 8	3.75	2.11	4.17	2.19	3.60	2.20	***

Note. SD = standard deviation, sig = independent samples t-tests between exploding head syndrome present and exploding head syndrome absent significance level, ** = $p < .01$, *** = $p < .001$, ± = actual range, not theoretical.

[1] Values for sex represent percentage female

EHS = Exploding head syndrome. A higher score indicates more frequent episodes.

SCI = Sleep condition indicator. A higher score indicates better sleep.

PSS = Perceived stress scale. A higher score indicates higher levels of life stress.

STAI = State trait anxiety index (trait). A higher score indicates higher levels of trait anxiety.

MFQ = Mood and feelings questionnaire. A higher score indicates higher levels of depressed mood.

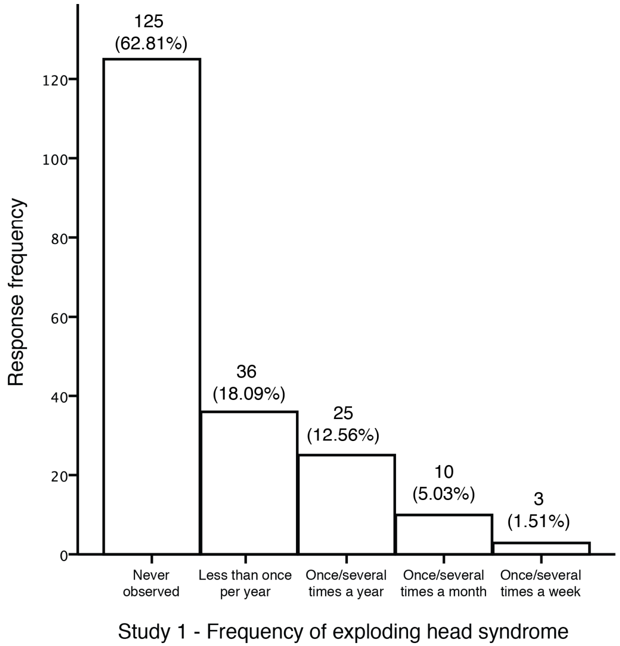
DES = Dissociative experiences scale. A higher score indicates higher levels of dissociative experiences.

Sleep paralysis, threatening hypnagogic/hypnopompic hallucinations, nightmares, false awakenings, and lucid dreaming. A higher score indicates more frequent episodes of the experience.

Table 5. Predictors of exploding head syndrome in Study 2

Independent variable [predicting exploding head syndrome]	Model information	
	Model 1	Model 2
Insomnia symptoms and well-being	χ^2 (df = 5) = 38.51, p < .001	χ^2 (df = 7) = 40.01, p < .001
	OR (95% CI)	OR (95% CI)
Age	-	1.01 (0.99 – 1.02)
Sex	-	0.93 (0.75 – 1.17)
Insomnia symptoms	0.72 (0.62 – 0.83) ***	0.73 (0.63 – 0.85) ***
Life stress	1.04 (0.82 – 1.31)	1.01 (0.80 – 1.29)
Anxiety symptoms	0.95 (0.74 – 1.22)	0.98 (0.77 – 1.26)
Depression symptoms	0.95 (0.77 – 1.22)	0.97 (0.78 – 1.21)
Dissociative experiences	1.23 (1.08 – 1.41) **	1.24 (1.09 – 1.42) **
Anomalous sleep experiences	χ^2 (df = 5) = 148.98, p < .001	χ^2 (df = 7) = 145.34, p < .001
	OR (95% CI)	OR (95% CI)
Age	-	1.01 (0.99 – 1.02)
Sex	-	1.02 (0.80 – 1.30)
Sleep paralysis	1.15 (1.02 – 1.29) *	1.15 (1.03 – 1.30) *
Threatening hypnagogic/hypnopompic hallucinations	1.59 (1.41 – 1.79) ***	1.55 (1.37 – 1.75) ***
Nightmares	1.12 (0.99 – 1.27)	1.15 (1.01 – 1.31) *
False awakenings	1.15 (1.01 – 1.30) *	1.18 (1.04 – 1.33) *
Lucid dreaming	1.14 (1.01 – 1.29) *	1.14 (1.01 – 1.29) *

Note. OR = Odds ratio, CI = 95% confidence intervals, *** = p < .001, ** = p < .01, * = p < .05



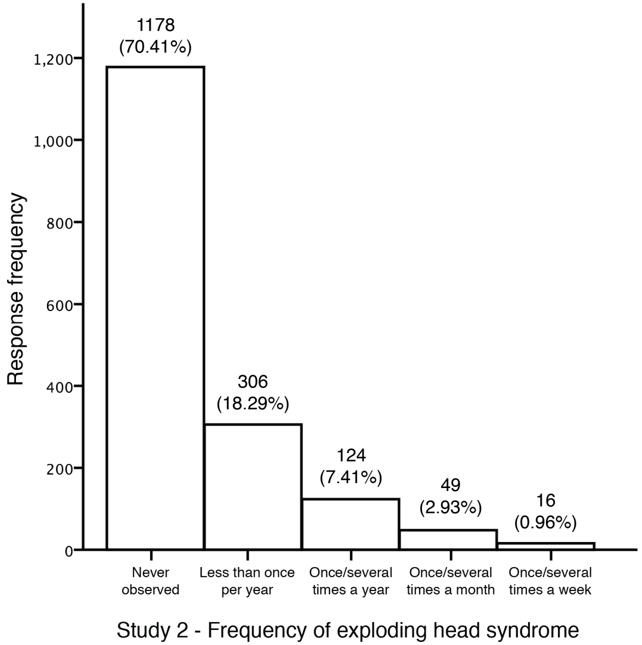


Figure 1. Histograms showing the distribution of exploding head syndrome frequency in the two samples
1