FRAGMENTATION IN SLEEP AND MIND: LINKING DISSOCIATIVE SYMPTOMS, SLEEP, AND MEMORY

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FRAGMENTATION IN SLEEP AND MIND: LINKING DISSOCIATIVE SYMPTOMS, SLEEP, AND MEMORY

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Fragmented sleep, fragmented mind. Art by Sam Price used under first use.

Fragmented, dissociated consciousness can characterize the mind in both wake and sleep states. Dissociative symptoms, during sleep, include vivid dreaming, nightmares, and alterations in objective sleep parameters (e.g., lengthening of REM sleep). During waking hours, dissociative symptoms exhibit disparate characteristics encompassing memory problems, excessive day-dreaming, absentmindedness, and impairments and discontinuities in perceptions of the self, identity, and the environment. Llewellyn has theorized that a progressive and enduring de-differentiation of wake and dream states of consciousness eventually results in schizophrenia; a lesser degree of de-differentiation may have implications for dissociative symptoms.

Against a background of de-differentiation between the dream and wake states, the papers in this volume link consciousness, memory, and mental illness with a special interest for dissociative symptoms

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Table of Contents

Chapter 3: Sleep, Memory and Psychopathology in Adolescents

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EDITORIAL
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Editorial: Fragmentation in Sleep and Mind: Linking Dissociative Symptoms, Sleep, and Memory

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Keywords: dissociation, unusual sleep experiences, memory, de-differentiation, hyperassociative thinking

Editorial on the Research Topic

Fragmentation in Sleep and Mind: Linking Dissociative Symptoms, Sleep, and Memory

Dissociative symptoms are notorious for their enigmatic, disparate nature encompassing excessive daydreaming, memory problems, absentmindedness, and impairments and discontinuities in perceptions of the self, identity, and the environment. Recent studies (e.g., Koffel and Watson, 2009) have linked dissociative symptoms to vivid dreaming, nightmares, and objective sleep parameters (e.g., lengthening of REM sleep) for discussion, see Van der Kloet et al. (2013). Germane to this link between dissociative symptomology and sleep, is the idea that in dissociative individuals, the waking state as compared to REM sleep may be marked by an increase in "fluid" and hyperassociative thinking.

Against this background, we invited contributions in the following areas: (1) a progressive and enduring de-differentation of wake and dream states of consciousness eventually results in schizophrenia (Llewellyn, 2011); a lesser degree of de-differentiation may have implications for dissociative symptoms; (2) sleep disturbances are not only linked to dissociation but to memory fragmentation also, further fuelling both dissociation and other manifestations of psychopathology; (3) sleep, memory and psychopathologies have complex interlinkages.

Our summary below, relates the contributions to our topic to these areas. The contributing articles also give a comprehensive overview on current directions and challenges in these research fields.

First, Soffer-Dudek elucidates why heightened sleep experiences (vivid dreams, nightmares, hypnagogic hallucinations) might be particularly associated with psychopathology. She explains how various psychopathologies may represent de-differentiation of the waking and dreaming states through intrusions of wake-like consciousness into sleep and dream-like cognition into wake. With regard to de-differentiation, she discusses theories of transliminality ("thin boundaries between consciousness states") and dissociation as potential mechanisms. Lucid dreaming is a hybrid state where wake-like cognition suffuses REM sleep/dreaming (Voss et al., 2009). Mota et al. compared the spontaneous occurrence of lucid dreaming in patients with psychotic symptoms (25 with schizophrenia and 20 with bipolar disorder) and 28 non-psychotic subjects. They found lucid dreaming was associated with psychosis- giving some support to the hypothesis of a link between state de-differentiation and psychopathology. In a methodological note, Ribeiro et al. having studied the prevalence of lucid dreaming using two questionnaires, show that the type of methodology used in lucid dreaming studies may have an effect upon their findings. Poerio et al. state that both research and theory points to dissociation being engendered by

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the intrusion of dream-like mentation into waking consciousness. To extend this idea they examine the role of sleep and daydreaming as potentiating states for subsequent dissociation in depersonalization/derealization disorder (DDD). They show the occurrence and content of daydreams may act as potentiating states for heightened, in the moment, dissociation. Sleep paralysis is a dissociated state where a heightened level of wake-like alertness coexists with muscle atonia. de Sá and Mota-Rolim take a broad interdisciplinary perspective on sleep paralysis through reviewing its occurrence in Brazilian folklore by exploring the "Pisadeira" with a sleep science approach and link this with the field of history and art.

There is now substantial evidence that active memory processing continues during sleep (see, for example, Rasch and Born, 2013) and dreaming may be involved (Llewellyn, 2013). De-differentiation of the wake, sleep and dream states would disrupt this memory processing fuelling dissociation and other psychopathologies. Horton presents an overview of discontinuity of consciousness in both wake and sleep, focusing on the processes of sleep-dependent memory consolidation and fragmentation. Nakagawa et al. focus specifically on working memory and the relation with sleep. With their article, they are the first to investigate differences between verbal working memory (VWM) and visuospatial working memory (VSWM) related to daytime nap duration, nap frequency, and dream content recall frequency (DCRF). They discuss sex-related differences in the effects of sleep habits on VMW and VSWM and ascribe this to differences in underlying neural correlates, and effectiveness of sleep habits in males and females. Rosales-Lagarde et al. related to emotional memory by designing an extended International Affective Picture System (IAPS) instrument to measure bizarreness and show some interesting age and gender disparities.

Finally, several authors took a developmental approach through focusing on sleep, memory and psychopathology in adolescents. Wang et al. show the relation between children and adolescents' mental health and sleep problems in a 10-year longitudinal trial, and find anxiety, depression, attention problems and aggressive behavior during childhood to be important predictors for later sleep problems. Importantly, sleep problems are also predictive of behavioral difficulties later in life. Nader et al. investigated changes in sleep in adolescents between 12 and 19 years old following procedural task training and found that contrary to earlier work, there were no changes in sleep spindle density. Interestingly, participants who successfully learned the task showed no changes in their sleep stage proportions, but participants who were not successful showed a decrease in the proportion of Stage 2 and increases in both SWS and REM sleep, which is in line with the two stage model of sleep and memory by Smith et al. (2004).

The self and the world during dreaming differ. The perceived world during waking depends on making sense of external sensory input, which engenders a strong sense of external reality in which the "self and its inner-world" exists. Self-organizing during waking and dreaming enables integration of the self and the world in both states. It is noteworthy, that within this research topic so many novel themes have emerged and new questions and speculations have been posed with regards to relations among unusual sleep experiences—specifically lucid dreaming—, dissociation, psychosis, and memory. It brings together a richness of research by combining fields that originally have worked in isolation from each other.

AUTHOR CONTRIBUTIONS

Both authors contributed to writing up the topic, handling the reviews and writing up the editorial.

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MINI REVIEW
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Arousal in Nocturnal Consciousness: How Dream- and Sleep-Experiences May Inform Us of Poor Sleep Quality, Stress, and Psychopathology

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The term "sleep experiences," coined by Watson (2001), denotes an array of unusual nocturnal consciousness phenomena; for example, nightmares, vivid or recurrent dreams, hypnagogic hallucinations, dreams of falling or flying, confusional arousals, and lucid dreams. Excluding the latter, these experiences reflect a single factor of atypical oneiric cognitions ("general sleep experiences"). The current study is an opinionated mini-review on the associations of this factor—measured with the Iowa sleep experiences survey (ISES, Watson, 2001)—with psychopathological symptoms and stress. Findings support a strong relation between psychological distress and general sleep experiences. It is suggested that that they should be viewed as a sleep disturbance; they seem to represent involuntary intrusions of wakefulness into sleep, resulting in aroused sleep. These intrusions may stem from excessively thin boundaries between consciousness states (e.g., "transliminality"), or, conversely, they may follow an attempt at disconnecting mental elements (e.g., dissociation), which paradoxically results in a "rebound effect." The extent to which unusual dreaming is experienced as intrusive, rather than controlled, may explain why general sleep experiences are related to psychopathology, whereas lucid dreams are related to psychological resilience. In conclusion, the exploration of the interplay between psychopathology and sleep should be expanded from focusing almost exclusively on quantitative aspects (e.g., sleep efficiency, latency) to including qualitative conscious experiences which may reflect poor sleep quality. Taking into account nocturnal consciousness—including unusual dreaming and permeable sleep-wake boundaries—may unveil rich information on night-time emotional states and broaden our definition of poor sleep quality.

Keywords: sleep experiences, dreaming, sleep quality, psychopathology, distress, nightmares, hypnagogic hallucinations, sleep-wake disorders

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A vast body of literature shows that sleep problems are related to an array of psychopathological disorders, including depression, bipolar disorder, anxiety disorders, posttraumatic stress disorder (PTSD), obsessive-compulsive disorder, schizophrenia, dissociation, alcoholism, eating disorders, attention deficit hyperactivity disorder, dementia, and autism (Benca et al., 1992; Chouinard et al., 2004; Spoormaker and Montgomery, 2008; Cortese et al., 2009; Sedky et al., 2014; van Heugten–van der Kloet et al., 2014a; Díaz-Román et al., 2015; Nota et al., 2015). Most studies on psychopathology and sleep assess sleep quality or disruption in terms of one's ability to fall asleep with ease and sleep through the night uninterrupted. Therefore, research has mostly relied on quantitative measures. These include, for example, total/true sleep time, sleep efficiency, sleep latency, wake after sleep onset, and number of awakenings (e.g., Elrod and Hood, 2015; Ng et al., 2015). Indeed, these variables play a central role in psychopathology and have the advantage of possible objective assessment (e.g., polysomnography, actigraphy).

However, the focus on quantitative measures is intertwined with a certain neglect of subjective—or qualitative—aspects of the sleeper's consciousness, such as dream characteristics. This relative neglect is evident in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; American Psychiatric Association, 2013); out of numerous disorders of sleep-wake processes, spanning problems with the amount and timing of sleep, breathing-disordered sleep, and parasomnias (e.g., sleepwalking), only one, namely, nightmare disorder (ND), is primarily concerned with an alteration in dreaming. Similarly, while symptoms involving quantitative sleep alterations appear in numerous diagnoses in other chapters of the manual (e.g., mood disorders), qualitative nocturnal experiences are hardly addressed. Other than "recurrent distressing dreams" related to traumatic content in the diagnosis of PTSD (American Psychiatric Association, 2013), dreaming does not play a major role in the DSM-5. Thus, although the field of Psychology is interested not just in behavior but also in subjective experience, it seems that current views of mental health do not tend to take into account characteristics of *nocturnal consciousness* when defining or diagnosing psychopathology. Granted, dream research suffers from the problem of subjectivity, and dream reports may be unreliable and open to bias (see Schwartz and Maquet, 2002, for a review of methodological problems in dream research). Yet, this problem may be reduced by conducting rigorous studies exploring relationships between dream- and sleep-experiences and emotion with daily diaries (e.g., Soffer-Dudek and Shahar, 2011), or by lexical analysis of dreams (Schwartz and Maquet, 2002). I assert that paying attention to nocturnal subjective experience is informative and worthwhile. The current investigation is a qualitative mini-review on the relation between psychopathology and a trait representing unique nocturnal consciousness.

NOCTURNAL CONSCIOUSNESS AND ITS IMPORTANCE FOR THE EXPLORATION OF PSYCHOPATHOLOGY

By using the term "nocturnal consciousness," rather than "dreaming," I refer to subjective experience throughout various sleep stages and sleep-wake transitions. Specifically, I wish to emphasize: (1) that I am not merely considering the content of dreams, but also their structural or formal aspects, such as repetitiveness, vividness, and bizarreness; and (2) that the review is not limited to typical REM dreams, but also includes non-REM mentation, which may be experienced as "thoughts" (McNamara et al., 2010), as well as sleep-wake transition phenomena such as sleep paralysis, hypnagogic hallucinations, and confusion upon awakening. Notably, the present review is meant to supplement and extend the already-established literature on non-REM sleep-wake disorders (sleepwalking, night terrors). These disorders, representing arousal in sleep, are strongly related to stress and psychopathology (Schenck and Mahowald, 2005).

Do alterations in nocturnal consciousness play a significant role in psychopathology? Indeed, there is ample evidence that dream characteristics are associated with several psychopathological symptoms. For example, nightmares are related to emotional distress, trauma, and personality disorders (e.g., Zadra and Donderi, 2000; Levin and Nielsen, 2009; Davis et al., 2011; Casement and Swanson, 2012; Schredl, 2016), and share a specific association with suicidality (Cukrowicz et al., 2006; Sjöström et al., 2007; Pigeon et al., 2012). Suicidality is also related to a reduction in dream-like quality of dream content reports between the first and second half of the night (Agargun and Cartwright, 2003). Alterations in dreaming seem to play a part in psychosis as well (D'Agostino et al., 2012, 2013; Cavallotti et al., 2014). In fact, the dream sleep stage (i.e., REM sleep), has been suggested as a model for schizophrenia (Gottesmann, 2006), and there is some evidence that psychosis may be conceptualized as sleeping mentation entering the waking state (e.g., Sponheim et al., 1994). The various nocturnal consciousness characteristics that have been related to stress, negative emotion, or psychopathological symptoms include—but are not limited to—traumatic and non-traumatic nightmares (e.g., van der Kolk et al., 1984; Hartmann, 1998; Levin, 1998; Cukrowicz et al., 2006; Pigeon et al., 2012), recurrent dreams (Zadra et al., 1997–1998; Duke and Davidson, 2002), falling dreams (e.g., Kroth et al., 2002; Schredl, 2007), dream bizarreness (e.g., Cavallotti et al., 2014), and hypnagogic hallucinations (Ohayon et al., 1996; Ohayon, 2000; Koffel, 2011).

Additionally, in recent years a broad trait of unique dream characteristics has been strongly and repeatedly linked with distress. In 2001, David Watson analyzed items addressing various aspects of unique dream and sleep-wake transition experiences, resulting in two factors for the "Iowa Sleep Experiences Survey" (ISES; Watson, 2001). Fifteen items loaded onto a non-specific factor, which includes an array of unusual dreams and sleep-wake phenomena (henceforth labeled general sleep experiences; GSEs; Watson, 2001), such as remembering dreams, nightmares, recurrent dreams, vivid dreams, dreams of flying or falling, confusion between dreams and reality, false awakenings (i.e., awakening within the dream), dreams of dying, and hypnagogic hallucinations. Three items loaded on a separate factor, pertaining to the experience of lucidity in dreams (i.e., awareness of the fact of dreaming, while maintaining the sleep state, and control over dream events). This subscale (LDs) is moderately related to GSEs (e.g., $r = 0.42$, $p < 0.001$, Soffer-Dudek and Shahar, 2009), suggesting that they are not identical. GSEs (but not LDs) have repeatedly been associated with negative emotionality, stress, and psychopathological symptoms. Notably, studies that explored relationships of psychopathology with

Abbreviations: GSEs, general sleep experiences; LDs, lucid dreams; PTSD, posttraumatic stress disorder; ND, nightmare disorder.

individual ISES items (e.g., Watson, 2001; Soffer-Dudek et al., 2011a) found relations with most items, suggesting that the relation of GSEs with psychopathology does not stem specifically from the nightmare item or any other single item. **Table 1** reviews research that examines the relationship between GSEs (as measures with the ISES) along with measure(s) of negative emotion, stress, or psychopathological symptoms[1].

As evident from the table, GSEs are positively associated with various psychopathological symptoms. The first types of symptoms associated with GSEs were dissociative experiences (Watson, 2001, 2003; Giesbrecht and Merckelbach, 2004, 2006a; Fassler et al., 2006) and schizotypy (Watson, 2001, 2003). On the basis of these relations, Watson concluded that the constructs form a common domain involving unusual cognitions and perceptions in waking and in sleep (Watson, 2001). Koffel and Watson (2009) further clarified that GSEs are characteristic of a psychopathological tendency for oddity, including magical ideation, suspiciousness, ideas of reference, unusual perceptions, and odd speech, behaviors, and beliefs. They reviewed findings of higher correlations of GSEs with dissociation (Koffel and Watson, 2009) and with dissociation and schizotypy (Watson, 2001), compared with negative affectivity and obsessive-compulsive symptoms (Koffel and Watson, 2009) or with neuroticism (Watson, 2001; see also Knox and Lynn, 2014). Hence, they suggested that GSEs are specific to dissociation and schizotypy, whereas insomnia and lassitude are specific to depression and anxiety (Koffel and Watson, 2009; Koffel, 2011).

However, Fassler et al. (2006) found that effect sizes of GSEs with dissociation were similar in magnitude to those with negative emotion. Subsequent research on GSEs pointed to strong non-specific associations with a wide array of psychological distress symptoms (Soffer-Dudek and Shahar, 2009, 2010, 2011; Watson et al., 2015; Soffer-Dudek, 2016). Moreover, this relationship has been extended from student samples to clinical samples (Soffer-Dudek et al., 2011a; Watson et al., 2015), including not only self-report methods but also using rigorous interview-based diagnoses (Watson et al., 2015). GSEs do not merely relate concurrently to distress, but also longitudinally. Specifically, psychological symptoms (a general distress score, as well as several subscales: somatization, obsessive-compulsive symptoms, depression, hostility, paranoid ideation, and psychoticism) prospectively predicted an elevation in GSEs across a 3 month interval (Soffer-Dudek and Shahar, 2009). Moreover, baseline GSEs were a potent prospective predictor of an elevation in psychopathological symptoms following exposure to terror 3 years later (Soffer-Dudek, 2016). Studies using other measures focusing on specific unusual sleep events also support these relations with distress. For example, in a study on adults reporting childhood trauma, McNally and Clancy (2005) found that sleep paralysis is related to both depression and dissociation, with similar effect sizes. In addition, nightmares show moderate to strong correlations with depression and anxiety in student and psychiatric samples (e.g., Koffel and Watson, 2010).

[1]See van der Kloet et al. (2012b) for a review on the ISES and dissociation.

The two views of GSEs, namely, as an altered consciousness trait pertaining to unusual cognitions and as a manifestation of psychological distress, are not necessarily contradictory. One study integrated them by demonstrating a symmetrical diathesis-stress interaction, according to which the effect of trait dissociation on daily GSEs was present only in the face of high daily stress, and the effect of daily stress on GSEs existed only among those high in trait dissociation (Soffer-Dudek and Shahar, 2011). Thus, it seems that for individuals who are prone to experience unusual cognitions, psychological distress may be manifested in alterations in nocturnal consciousness.

GSES AS DISRUPTED SLEEP

The relationship of GSEs with various forms of psychopathological distress, reviewed in **Table 1**, suggests that GSEs may represent a form of distressed sleep. This raises a question, namely: Should there be some correlation between GSEs and traditional (quantitative) measures of disturbed sleep quality? Or are GSEs an entirely different, independent form of sleep disturbance? Research has been equivocal on this matter. Several studies did find a relation (Kucukgoncu et al., 2010; Soffer-Dudek and Shahar, 2011; van Heugten–van der Kloet et al., 2014a, 2015a,b; Soffer-Dudek, 2016). However, others did not (Watson, 2003; Van Der Kloet et al., 2013). Knox and Lynn (2014) found it only in one of their two samples. These null findings may be rooted in the fact that Van Der Kloet et al. (2013) and Watson (2003) used the total ISES score, which included LDs, and that Watson (2003) and Knox and Lynn (2014) did not separate sleep quality from sleep duration. In a rigorous daily study, Soffer-Dudek and Shahar (2011) showed that elevated GSEs were related to poor sleep quality, but also to long sleep duration (see also van Heugten–van der Kloet et al., 2015a, for somewhat similar results).

GSEs as sleep disruptions have been conceptualized as arousal and hypervigilance permeating the dream state (Soffer-Dudek and Shahar, 2011). This conceptualization is similar to the classic view of disrupted sleep, according to which, vigilance to threat pulls one away from sleep and toward waking (e.g., Dahl, 1996); except that it does not view sleep and waking as *mutually exclusive* states, but rather posits that arousal may exert its influence on consciousness even without waking up the sleeper. Undeniably, non-REM parasomnias (e.g., sleepwalking) are hybrid sleep-wake states; GSEs may represent the corresponding REM sleep phenomena (e.g., elevated dream recall, nightmares, hypnagogic hallucinations, intensely kinesthetic dreams, vivid dreams, confusional arousals, false awakenings, and recurrent dreams, characterized by increased access to memory). Indeed, individuals suffering from insomnia show greater brain metabolism during sleep (Nofzinger et al., 2004), and higher frequency EEG activity during sleep onset and non-REM sleep (e.g., Perlis et al., 2001), especially in the face of stress (Hall et al., 2007). Moreover, stress and worry carry prolonged cardiovascular effects into sleep, independent of sleep quality, which have been labeled "unconscious worry" (Brosschot et al., 2007). Importantly, some individuals seem to

TABLE 1 | Studies demonstrating relationships between general sleep experiences (GSEs) as assessed by Watson's (2001) Iowa sleep experiences survey (ISES), and psychopathology-related constructs such as negative affectivity, stress, and psychological symptoms.

Study	Sample characteristics	Effect size and statistical significance for each related construct	Relation type
Watson, 2001	Sample 1: $N = 471$ undergraduate students, ~59% females.	Neuroticism: $r = 0.28^{**}$; Dissociation: $r = 0.42^{**}–0.57^{**}$; Schizotypy: $r = 0.36^{**}–0.47^{**}$.	Cross-sectional correlations.
	Sample 2: $N = 457$ undergraduate students, ~64% females.	Neuroticism: $r = 0.24^{**}$; Dissociation: $r = 0.44^{**}–0.54^{**}$; Schizotypy: $r = 0.31^{**}–0.45^{**}$.	
Watson, 2003	$N = 169$ undergraduate students, 73.37% females.	Neuroticism/Negative Emotionality: $r = 0.18^{*}$; Dissociation: $r = 0.30^{**}–0.52^{**}$; Schizotypy: $r = 0.20^{**}–0.36^{**}$ (note: this study used an earlier version of the ISES, which included items pertaining to lucid dreaming in the same factor score. Thus, correlations with psychopathology are lower, compared to studies using the GSEs factor).	Cross-sectional correlations (note: the neuroticism measure was administered 2 months before the other measures).
Giesbrecht and Merckelbach, 2004	$N = 94$ undergraduate students, 68.09% females. $M_{age} = 21.25$, $SD_{age} = 2.16$, age range: 18–27.	Dissociation: $r = 0.38^{**}$.	Cross-sectional correlation.
Fassler et al., 2006	$N = 163$ undergraduate students, 66.87% females. $M_{age} = 19.77$, $SD_{age} = 1.96$, age range: 18–35.	Negative affect: $r = 0.37^{**}$; Dissociation: $r = 0.35^{**}$.	Cross-sectional correlations.
Giesbrecht and Merckelbach, 2006a	$N = 205$ undergraduate students, 68.29% females. $M_{age} = 19.4$, $SD_{age} = 1.75$, age range: 17–26.	Dissociation: $r = 0.35^{**}$.	Cross-sectional correlation.
Giesbrecht and Merckelbach, 2006b	$N = 87$ undergraduate students.	Dissociation: $r = 0.37^{**}$.	Cross-sectional correlation.
Giesbrecht et al., 2006	$N = 67$ undergraduate students, 88.06% females. $M_{age} = 21.1$, $SD_{age} = 2.68$, age range: 18–31.	Dissociation: $r = 0.47^{**}–0.55^{**}$.	Cross-sectional correlation.
Koffel and Watson, 2009	Sample 1: $N = 376$ undergraduate students (note: Sample 2 is not reported because no correlations were reported for that sample).	Negative affectivity: $r = 0.27$; obsessive-compulsive symptoms: $r = 0.34$; Dissociation: $r = 0.45$ (Note: statistical significance levels were not presented in this study; however, the authors stated that the correlation coefficient of GSEs with dissociation was significantly stronger than the other two correlation coefficients).	Cross-sectional correlations.
Soffer-Dudek and Shahar, 2009	$N = 203$ undergraduate students, 85% females. $M_{age} = 23.6$, $SD_{age} = 1.86$, age range: 17–33.	Dissociation: $r = 0.33^{**}–0.44^{**}$; Psychological distress symptoms: $r = 0.34^{**}–0.40^{**}$; Stressful life events: $r = 0.23^{**}–0.30^{**}$.	Cross-sectional correlations.
		An elevation over the course of 3 months in stressful life events was related to a parallel elevation in GSEs ($\beta = 0.34^{**}$).	Correlations extended in time (predicting change with change over a 3 month interval).
		Psychological distress at Time 1 predicted an elevation in GSEs ($\beta = 0.14^{**}$) while dissociation ($\beta = 0.05$) and stressful life events ($\beta = -0.08$) did not.	Prospective-longitudinal prediction of GSEs over the course of 3 months.
Soffer-Dudek and Shahar, 2010	$N = 91$ participants recently exposed to missile terror attacks, through direct exposure or media and relational exposure. They were taken from the pool of participants from Soffer-Dudek and Shahar (2009) which was conducted 3 years prior to this study. Approx. 80% females. $M_{age} = 23.8$, age range: 21–33.	Psychological distress symptoms: $r = 0.50^{**}$; Exposure to terror through the media: $r = 0.26^{*}$; Physical exposure: $r = -0.21^{*}$ (reverse effect); physical location: $r = -0.33^{**}$ (reverse effect); Stress-related exposure: $r = 0.19$; Relational exposure: $r = -0.04$.	Cross-sectional correlations.
		Exposure to the attacks through the media (as reported at Time 2) predicted an elevation in GSEs ($\beta = 0.27^{**}$). Physical location had a reverse effect ($\beta = -0.26^{**}$), suggesting that the closer to the area of attacks one resided, the more GSEs decreased. (Note: sleep loss due to nocturnal alarms was not controlled for in this study, which may have confounded the association). Time 1 psychological distress ($\beta = 0.16$), relational exposure ($\beta = 0.16$), physical exposure ($\beta = -0.16$), and stress-related exposure ($\beta = -0.04$) did not have a statistically significant effect on change in GSEs.	Prediction of longitudinal change in GSEs over the course of 3 years.
Kucukgoncu et al., 2010	$N = 200$ undergraduate students with no current psychiatric complaints. 52.76% females. $M_{age} = 23.07$, $SD_{age} = 2.12$, range = 10.	Dissociation: $r = 0.49^{**}–0.56^{**}$	Cross-sectional correlation.

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	Effect size and statistical significance for each related construct	Relation type
Soffer-Dudek and Shahar, 2011	$N = 200$ undergraduate students, 77.50% females. $M_{age} = 23.36$, $SD_{age} = 1.40$, age range: 18–28.	Dissociation: $r = 0.29^{**}$–0.53^{**}; Psychological distress symptoms: $r = 0.50^{**}$; depressive symptoms: $r = 0.44^{**}$; Stressful life events: $r = 0.44^{**}$ -0.46^{**}.	Cross-sectional correlations.
	$N = 60$, a random subset from the participant pool described above. 71.67% females. $M_{age} = 23.54$, $SD_{age} = 1.16$, age range: 21–26.	Daily stress ratings: *semi-partial* $R^2 = 0.08^{*}$; Trait dissociation: *semi-partial* $R^2 = 0.12^{**}$; state dissociation (*semi-partial* $R^2 = 0.00$), psychological distress (*semi-partial* $R^2 = 0.00$) and life stress (*semi-partial* $R^2 = 0.00$) did not have a statistically significant effect (Note: standardized effect sizes for multilevel modeling analyses were not originally published. They were calculated here based on the degrees of freedom and the *t*-value which were included in the published data. For each relevant predictor effect, a standardized effect size of explained variance was calculated, namely semi-partial R^2; Edwards et al., 2008).	Longitudinal prediction of change in daily GSEs across 14 days.
Soffer-Dudek et al., 2011a	$N = 19$ outpatients of a mental health clinic, 13 of them diagnosed with schizophrenia or related diagnoses, 4 with bipolar disorder, and 2 with anxiety disorders (52.63% females. $M_{age} = 37.55$, $SD_{age} = 13.53$), and $N = 26$ controls from the community (53.85% females. $M_{age} = 38.58$, $SD_{age} = 13.74$).	Psychological distress symptoms: $r = 0.34$–0.35; Stress: $r = 0.00$–0.46^{*}; Daytime dysfunction: $r = 0.36$–0.61^{**}; Illness intrusiveness: $r = 0.49^{*}$.	Cross-sectional correlations within each group separately.
		GSEs of outpatients: $M = 3.17$, $SD = 1.23$; GSEs of controls: $M = 2.30$, $SD = 0.84$; comparison: $t_{(43)} = 2.82^{**}$.	Comparison of means between groups.
van der Kloet et al., 2012a (Note: this study did not use the ISES *per se* but used subscales of a sleep measure pertaining to nightmares and narcoleptic symptoms to mimic the ISES and explicitly aimed to test Watson's predictions)	$N = 195$ mixed (mainly depressed) inpatients undergoing eclectic psychotherapy for 6–8 weeks. Approx. 43% females. Approx. $M_{age} = 44.2$, $SD_{age} = 11.5$, age range: 18–74.	*For the narcolepsy subscale:* Dissociation: $r = 0.29^{**}$; Psychopathology composite: $r = 0.23^{**}$.	Correlations extended in time: correlations between change variables (across 6–8 weeks).
		For the nightmares subscale: Dissociation: $r = 0.01$; Psychopathology composite: $r = -0.06$.	
Van Der Kloet et al., 2013 (Note: this study relied on the general ISES score rather than the subscale score for GSEs)	$N = 45$ inpatients diagnosed with primary insomnia, 62.22% females, $M_{age} = 41.5$, $SD_{age} = 13.68$, age range: 17–78.	Psychological distress symptoms: $r = 0.37^{*}$; Dissociation: $r = 0.40^{**}$.	Cross-sectional correlations.
Knox and Lynn, 2014	$N = 86$ undergraduate students (63.95% females) in the out-of-context condition, and $N = 87$ undergraduate students (58.62% females) in the in-context condition. $Median_{age} = 18$, age range: 17–24.	*Out of context condition:* Negative emotion: $r = 0.29^{**}$; Schizotypy: $r = 0.25^{*}$–0.38^{**}; Dissociation: $r = 0.36^{**}$.	Cross-sectional correlations in each condition separately
		In-context condition: Negative emotion: $r = -0.10$–0.08; Schizotypy: $r = -0.09$–0.42^{**}; Dissociation: $r = 0.42^{**}$.	
van Heugten–van der Kloet et al., 2014a	Patients (100% female) with dissociative identity disorder (DID; $n = 12$, $M_{age} = 42$, $SD_{age} = 11.8$) and post-traumatic stress disorder (PTSD; $n = 27$, $M_{age} = 42$, $SD_{age} = 13.1$), and healthy female controls ($n = 55$, $M_{age} = 42$, $SD_{age} = 13.1$).	Dissociation: $r = 0.63^{**}$	Cross-sectional correlation across groups.
		GSEs of DID: $M = 62.50$, $SD = 17.71$; GSEs of PTSD: $M = 57.93$, $SD = 19.96$; GSEs of controls: $M = 34.11$, $SD = 12.48$; comparison: $F = 30.10^{**}$ (the authors state that DID significantly differed from controls and PTSD significantly differed from controls, with no significant difference between DID and PTSD).	Comparison of means between groups.
Van Heugten–van der Kloet et al., 2014b	$N = 139$ undergraduate students, 87.77% females. $M_{age} = 21.4$, age range: 17–32.	Dissociation: $r = 0.39^{*}$(after transformation of the dissociation score: $r = 0.41^{**}$).	Cross-sectional correlation.

(Continued)

TABLE 1 | Continued

Study	Sample characteristics	Effect size and statistical significance for each related construct	Relation type
van Heugten–van der Kloet et al., 2015a	$N = 72$ participants older than 18 who chose to enter a photo contest, ~77% females. $M_{age} = 35.8$, $SD_{age} = 16.9$.	Dissociation: $r = 0.40^{*}$–0.54^{*}.	Cross-sectional correlations.
van Heugten–van der Kloet et al., 2015b (Note: this study relied on the general ISES score rather than the subscale score for GSEs).	$N = 56$ undergraduate students with no serious mental disease or sleep problems. 76.79% females. $M_{age} = 20.7$, $SD_{age} = 2.33$, age range: 18–29.	Dissociation: $r = 0.45^{**}$–0.55^{**}.	Cross-sectional correlations.
		Dissociation: −0.21–0.27; Mood: 0.34 (Note: statistical significance in this study is reported only at the $p < 0.01$ level; the deterioration in mood following sleep loss seems to be significant at the $p < 0.05$ level but it cannot be ascertained based on the published data).	Correlation of ISES score with the change score of psychopathology following a period of sleep loss.
Merckelbach et al., 2015	$N = 22$ inpatients hospitalized at a psychiatric facility specializing in trauma (participants were diagnosed with PTSD, dissociative disorders), mood disorders, and borderline personality disorder. 81.82% females, $M_{age} = 38.8$, $SD_{age} = 10.15$, age range: 20–59.	Dissociation: 0.40–0.59**.	Cross-sectional correlations.
Watson et al., 2015 *(Note: this study used a composite score encompassing both the ISES and additional scales assessing unusual sleep experiences)*	$N = 406$ adults, 68.49% females. $M_{age} = 44.9$, $SD_{age} = 13.3$, age range: 18–74. Nearly half of the sample ($N = 188$) received treatment for mental health issues.	Panic: $r_{SR} = 0.67$, $r_{ID} = 0.33$; Posttraumatic stress: $r_{SR} = 0.65$, $r_{ID} = 0.40$; Generalized anxiety: $r_{SR} = 0.61$, $r_{ID} = 0.44$; Depression: $r_{SR} = 0.58$, $r_{ID} = 0.39$–0.48; Obsessive-compulsive: $r_{SR} = 0.53$, $r_{ID} = 0.35$; Social anxiety: $r_{SR} = 0.47$, $r_{ID} = 0.30$; Agoraphobia: $r_{SR} = 0.45$, $r_{ID} = 0.38$; Substance use: $r_{SR} = 0.12$–0.24, $r_{ID} = 0.10$–0.18; Bipolar: $r_{SR} = 0.20$–0.50, $r_{ID} = 0.46$; Schizotypy/psychosis: $r_{SR} = 0.24$–0.65, $r_{ID} = 0.42$–0.51; Dissociation: $r_{SR} = 0.69$ (no r_{ID} for dissociation). (Note: Statistical significance of the correlations is not reported in this study. SR, self-report. ID, interview diagnosis).	Cross-sectional correlations with self-report scales and (polyserial correlations) with interview diagnoses.
Soffer-Dudek, 2016	$N = 53$ participants recently exposed to missile terror attacks, through direct exposure or media and relational exposure. They were taken from the pool of participants from Soffer-Dudek and Shahar (2011) which was conducted 3 years prior to this study. 79.25% females. $M_{age} = 26.23$, age range: 24–29.	Psychological distress symptoms: $r = 0.47^{**}$; Dissociation: $r = 0.42^{**}$; Exposure to terror through the media: $r = 0.33^{*}$; Physical exposure: $r = -0.14$; Stress-related exposure: $r = 0.15$; Relational exposure: $r = 0.04$.	Cross-sectional correlations.
		Time 1 GSEs predicted an elevation in psychological distress symptoms: $\beta = 0.34^{**}$, even when controlling for the effect of the degree of exposure to terrorism. This effect was replicated when reanalyzing data from Soffer-Dudek and Shahar (2010): $\beta = 0.23^{*}$.	GSEs predicting, prospectively-longitudinally, change in psychological symptoms over the course of 3 years.
Vissia et al., 2016	Patients (100% female) with genuine dissociative identity disorder (DID-G; $n = 17$) and post-traumatic stress disorder (PTSD; $n = 16$), and healthy female controls ($n = 16$), as well as DID simulators (DID-S; $n = 16$). All participants' ages ranged from 18 to 65 and were matched between groups.	GSEs of DID-G: $M = 57.88$, $SD = 16.83$; GSEs of PTSD: $M = 50.81$, $SD = 14.81$; GSEs of controls:$M = 28.63$, $SD = 10.22$; GSEs of DID-S: $M = 38.07$, $SD = 11.91$; comparison: $H_{(3)} = 27.80^{**}$ (DID-G significantly differed from controls and PTSD significantly differed from controls, with no significant difference between DID-G and PTSD. DID-G significantly differed from DID-S).	Comparison of means between groups.

*Age and gender are reported only when such data are available. *p < 0.05, two-tailed. **p ≤ 0.01 or lower, two-tailed.*

be especially capable of lingering in mixed sleep-wake states, including dissociative experiences and parasomnias (Mahowald and Schenck, 2001; Giesbrecht et al., 2008; Koffel and Watson, 2009; van der Kloet et al., 2012b). Dissociation and GSEs may reflect a reciprocal process in which sleep and waking intrude into one another. The conceptualization of GSEs as an intrusion of waking into sleep is concordant with the finding that among patients with severe psychopathology, GSEs were related to their experience of the mental illness as intrusive (Soffer-Dudek et al., 2011a).

THE PARADOX OF INTRUSION: NOTES ON THE TRAITS THAT LEAD TO GSES

Enduring the intrusion of waking within dreaming suggests increased fusion and association between consciousness states. Watson (2001) proposed that the trait responsible for the continuum of unusual cognitions may be "thin boundaries"—a tendency for ideas, emotions, memories, and sensations to associate or merge (Hartmann, 1991), or "transliminality"—a similar tendency for psychological material to pass fluidly between consciousness thresholds (Lange et al., 2000). Indeed, GSEs are related to transliminalty (Soffer-Dudek and Shahar, 2009) and synaesthesia (Terhune, 2009). Yet, dissociation, which is closely related to GSEs, is a state of *separation* of mental elements, as can be inferred from its name. Dissociative absorption, for example, is defined as the total allocation of attention to a stimulus while being oblivious to surrounding stimuli (Soffer-Dudek et al., 2015). How can these definitions harmoniously co-exist?

A possible explanation for this seeming discrepancy is the dream rebound effect of avoidance. Specifically, actively attempting not to think about a stimulus (e.g., a white bear), results in increased dreaming about that object (Wegner et al., 2004; Taylor and Bryant, 2007; Schmidt and Gendolla, 2008; Kröner-Borowik et al., 2013; Malinowski, 2016), and especially when facing cognitive load (Bryant et al., 2011). Ironically, suppressing thoughts leads to attempts at monitoring those thoughts, which in turn generate intrusions, resulting in an increase in the occurrence of the thoughts (Wegner, 1994; Wenzlaff and Wegner, 2000). This pertains to the core dynamics of PTSD: The more the individual exerts effort in avoiding thoughts of the trauma, the more they will appear uninvited, as dissociative flashbacks and nightmares. These processes may similarly govern the occurrence of GSEs: Intrusion of arousal into dreaming may be rooted not only in a tendency for increased *association* of mental elements (i.e., thin boundaries, enhanced continuity between waking and dreaming), but also in a tendency for increased *avoidance* and attempts at separating consciousness elements from each other (e.g., memories and emotions), such as dissociative mechanisms, which ironically also result in increased intrusion.

The idea that GSEs are experienced as an uncontrolled intrusion into sleep may be the explanation for the relative lack of findings on LDs and psychopathology. Specifically, LDs are also a "mixed state" between waking and sleeping (Mahowald and Schenck, 2001; Voss et al., 2009); they are even related to blurred boundaries between reality and fantasy (Corlett et al., 2014). However, they do not show the same strong and persistent relation with psychopathology and stress that GSEs do (e.g., Soffer-Dudek and Shahar, 2009; Soffer-Dudek, 2016). This difference may stem from the subjective feeling of control characterizing many LDs, in which the plot of the dream may be volitionally influenced by the dreamer. Indeed, LDs have been related to an internal locus of control (Blagrove and Tucker, 1994; Blagrove and Hartnell, 2000; Patrick and Durndell, 2004) and to psychological resilience in the face of exposure to terror (Soffer-Dudek et al., 2011b).

In contrast, GSEs seem to resemble uncontrolled nocturnal rumination: the uninhibited lingering of distress in the sleeper's consciousness. Indeed, during stressful military conflicts, GSEs are related to a somewhat ruminative inclination to keep watching the news, even though it causes the watcher distress (Soffer-Dudek and Shahar, 2010; Soffer-Dudek, 2016). This tendency to hold on to distress, whether during daytime or nighttime, may be the explanation for some enigmatic findings. Specifically, Soffer-Dudek and Sadeh (2013) found that self-reported unusual dreaming in children predicted an increase in parental ratings of the children's behavior problems (internalizing and externalizing) from age 10 to 12; this suggested that unusual dreaming identified somewhat covert distress or *potential* for psychopathology, undetectable by parents at age 10. Similarly, Soffer-Dudek (2016) also demonstrated that GSEs may reflect covert aspects of distress. Specifically, baseline GSEs prospectively predicted an elevation in psychological distress following exposure to terror attacks 3 years later, over and above the participants' own account of how much they were exposed and distressed by the attacks. GSEs may identify potential future distress, because they represent the inclination to ruminatively and uncontrollably linger in a mixed sleep-wake state, an inclination which places the individual at risk for psychopathology[2].

LIMITATIONS, FUTURE DIRECTIONS, AND CONCLUSIONS

A major methodological limitation of the research reviewed is that it is largely questionnaire-based; hence relationships may suffer from inflation due to biased reporting and shared method variance. Notably, however, daily diaries (e.g., Soffer-Dudek and Shahar, 2011), are less biased than self-reporting on the past month or year because reporting is proximal to the experience, thus less distorted by memory. Future research should also examine daily emotion using ecological momentary assessment and relations with GSEs, to investigate directional relationships, perhaps in conjunction with polysomnography. In addition, scoring dream content using blind raters may provide a less biased approach to the assessment of the relation

[2]The notion that individuals are unaware of the connection between their GSEs and distress is concordant with the finding that the relationship between sleep experiences and dissociation does not stem from symptom exaggeration (Merckelbach et al., 2015).

between dream themes and psychopathology (e.g., Schredl and Engelhardt, 2001). Still, the field would benefit from the inclusion of basic and experimental research. For example, although psychiatric medications affect dreaming, such examinations are scarce (Tribl et al., 2013). Also, although interventions of lucidity with nightmare re-scripting are probably useful in reducing distress (Gavie and Revonsuo, 2010), such research is in its infancy.

Additionally, more work is needed in order to integrate the literatures on nocturnal consciousness and non-REM parasomnias; these also represent mixed sleep-wake states, relate to dissociation (Mahowald and Schenck, 2001), and to psychopathological distress (Schenck and Mahowald, 2005). It is yet to be determined why stress should affect deep sleep in one individual (bringing about unremembered behavioral episodes), and dreaming consciousness in another (resulting in unusual nocturnal cognitions). Possibly, the extent of dissociative tendencies may be responsible; this remains an issue for future research to explore. Future studies should also work to integrate quantitative and qualitative nocturnal characteristics. For example, severely depressed individuals have more REM at the beginning of the night, but less of it during morning-time (Vogel et al., 1980), when dreaming is most frequent; Indeed, their dreaming is impoverished (Cartwright, 2010), suggesting that a complete quantitative-qualitative picture may elucidate psychopathology.

Finally, another limitation of some of the studies reviewed is their correlational design, limiting the ability to draw causal conclusions. However, several studies employed prospective-longitudinal paradigms, assessing change and examining directionality; these studies showed that GSEs both *follow* and prospectively *predict* change in psychopathology. Also, one study implemented time-lag analysis on daily data, showing that GSEs followed stress, rather than vice versa (Soffer-Dudek and Shahar, 2011). Further, research should establish whether GSEs are a consequence of emotional distress, a cause, or both. Several researchers have assigned an active role of emotion regulation and modification to dreaming (e.g., Hartmann, 1998; Levin and Nielsen, 2009; Cartwright, 2010) and more generally, to REM sleep (e.g., Genzel et al., 2015). GSEs may either reflect impaired regulation, or act as a dysregulating force in and of themselves. For example, dreams may engender predictive coding (Kirov, 2016), functioning as a "virtual-reality generator" (Hobson et al., 2014); GSEs may actively impede this mechanism, by introducing external arousal and awareness instead of fully delusional and endogenous REM dreams. Indeed, emotional arousal has been conceptualized as energetic impingement, which brings about both psychopathological symptoms and dream imagery, as the brain's attempt to reduce free energy (Hopkins, 2016); GSEs may reflect impinged-upon dreaming, which joins forces with waking mechanisms to create psychopathological disorders.

In conclusion, some unusual nocturnal experiences seem to be "waking" processes entering sleep states. They increase in frequency during stressful periods, and may be viewed as sleep disruptions. Some of these phenomena are widely accepted as sleep disturbances (e.g., nightmares), whereas others are regarded as esoteric or are hardly regarded at all (e.g., falling dreams, false awakenings). Although GSEs and other dream characteristics are associated with psychopathological symptoms, qualitative aspects of sleep are not included in most diagnostic criteria and rarely routinely assessed. Unusual nocturnal consciousness characteristics are an important way to explore sleep impairment in psychopathology. This relatively under-researched field may lead to novel insights regarding nocturnal emotional states and the underpinnings of consciousness, and may contribute to understanding the specificity of sleep impairment in different psychopathological disorders.

AUTHOR CONTRIBUTIONS

NSD is solely responsible for the conception, literature review, and writing of this paper.

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Psychosis and the Control of Lucid Dreaming

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Dreaming and psychosis share important features, such as intrinsic sense perceptions independent of external stimulation, and a general lack of criticism that is associated with reduced frontal cerebral activity. Awareness of dreaming while a dream is happening defines lucid dreaming (LD), a state in which the prefrontal cortex is more active than during regular dreaming. For this reason, LD has been proposed to be potentially therapeutic for psychotic patients. According to this view, psychotic patients would be expected to report LD less frequently, and with lower control ability, than healthy subjects. Furthermore, psychotic patients able to experience LD should present milder psychiatric symptoms, in comparison with psychotic patients unable to experience LD. To test these hypotheses, we investigated LD features (occurrence, control abilities, frequency, and affective valence) and psychiatric symptoms (measure by PANSS, BPRS, and automated speech analysis) in 45 subjects with psychotic symptoms [25 with Schizophrenia (S) and 20 with Bipolar Disorder (B) diagnosis] versus 28 non-psychotic control (C) subjects. Psychotic lucid dreamers reported control of their dreams more frequently (67% of S and 73% of B) than non-psychotic lucid dreamers (only 23% of C; S > C with $p = 0.0283$, B > C with $p = 0.0150$). Importantly, there was no clinical advantage for lucid dreamers among psychotic patients, even for the diagnostic question specifically related to lack of judgment and insight. Despite some limitations (e.g., transversal design, large variation of medications), these preliminary results support the notion that LD is associated with psychosis, but falsify the hypotheses that we set out to test. A possible explanation is that psychosis enhances the experience of internal reality in detriment of external reality, and therefore lucid dreamers with psychotic symptoms would be more able to control their internal reality than non-psychotic lucid dreamers. Training dream lucidity is likely to produce safe psychological strengthening in a non-psychotic population, but in a psychotic population LD practice may further empower deliria and hallucinations, giving internal reality the appearance of external reality.

Keywords: psychosis, schizophrenia, bipolar disorder, lucid dreams, dreaming

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INTRODUCTION

Dreaming and psychosis share important phenomenological and neurophysiological features (Gottesmann, 2005; Manoach and Stickgold, 2009; Mota-Rolim and Araujo, 2013; Dresler et al., 2014). In terms of subjective experience, both phenomena present intrinsic sense perceptions independent of external stimulation, associated with a lack of criticism (or rational judgment) regarding the bizarreness of these experiences (Cicogna and Bosinelli, 2001). The latter feature has been hypothesized to stem from the decrease in frontal cerebral activity that characterizes both psychosis and rapid-eye-movement (REM) sleep (Dresler et al., 2014; Voss et al., 2014). Yet, executive functions are not necessarily impaired during dreaming. It is possible to be aware of dreaming while a dream is happening, with partial or total control of the dream contents by the dreamer, a phenomenon called lucid dreaming (LD; Laberge et al., 1986; Mota-Rolim and Araujo, 2013; Stumbrys et al., 2013; Voss et al., 2014). Recent studies using functional magnetic resonance imaging (Dresler et al., 2012) and electroencephalography (Voss et al., 2009) indicate that LD is related to increased activity in the prefrontal cortex (Voss et al., 2009, 2014; Mota-Rolim et al., 2010; Neider et al., 2011; Dresler et al., 2012; Stumbrys et al., 2013). In agreement with this notion, transcranial electrical stimulation of the prefrontal cortex can induce dream awareness during REM sleep (Stumbrys et al., 2013; Voss et al., 2014). Frontal cortex activity correlates with self-consciousness, working memory, and attention (Postle, 2006). Therefore, an increase in frontal activity should contribute to lucidity during dreaming (Hobson, 2009; Voss et al., 2009), while a decrease in prefrontal activity should explain the lack of rational judgment in both psychosis and non-lucid dreams (Anticevic et al., 2012; Dresler et al., 2014).

Theories about human consciousness propose that the LD phenomenon is possible due to the linguistic ability of our species, which permits the semantic access of episodic memories of sensory origin (Edelman, 2003; Voss et al., 2013). By accessing episodic memories, the flow of thoughts can be reported, and the subjective ability of "mind wandering" can be shared with others. Similarly, dream mentation can be understood as spontaneous thinking, not associated to any external task (Fox et al., 2013). An important set of systems involved in this process is the default mode network (DMN), a functional circuit comprising brain areas activated during resting states, and suppressed during cognitive tasks (Anticevic et al., 2012; Fox et al., 2013). Some core DMN areas are also engaged during REM sleep, such as the medial pre-frontal cortex and multiple temporal structures (parahippocampal, hippocampal, and entorhinal cortices; Fox et al., 2013). In patients with schizophrenia, there is an impairment in DMN suppression during attention tasks that may contribute to the cognitive deficits found in these subjects (Anticevic et al., 2012).

The dream experience is also peculiar for psychotic patients. Dream report analysis reveals a higher frequency of nightmares among schizophrenic patients than in healthy subjects (Okorome Mume, 2009; Michels et al., 2014), with more hostile contents, higher proportion of strangers among the dream characters, and a lower frequency of dreams in which the dreamer is the main character (Skancke et al., 2014). We have recently uncovered evidence of language impairments in the dream reports of schizophrenic subjects, who produce substantially less complex narratives than non-schizophrenic subjects (Mota et al., 2014). Using a graph-theoretical approach to represent and quantify word trajectories, we found that the recurrence, connectivity and global complexity of dream reports characterize the distinct patterns of thought disorder that correspond to schizophrenia and bipolar disorder type I, two different diseases associated with psychosis (Mota et al., 2012, 2014). Interestingly, graph connectivity attributes were strongly correlated with negative and cognitive symptoms among psychotic patients (Mota et al., 2014). In other words, psychosis-related cognitive deficits are accompanied by impairment in the ability to share a flow of thoughts when remembering a dream, leading to less connected reports than those produced by healthy subjects. Notably, these differences were more prominent for dream reports than for waking reports (Mota et al., 2014). A likely explanation is the hypo-function of the prefrontal cortex in psychosis, which resembles the reduction of prefrontal cortex activity during REM sleep in healthy subjects, in comparison to the levels found in waking. Both in psychosis and regular dreaming, prefrontal cortex hypo-function seems to be causally related to the decreased criticism typical of these states (Dresler et al., 2014; Laruelle, 2014). Since LD displays increased frontal activity in comparison with non-LD (Mota-Rolim et al., 2010; Stumbrys et al., 2013; Voss et al., 2014), LD has been proposed as potential therapy for psychotic patients (Dresler et al., 2014; Voss et al., 2014).

Despite the large amount of evidence linking sleep and dreaming to psychosis (Gottesmann, 2005; Manoach and Stickgold, 2009; Mota-Rolim and Araujo, 2013; Dresler et al., 2014), there is a lack of quantitative information regarding dreaming in psychotic patients. In particular, there are simply no studies of LD in psychotic patients. To address these gaps, we set out to quantitatively characterize LD in a psychotic sample, using graph-theoretical tools and standard psychiatric instruments to test three hypotheses: (1) Psychotic patients report LD less frequently than non-psychotic subjects; (2) Psychotic patients report LD control less frequently than non-psychotic subjects; and (3) Psychotic patients who experience LD present attenuated psychiatric symptoms and present less thought disorder, in comparison with psychotic patients who do not experience LD.

MATERIALS AND METHODS

Participants

Seventy-three Brazilian individuals (43 males and 22 females, mean age 35.59 ± 10.92 years), comprising 28 subjects without psychotic symptoms (control group – C), 25 patients diagnosed with schizophrenia (S), and 20 patients diagnosed with bipolar disorder type I (B), for a total of 45 medicated patients with psychotic symptoms (**Table 1**). The study was approved by the UFRN Research Ethics Committee (permit#102/06-98244),

TABLE 1 | Socio-demographic and psychiatric information about the groups investigated.

		Psychotic subjects		Control subjects	*P*-value		
		Schizophrenia	Bipolar		S × B	S × C	B × C
Demographic characteristics							
Age	Years	34 ± 9.55	39.05 ± 11.79	34.79 ± 11.25	0.1342	0.8369	0.2910
Sex	Male	84%	65%	61%	0.1406	0.0603	0.7624
	Female	16%	35%	39%			
Education	Years	6.92 ± 4.02	9.35 ± 4.20	8.79 ± 3.94	0.0592	0.0867	0.7232
Marital status	Married	24%	50%	60%	0.0702	**0.0071****	0.4607
	Previously Married	20%	30%	8%	0.4380	0.1676	**0.0362***
	Never Married	56%	20%	32%	**0.0143***	0.0802	0.3507
Psychiatric assesment							
Medication	Typical Antipsychotic	72%	65%	0	0.6143	**0.0000****	**0.0000****
	Atypical Antipsychotic	36%	20%	0	0.2393	**0.0027****	**0.0350***
	Mood Stabilizer	12%	55%	5%	**0.0020****	0.4123	**0.0006****
	Benzodiazepine	28%	30%	15%	0.8831	0.2973	0.2560
	Antidepressants	0%	20%	20%	**0.0191***	**0.0191***	1
Age of onset	Years	22.84 ± 8.27	27.1 ± 9.73	36.8 ± 8.9	0.1013	0.0101*	0.0569
Disease duration	Months	17.32 ± 12.10	12.45 ± 9.98	1.24 ± 1.57	0.2162	**0.0011****	**0.0042****

*Age (years), years of education, frequency of sex, marital status, and medication for the groups studied. Mean and standard deviation are indicated. All subjects were Brazilian. Control subjects were non-psychotic individuals with depression (N = 5), generalized anxiety disorder (N = 2), one past episode of post-traumatic stress disorder (N = 1), various symptoms of mood/anxiety disorder without reaching diagnostic criteria (N = 11), plus nine healthy individuals. The groups were compared in pairs using the chi-square test for sex, marital status, and medication, and the Wilcoxon Ranksum test for age, years of education, age of onset, and disease duration. P-values are described for each pair comparison (*p < 0.05 and **p < 0.01).*

and the data were collected by convenience sampling at the "Onofre Lopes" and "João Machado" Hospitals. The control group was recruited at the same clinical institutions among subjects presenting anxiety or depression symptoms but without a psychiatric diagnosis ($N = 11$), among psychiatric patients without psychotic symptoms [individuals with depression ($N = 5$), generalized anxiety disorder ($N = 2$), one past episode of post-traumatic stress disorder ($N = 1$)] and healthy individuals accompanying patients ($N = 9$). All individuals gave written informed consent. During the psychiatric interview, patients were examined for major changes in state and level of consciousness (e.g., drowsiness, torpor), for signs of autopsychic and allopsychic disorientation (e.g., inability to remember name, age, spatial localization), and for signs of reduced mnemonic and cognitive capacity. All psychotic subjects were medicated and out of the acute psychotic phase at the onset of the study, so typically they were in good capacity to provide informed consent. When signs of disorientation or reduced mnemonic capacity were detected, the experimenter also obtained written informed consent on their behalf from their legal guardians (next of kin). There were differences related to marital status (more single subject on S than on B, previously married on B than on C and more married subjects on C than on S – which could be explained by social behavior impairments in the psychotic group), medication (more antipsychotics for psychotic groups, more mood stabilizers for B and less antidepressants for S – which reflects the clinical symptoms treated), the age of onset and the duration (smaller age of onset for S compared to C, and larger duration to psychotic group – also expected for the different diseases). Those differences mostly reflect the epidemiological features of a psychotic population within a regular clinical setting.

Instruments

Diagnosis was obtained with SCID DSM IV (First et al., 1990), followed by application of the psychometric scales PANSS (Kay et al., 1987) and BPRS (Bech et al., 1986). We used all the 48 symptoms measured by both scales (30 symptoms measured by PANSS, grades of severity from 1 until 7; and 18 symptoms measured by BPRS, grades of severity from 0 until 3). Next a dream report was requested. Specifically, we asked the subject to report the most recent dream they could remember, followed by questions about regular dreaming (translated from Portuguese: *"Do your dreams usually resemble your daily life?," "Do your dreams usually resemble your psychotic symptoms?,"* and *"Do your dreams change following changes in medication?"*), and also about LD (*"Can you be aware of dreaming during sleep?," "Can you control your dream when this happens?," "How frequently does this happen: Once in lifetime, more than once but less than 10 times, more than 10 times but less than 100 times, or more than 100 times?," "How do you feel when you wake up from these dreams: very good, good, bad or very bad?"*). We considered as lucid dreamers individuals that claimed to be aware of dreaming during a dream at least once in lifetime. All the verbal reports were digitally recorded and transcribed. Analysis: The chi-square test was used to establish statistically significant differences between groups (S, B, and C) on questions about LD, and between

TABLE 2 | Speech graph attributes (SGA): detail description of each speech graph attribute measured from dream reports.

N: Number of nodes.

E: Number of edges.

RE (Repeated Edges): sum of all edges linking the same pair of nodes.

PE (Parallel Edges): sum of all parallel edges linking the same pair of nodes given that the source node of an edge is the target node of the parallel edge.

L1 (Loop of one node): sum of all edges linking a node with itself, calculated as the trace of the adjacency matrix.

L2 (Loop of two nodes): sum of all loops containing two nodes, calculated by the trace of the squared adjacency matrix divided by two.

L3 (Loop of three nodes): sum of all loops containing three nodes (triangles), calculated by the trace of the cubed adjacency matrix divided by three.

LCC (Largest Connected Component): number of nodes in the maximal subgraph in which all pairs of nodes are reachable from one another in the underlying undirected subgraph.

LSC (Largest Strongly Connected Component): number of nodes in the maximal subgraph in which all pairs of nodes are reachable from one another in the directed subgraph (node a reaches node b, and b reaches a).

ATD (Average Total Degree): given a node n, the Total Degree is the sum of "in and out" edges. Average Total Degree is the sum of Total Degree of all nodes divided by the number of nodes.

Density: number of edges divided by possible edges. [$D = 2*E/N*(N-1)$], where E is the number of edges and N is the number of nodes.

Diameter: length of the longest shortest path between the node pairs of a network.

Average Shortest Path (ASP): average length of the shortest path between pairs of nodes of a network.

CC (Average Clustering Coefficient): given a node n, the Clustering Coefficient Map (CCMap) is the set of fractions of all n neighbors that are also neighbors of each other. Average CC is the sum of the Clustering Coefficients of all nodes in the CCMap divided by number of elements in the CCMap.

lucid dreamers and non-lucid dreamers (within groups S and B) on questions about regular dreams.

Graph Analysis

Thought disorder was investigated by representing the verbal reports of experimental and control subjects as directed graphs. These were computed by the custom-made free software *Speech Graphs* (http://www.neuro.ufrn.br/softwares/speechgraphs), which allows the calculation of several attributes related to the recurrence, connectivity, and global complexity of graphs (Mota et al., 2014). This methodology is free of subjective bias, since it does not take into account any personal evaluation of the semantic content of the verbal reports. Rather, it mathematically analyzes various structural aspects of the reports. We have previously validated this methodology for the diagnosis of psychosis (Mota et al., 2012, 2014) and dementia (Bertola et al., 2014). The rationale for combining the use of psychometric scales and speech graph analysis was to quantitatively analyze the psychiatric symptoms, so as to compare groups of lucid and non-lucid psychotic dreamers and better characterize their mental functioning. A graph is a mathematical representation of a network with nodes linked by edges, formally defined as $G = (N, E)$, with the set of nodes $N = \{w_1, w_2, \ldots, w_n\}$ and the set of edges $E = \{(w_i, w_j)\}$ (Mota et al., 2012, 2014; Bertola et al., 2014). A speech graph represents the sequential relationship of spoken words in a verbal report, with each word represented as a node, and the sequence between successive words represented as a directed edge (Mota et al., 2012, 2014; Bertola et al., 2014). A total of 14 speech graph attributes (SGA) were calculated for each dream report, comprising general graph attributes (N, total of nodes; E, total of edges), recurrence (PE, parallel edges; RE, repeated edges; L1, L2, and L3, loops of one; two and three nodes), connectivity (LCC, largest connected component and LSC, largest strongly connected component) and global attributes (ATD, average total degree; Density, Diameter; ASP, average shortest path; CC, clustering coefficient; **Table 2**).

The non-parametric statistical test Wilcoxon Ranksum was used to establish SGA differences between lucid dreamers and non-lucid dreamers, as well as differences in the symptomatology measured by psychometric scales and speech measures (corrected for the number of symptoms and speech attributes by the Bonferroni method, $\alpha = 0.0008$). Effect size was measured by Cohen's d.

RESULTS

About half of the psychotic subjects (48% of S and 55% of B) and 46% of C reported having at least one LD in life, but we found no statistically significant difference among the groups S versus B ($p = 0.6407$), S versus C ($p = 0.3138$), or B versus C ($p = 0.5582$; **Figure 1A**). Psychotic lucid dreamers reported control of their dreams more frequently (67% of S and 73% of B) than non-psychotic lucid dreamers (only 23% of C; S versus C $p = 0.0283$, B versus C $p = 0.0150$; **Figure 1B**). There was no statistical difference among groups concerning the number of lifetime LD episodes (33% of S, 55% of B, and 31% of C reported having had more than 10 LD in life; S versus B $p = 0.3053$, S versus C $p = 0.8908$, B versus C $p = 0.2391$; **Figure 1C**), nor for the proportion of subjects that reported feeling good after waking up from a LD (58% of S, 91% of B, and 77% of C; S versus B $p = 0.0755$, S versus C $p = 0.3195$, B versus C $p = 0.3596$; **Figure 1D**). Specifically regarding lucid dreamers in the psychotic groups, 57% of those that were unable to control LD, and 81% of those that claimed to control LD, reported pleasant feelings after waking from a LD (no statistical difference between lucid dreamers that control the dream and lucid dreamers that do not control the dream on S and B groups, $p = 0.2257$).

A possible confounding factor to interpret the higher frequency of dream control in the psychotic groups is the use of antipsychotic medications. Neurons in the prefrontal cortex are among the main targets of antipsychotics, via modulation

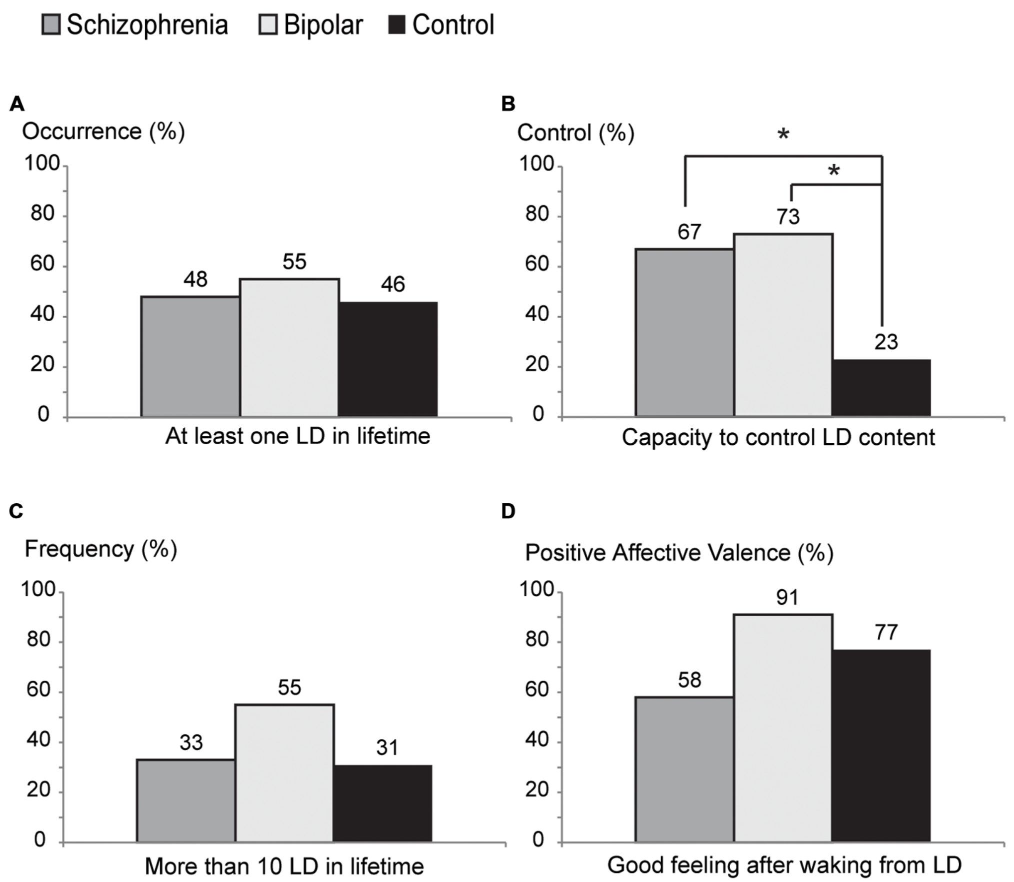

FIGURE 1 | Characteristics of lucid dream reports in schizophrenia (S), bipolar (B), and control (C) groups. (A) Percentage of each group reporting occurrence of lucid dreaming at least once in a lifetime. **(B)** Percentage of the ability to control their dreams: psychotic groups report control ability more frequently than control group (S vs. C: $p = 0.0283$, B vs. C: $p = 0.0150$). **(C)** Percentage of high frequency of lucid dreams (more than 10 lucid dreams in a lifetime). **(D)** Percentage of positive affective valence (good feeling after wake up from a lucid dream) (*$p < 0.05$).

of the prefrontal cortex output to basal ganglia circuits (Monti and Monti, 2004; Merikangas et al., 2011). First generation antipsychotics enhance total sleep time and sleep efficiency by controlling psychotic symptoms, but there are no consistent results in non-psychotic subjects. Second generation antipsychotics increase total sleep time and sleep efficiency in both psychotic and non-psychotic subjects, with some drugs having specific effects on sleep patterns (e.g., olanzapine increases the amount of the N2 stage of sleep; Monti and Monti, 2004; Cohrs, 2008). To investigate this effect in our psychotic sample, we compared the doses of antipsychotics (chlorpromazine-equivalent) between lucid and non-lucid dreamers. Within lucid dreamers, we compared the antipsychotic doses administered to those that reported to control LD to the doses administered to those who reported not to control their dreams. Neither comparison showed statistically significant differences (lucid versus non-lucid dreamers $p = 0.5460$, and control versus non-control $p = 0.8556$), thus strengthening the conclusion that the differences between psychotic and control groups concerning the ability to control LD are related to the psychotic state, not to the different medications used.

Among psychotic patients, lucid dreamers reported similarities between dreams and daily life more frequently than non-lucid dreamers (for B: 73% of lucid dreamers and 22% of non-lucid dreamers, $p = 0.0246$; for S: 94% of lucid dreamers and 69% of non-lucid dreamers, $p = 0.0596$; **Figure 2**). Following changes in medication, lucid dreamers were much more likely to report changes in dream content (100% of B and 92% of S) than non-lucid dreamers (0% of B, and 8% of S; $p = 0.0000$ on S and B; **Figure 2**). **Figure 2** also shows that there was no difference concerning the similarity of dreams and symptoms between lucid (55% of B, and 58% of S) and non-lucid (44% of B, and 38% of S; $p = 0.3204$ on S and $p = 0.6531$ on B) dreamers.

With regard to the application of standard psychometric scales and speech quantitative analysis, we did not find any difference between lucid and non-lucid dreamer patients, neither in S nor in B groups after correction for multiple comparisons ($\alpha = 0.0008$). We failed to detect any clinical advantage for lucid dreamers even when multiple comparisons were disregarded ($\alpha = 0.05$), even for the item G12 on PANSS, related to the symptom "Lack of judgment and insight." This means that the psychotic patients that were more able to have insight during

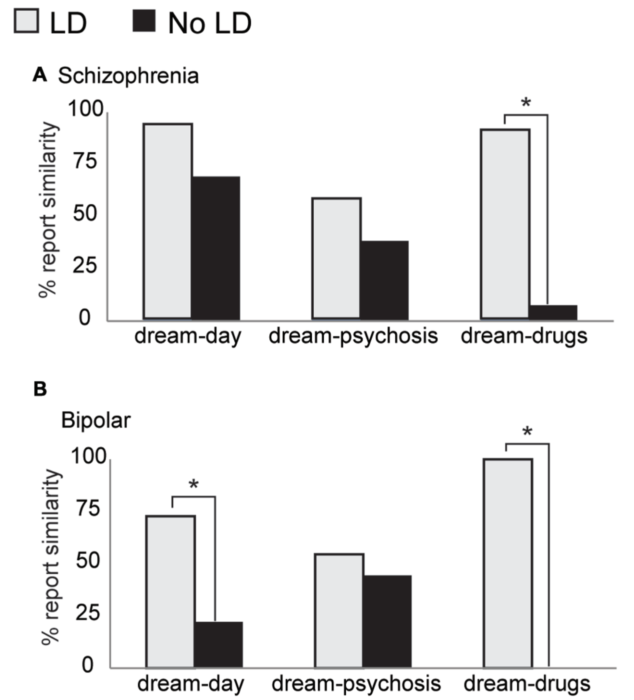

FIGURE 2 | Characteristics of regular dream reports among psychotic patients. (A) Within the S group, there were no significant differences between lucid dreamers and non-lucid dreamers concerning similarities between dream and daily experiences, but lucid dreamers reported changes on dream contents after changes on medication more frequently than non-lucid dreamers ($p < 0.00005$). **(B)** In the B group, lucid dreamers reported similarities between dream and daily experiences, as well as changes on dreams after medication changes, more frequently than non-lucid dreamers ($p = 0.0246$ and $p < 0.00005$, respectively). Neither S nor B showed differences between lucid and non-lucid dreamers on reports about similarities between dreams and psychotic symptoms (*$p < 0.05$).

dreaming were not more able to have insight about their own psychotic reality than patients that were less aware during dreaming. On the contrary, the emotional retraction symptom measured by item N2 of the PANSS Negative Subscale, (Kay et al., 1987) was more prevalent in lucid dreamers than in non-lucid dreamers among S [**Figure 3** and Supplementary Table 1; LD versus non-LD on S: $p = 0.0329$, mean ± SD non-lucid ($n = 13$): 2.54 ± 1.28 lucid ($n = 12$): 3.75 ± 1.36; Cohen's d: –0.92, a large effect size]. This symptom is characterized by the lack of interest in external events, with little involvement or affective commitment. Likewise, with regard to the structural features of speech, only in S we found that lucid dreamers displayed a significantly different SGA, namely smaller clustering coefficient [CC; $p = 0.0171$, mean ± SD non-lucid ($n = 13$): 0.065 ± 0.047 lucid ($n = 12$): 0.030 ± 0.037; Cohen's d: 0.83, a large effect size] in comparison with non-lucid dreamers (**Figure 4** and Supplementary Table 2). This means that lucid dreamers in the S group produced less complex speech graphs when reporting a regular dream, in comparison with S subjects that were not lucid dreamers, reflecting a less complex flow of thought.

DISCUSSION

Altogether, the results falsified the three hypotheses that we set out to test. First, psychotic patients did not report LD less frequently than non-psychotic subjects. Second, among the subjects that reported being lucid dreamers, psychotic patients reported LD control more frequently than non-psychotic subjects. Finally, patients who reported LD did not present attenuated psychiatric symptoms, in comparison with patients who did not report LD. Indeed, schizophrenia patients that qualified as lucid dreamers showed a tendency to be more, not less symptomatic than non-lucid dreamers in the same group. Therefore, although the results on the lifetime occurrence of LD replicate prior data (Snyder and Gackenbach, 1988; Mota-Rolim et al., 2013), we could not find support for the notion that a psychotic sample would report less LD than a non-psychotic sample. There was no difference between psychotic and non-psychotic subjects regarding the number of LD events in life. As previously detected in a non-psychotic sample (Voss et al., 2013), we found positive emotions to be more frequently associated with LD in all groups, without significant differences.

In a sample of 3,427 Brazilian subjects interviewed online, 29% of the subjects reported the ability to control LD (Mota-Rolim et al., 2013). In the present study, only 23% of the non-psychotic sample reported LD control, in contrast with significantly larger numbers among psychotic subjects (67% of S and 73% of B). This result was unexpected, considering that non-psychotic lucid dreamers show increased control of internal reality (Blagrove and Tucker, 1994; Blagrove and Hartnell, 2000), being more frequently able to regulate cognition and emotion than non-lucid dreamers (Blagrove and Hartnell, 2000). A possible explanation is that psychosis enhances the experience of the internal reality in detriment of the external reality, and therefore lucid dreamers with psychotic symptoms would be more able to control their internal reality than non-psychotic lucid dreamers. If we hypothesize that the positive symptoms of psychosis may represent the intrusion of REM sleep mentation into waking (Freud, 1900; Dzirasa et al., 2006; Dresler et al., 2014), and that LD may reflect the intrusion of waking mentation into REM sleep (Mota-Rolim and Araujo, 2013), subjects who frequently experience both conditions may be more cognitively trained to control their internal reality than those who rarely experience LD. This line of reasoning is supported by the fact that lucid dreamers with psychotic symptoms reported more similarity between dreams and daily life than non-lucid dreamers with psychotic symptoms. Lucid dreamers were also much more likely than non-lucid dreamers to report changes in dream content following changes in medication, possibly reflecting a higher awareness of dream reality in the former. Indeed, the frequent experience of REM sleep-like mentations into the waking life might train control of internal reality, and thus explain higher control of lucid dream in psychotic patients. This might be particularly true for transition phases between acutely psychotic and non-psychotic phases. Within the dreaming/psychosis model, such transition phases might thus be considered as "pre-lucid." Future studies should consider a longitudinal design, and aim to characterize the transition between acute and non-acute psychotic phases.

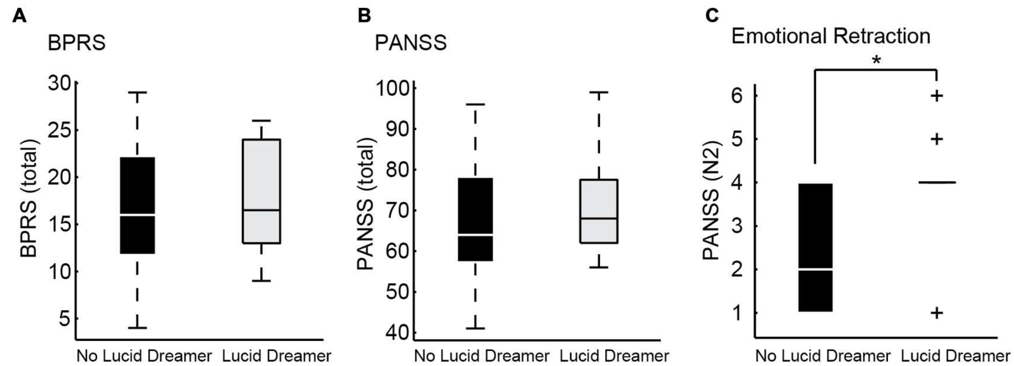

FIGURE 3 | Psychometric differences between lucid dreamers and non-lucid dreamers among schizophrenia patients. (A) Boxplots showing total BPRS of lucid dreamers and non-lucid dreamers in the S group ($p = 0.5930$). **(B)** Boxplots showing total PANSS of lucid dreamers and non-lucid dreamers in the S group ($p = 0.6434$). **(C)** Among S subjects, lucid dreamers showed higher scores on PANSS item N2 about emotional retraction ($p = 0.0329$), without significant differences for the other symptoms; no significant differences were found among B subjects (see Supplementary Table 1) (*$p < 0.05$).

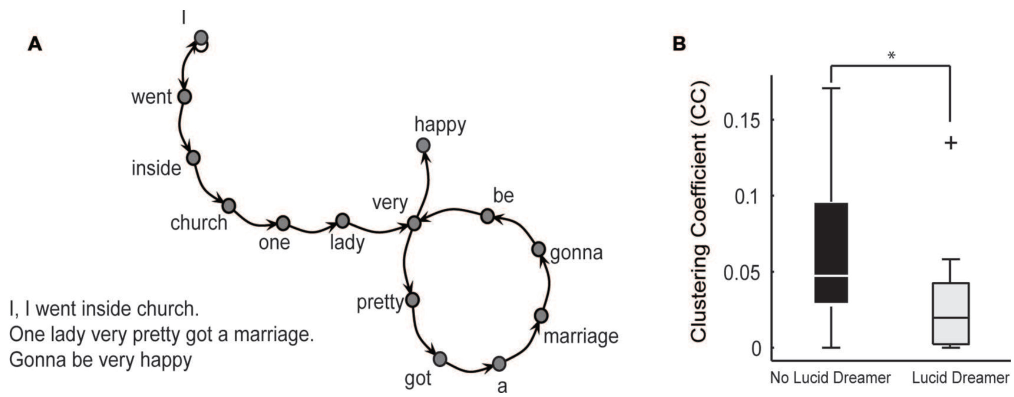

FIGURE 4 | Differences on speech structure when reporting a regular dream between lucid dreamers and non-lucid dreamers among schizophrenia patients. (A) Example of a text (regular dream report) represented as a speech graph. For this plot the original text was in Portuguese and each word was translated to English, preserving the original grammatical structure. Speech graph attributes (SGA, see **Table 2**) were used to characterize speech structure from dream reports. **(B)** In the S group, speech graphs from dream reports of lucid dreamers showed smaller clustering coefficient (CC) than non-lucid dreamers ($p = 0.0171$) (*$p < 0.05$).

We found no clinical advantages of having LD with regard to psychiatric symptomatology, to speech structure, and in particular to criticism of reality [question G12 of PANSS (Kay et al., 1987), Supplementary Table 1]. On the contrary, we found that lucid dreamers in the S group tends to be more emotionally retracted than non-lucid dreamers, which means that they were more isolated from others. These subjects also tended to report their regular dreams in a less clustered manner, reflecting a decrease in the complexity of the flow of thought when reporting a dream, a symptom related to cognitive and negative severity in schizophrenia (Mota et al., 2014), and with cognitive impairment in dementia (Bertola et al., 2014). Although these results do not reach significance after Bonferroni correction, they have a large effect size that should not be neglected. Possibly if the number of subjects per group was higher, these symptomatology differences would become clearer. Taken together, both psychometric features reveal impairment of social behavior and thought disorganization among lucid dreamers in the S group, which could be considered a potential disadvantage related to clinical severity. But considering that those lucid dreamers tend to control dream contents more frequently, we can also interpret this result as a compensatory attempt to enhance dream control, rather than trying the more difficult control of reality. Do changes in dream control precede changes in reality control, or vice-versa? While the transversal design employed here cannot answer this question, future longitudinal studies should help to disentangle these alternatives, by synchronously collecting data on insights about dreaming and psychotic reality, to determine the order of occurrence of changes in these states.

Our study has other limitations that need to be considered. First, sample sizes were relatively small, reflecting the scarcity of individuals that experience both psychotic symptoms and LD. The prevalence of LD (considering the definition adopted in this study) is high in the Brazilian population (77.2%; Mota-Rolim et al., 2013) and was not found to be low in our sample

(48% in S, 55% in B, and 46% in C), but the prevalence of psychosis is much lower (B prevalence data from 11 countries: 0.6%; Merikangas et al., 2011, S prevalence data from 46 countries: 0.55%; McGrath et al., 2008). We also had differences between the groups that mostly reflect general epidemiological differences regarding marital status within psychotic populations, but should be considered as a potential confounding factor. In addition, the control sample (subjects without psychotic symptoms in lifetime) had a mixture of individuals with and without psychiatric symptoms, some with psychiatric diagnosis like depression and others without any psychiatric symptom in lifetime, what make this control group very heterogeneous; in future studies a control sample without any psychiatric symptoms should be investigated.

Another caveat is the fact that the research was only based on self-reports of LD, with possible confounds of secondary elaboration, motivation, conscious and unconscious intentions (Freud, 1900). Ideally lucidity should be assessed by external judges to avoid fallacious interpretations (Stumbrys et al., 2012). Moreover, we assessed LD throughout the lifetime, but did not investigate whether the patients experienced lucid dreams specifically during the psychotic episode(s). This is an important issue to be clarified in future studies, specifically when considering symptomatology differences, such as the increase of insight. Maybe the patients that were considered as lucid dreamers in the present study were not experiencing lucid dreams during that period, and would not show potential clinical advantages such as increased insight.

Medication was another limitation to consider (**Table 1**), since all the psychotic subjects were medicated with a variety of different drugs, and the use of psychotropic drugs can modify dream perception and recall (Solms, 2000; Gottesmann, 2005). Future studies should also interview psychotic patients during acute crises, to compare with the data collected during non-acute states as in the present study. In principle, data sampled during acute phases should be more informative. The symptomatology during this transition phase (acute to non-acute phase) should give important information regarding changes in insight of the differences between fantasy and reality.

Furthermore, we did not control for differences in dream recall frequency among the patients, an important methodological issue for dream research (Schredl, 2011; Michels et al., 2014; Skancke et al., 2014), which could perhaps explain the differences in continuity between daily life and dreams, or changes of dream content after change of medication. In addition, we did not control for differences in the frequency of nightmares, which is heightened in S patients (Okorome Mume, 2009; Michels et al., 2014; Skancke et al., 2014), and may be related with lucidity in pathological conditions (Rak et al., 2015). However, nightmares are by definition associated with unpleasant feelings after waking up, and we found a high frequency of pleasant feelings after waking up from a lucid dream in this sample (58% for S and 91% for B). Finally, we did not employ training or induction techniques for LD generation (Stumbrys et al., 2012), but rather dealt with natural recollections of spontaneous LD. The results in trained subjects may be quite different from those reported here. Beyond these limitations, our results suggest that psychotic lucid dreamers, which fail the "external reality test," are nevertheless more able to control their internal reality during dreaming.

To the best of our knowledge, the present study is the first to assess LD in a clinically characterized psychotic sample. Overall the results confirm the notion that LD is associated with psychosis. This relationship deserves a closer investigation, since the present data does not conform to the hypothesis that LD control is helpful to psychotic patients. The distinctive features of the LD experience in our sample pose a challenge to the perspective of clinically using LD for the treatment of psychosis (Dresler et al., 2014; Voss et al., 2014). Also, the results point to an intriguing relationship between dream lucidity and judgment of reality among psychotic patients, which deserves deeper investigation with larger samples. Training dream lucidity is likely to produce safe psychological strengthening in a non-psychotic population (Stumbrys et al., 2012), but in a psychotic population LD practice may further empower deliria and hallucinations, giving internal reality the appearance of external reality.

AUTHOR CONTRIBUTIONS

NM and SR designed the study, collected the data, NM, AR, SM-R, MC, and SR analyzed the data, and NB, SR, SM-R, and MC wrote the paper.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fpsyg.2016.00294

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Investigating on the Methodology Effect When Evaluating Lucid Dream

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Lucid dreaming (LD) is a state of consciousness in which the dreamer is aware that he or she is dreaming and can possibly control the content of his or her dream. To investigate the LD prevalence among different samples, researchers have used different types of methodologies. With regard to retrospective self-report questionnaire, two ways of proceeding seem to emerge. In one case, a definition of LD is given to participants ("*During LD, one is–while dreaming–aware of the fact that one is dreaming. It is possible to deliberately wake up, to control the dream action, or to observe passively the course of the dream with this awareness*"), while in the other instances, participants are presented separate questions targeting specific LD indicators (dream awareness and dream control). In the present study, we measured LD frequency in a sample of French student in order to investigate for possible disparities in LD frequency depending on the type of questionnaire as outlined above. Moreover, we also study links between the prevalence of LD as assessed, respectively, by each questionnaire with various factors such as *Vividness of Mental Imagery* and *Parasomnia*. Results revealed no significant difference between LD frequencies across questionnaires. For the questionnaire with definition (DefQuest), 81.05% of participants reported experience of LD once or more. Concerning the questionnaire based on LD indicators (AwarContQuest), 73.38% of participants reported having experienced LD once or more. However, with regard to the correlations analysis, links between LD prevalence and factors such as *Vividness of Mental Imagery* and *Parasomnia*, varied across questionnaires. This result is an argument suggesting that researchers should be careful when investigating links between LD and other factors. The type of methodology may influence findings on LD research. Further studies are needed to investigate on the methodology effect in LD research namely on the respective weight of awareness and control.

Keywords: lucid dream, awareness, control, prevalence, frequency, questionnaire

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INTRODUCTION

Lucid dreaming (LD) is a state of consciousness in dreams during which the dreamer is aware that he or she is dreaming. The awareness of the dream state is a *sine qua none* condition in labeling LD (Gillespie, 1983) but this feature may be insufficient in fully assessing this phenomenon (Tholey, 1988). The possibility of controlling the dream content is cited as another core criterion of LD (Van Eeden, 1913; Snyder and Gackenbach, 1988). It is thus unclear in the literature how LD is defined (Erlacher et al., 2008; Hobson, 2009; Voss et al., 2009; Noreika et al., 2010). Moreover, there is to date no consensual method on how LD should be investigated.

Snyder and Gackenbach (1988) suggested that imprecise definition can affect LD prevalence and that a multi-component definition that encompasses various elements (such as lucidity and/or the possibility of control), is needed to ensure that LD is well understood by participants. For Green and McCreery (1994) dream awareness is sufficient to define LD. Indeed, the rationale for proposing a definition which aggregates several elements of LD is questionable considering that control does not systematically occur along with dream awareness (Mota-Rolim et al., 2013; Voss et al., 2013). It is thus of upmost importance to have a consensual definition of LD since this element is crucial in devising methodologies to investigate LD.

Lucid dreaming incidence gathered in Latin America, USA, Europe, and Asia suggests that LD is a widespread phenomenon (Mota-Rolim et al., 2013) but its prevalence appears to vary across studies (cf. **Table 1**). The origin of these variations has recently been addressed by Saunders et al. (2016) in a quality meta-analysis but the authors failed to identify any explanatory systematic bias. Thus, considering that, to our knowledge, no study has directly specified the origin of variations in LD prevalence, the purpose of the present study is to address this issue by targeting the type of methodology used which is a common source of variability across studies (Schredl and Erlacher, 2004; Alvarado and Zingrone, 2008; Voss et al., 2012; Fingerlin, 2013). More precisely, we investigated experimentally whether LD prevalence would be influenced by the type of interrogation formulation (Dream Awareness and possibility of control within the same definition versus a separate evaluation for awareness and effective control).

Indeed, different methodologies have been devised to measure the frequency or prevalence of LD. For instance, some studies used questionnaires with a definition of LD (for example: "During LD, 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"). This definition is then usually followed by a question on LD frequency (Schredl and Erlacher, 2004; Erlacher et al., 2008, 2012; Rak et al., 2015). In other studies, questionnaires do not contain a definition of LD and instead, propose a specific question on dream awareness. These questionnaires sometimes also cover questions on other LD dimensions, more specifically on the control of the dream content (for example: "Do you sometimes realize in your dreams that you are dreaming?" and "I am able to control or direct the content of my dreams"; Stepansky et al., 1998; Watson, 2001; Fassler et al., 2006; Soffer-Dudek et al., 2011). The effect of using these different methodologies in assessing the prevalence of LD is considered in the present study.

Using different methodologies, many researchers have tried to understand the various factors linked to LD (Blagrove

TABLE 1 | Prevalence differences of lucid dreaming (LD) across studies.

Author	Sample size	Age	Gender repartition	Country and sample type	Methodology	Prevalence LD (least at once)
Schredl et al., 2016	1375	26.5 ± 18.0 years	67.42% Women	United Kingdom	Question awareness	56.32%
Schredl et al., 2012	3579	12.0 ± 1.9 years	61.36% Girls	United Kingdom	Question awareness	43.5%
Alvarado and Zingrone, 2008	492	–	68% Women	Spanish New age magazine lecturers	Question awareness	89%
Schredl and Erlacher, 2004	444	23.5 ± 5.7 years	84% Women	Unselected student sample	Definition based on awareness and control	82%
Erlacher et al., 2008	153	19.1 ± 1.1 years	60.1% Women	Japan students	Definition based on awareness and control	47%
Schredl and Erlacher, 2011	919	48.1 ± 18.4 years	54% Women	Germany representative sample	Definition based on awareness and control	51%
Erlacher et al., 2012	840	21.59 years ± 6.33	57.5% Men	German athletes	Definition based on awareness and control	56.6%
Stumbrys et al., 2013	684	25.5 ± 9.7 years	59.35% Women	German voluntaries	Definition based on awareness and control	83.5%
Smith and Blagrove, 2015	84	33.80 ± 15 years	50% Women	LD forum lecturer	Definition based on awareness and control	72.6%
Fingerlin, 2013	214	17.2 ± 1.2 years	70.6% Women	Swiss Junior college student	Definition based on awareness and control + Question LD and questions control	50%
Mota-Rolim et al., 2013	3,427	Median = 25 years	50% Women	Brazil voluntaries	Definition based on awareness and control + Question Awareness and questions control	77.2%
Voss et al., 2012	793	year range [6–19]	50% Women	German student	One-on-one Interview Description based on awareness	51.9%

***Literature search**: The purpose of this table is to illustrate how LD prevalence and methodology vary across studies focusing on LD prevalence evaluation. Titles and abstracts were searched in the electronic PubMED and PsycINFO databases and in google scholar search engine (limited to the 10 first pages) using the following search terms: lucid dream*/AND (frequency OR prevalence OR incidence). Only studies published after 2000 were examined.*

and Hartnell, 2000; Patrick and Durndell, 2004; Schredl and Erlacher, 2004; Doll et al., 2009; Zink and Pietrowsky, 2013). For instance, studies have shown strong correlations between LD and dream recall frequency (Schredl and Erlacher, 2011; Jones and Stumbrys, 2014). Links between sleep characteristics and LD have been investigated with various types of retrospective questionnaires (Mota-Rolim et al., 2013). For example, it was found that lucid dreamers tend to report experiencing more spontaneous out-of-body experience than those who have not reported LD (Spanos et al., 1995; Levitan et al., 1999). Other studies have investigated the nature of the relations between LD and cognitive performances. For example, Blagrove et al. (2010) sought links between LD and Stroop task performance. In their study, lucid dreamers were able to complete the incongruent Stroop condition faster than occasional or non-lucid dreamers. Relationships have also been shown between LD and personality factors. For instance, it appears that Lucid dreamers are likely to have a more creative personality than non-lucid dreamers (Zink and Pietrowsky, 2013). Various sleep disorders have been investigated within the scope of *parasomnia*. For instance narcolepsy patients are found to report markedly higher LD frequency than typical dreamers (Dodet et al., 2015; Rak et al., 2015). Schredl and Erlacher (2004) also found an association between nightmare frequency and LD frequency. Several studies have likewise revealed links between LD and mental imagery for visual, auditory, gustatory, kinesthetic olfactory, and tactile modalities (Hearne, 1983; Kueny, 1985; Saunders et al., 2016).

For the purpose of investigating whether typical links between LD and other factors would vary depending on the type of methodology, we perform correlations between LD frequency with factors often associated with LD. We choose to focus on the following two factors: *Vividness of Mental Imagery* and *Parasomnia*.

The present study is the first to our knowledge conducted on LD prevalence using a French sample. We aimed at investigating possible disparities in LD frequency depending on the type of question form used. More precisely, the prevalence of LD was investigated with two types of questionnaires widely used in the literature: the first questionnaire contained a definition of LD and a frequency question as used by Schredl and Erlacher (2004). The second questionnaire contained two separate questions on two specific LD dimensions, one targeted the frequency of dream awareness and the other one concerned dream control. A series of questions were common to both questionnaires in order to investigate the correlation of certain factors (the *Vividness of Mental Imagery* and *Parasomnia*) with the LD prevalence. We hypothesize that the type of methodology used could have an effect on LD frequency and its correlation with *Vividness of Mental Imagery* and *Parasomnia.*

MATERIALS AND METHODS

Participants

Participants were all students of Picardie Jules Verne University recruited from January to March 2015 through a social media website and posters pasted on the university notice boards. The term "LD" was deliberately not mentioned during the recruitment process, to ensure that participants remained blind to the purpose of the study. Participants completed a "sleep questionnaire" which lasted for approximately 35 min. Twenty participants were involved in a pre-test and were not included in the sample of the experiment. Overall, 315 participants were enrolled in the present study, 80% female and 20% male (median age: 20.8 years). An identification number corresponding to each participant guaranteed the confidentiality and anonymity of investigations. Participants were randomly assigned to two different groups.

Material

Using the online software "google forms," we created two questionnaires, each composed of 150 questions. The first questionnaire contained an adapted French version of a definition of LD ("*During LD, 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*") and a frequency question, as used by Schredl and Erlacher (2004). The second questionnaire contained two separate questions, one on the frequency of dream awareness and the other one on dream control: "*While dreaming, have you ever been aware that you were actually dreaming*?"; "*While dreaming, have you ever been able to control the content of your dream*?" These two questions were devised from existing formulations in English. They were reformulated in order to ensure a good comprehension in French language but were conceptually similar to those typically used in the literature (Stepansky et al., 1998; Watson, 2001; Fassler et al., 2006; Soffer-Dudek et al., 2011). The remaining questions were the same in both questionnaires and could be classified in the following four categories (see Annexes).

(i) *Demographics and characteristics of the participant* including 10 questions.
(ii) *Sleep quality* and *Parasomnia* (90 questions) including 24 questions from the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989), 61 questions from the Diagnostic Sleep Questionnaire of Hotel Dieu Paris Sleep Center (Léger et al., 2006), and 15 questions specifically devised for the present study (e.g., number of hours of sleep, frequency of waking up during the night, how rested the participant felt).
(iii) *Vividness of Mental Imagery* using 35 questions from the Psi-Q (Plymouth sensory imagery Questionnaire; Andrade et al., 2014) with five questions for each of the seven sensory modalities.
(iv) *Consumption questionnaire* including 10 questions focusing on alcohol, marijuana, caffeine, tea, soda, and cigarette consumption.

Procedure

By clicking on the hotlink associated with the recruitment text, participants were randomly redirected to one of the two questionnaires. A PHP/HTML page hosted on a personal web server managed the random distribution. After completion of the questionnaire all the answers marked with a timestamp were created in an online spreadsheet. The data were then transferred to an Excel spreadsheet where we excluded duplicated data and incomplete responses.

Data Acquisition and Pre-processing

As a reminder, the purpose of the present study is (1) To investigate whether the prevalence of LD would vary depending on the type of methodology and (2) To study links between the prevalence of LD as assessed, respectively, by each questionnaire, with the following two factors: Vividness of Mental Imagery and Parasomnia.

Analysis would thus concern only items of the Mental Imagery scale and the 10 questions on parasomnias that could be remembered by participants at wake. Exploratory items were not considered in the present statistical analysis (for example, questions on sleep position, consumptions, duration of sleep. . .).

For the questionnaire in which a definition of LD was presented (DefQuest), LD frequency per week was measured with an 8-point rating scale ranging from zero (never) to seven (several times). For the other questionnaire which contained a question about the frequency of dream awareness and about dream control (AwarContQuest), awareness and dream control were both, respectively, measured with a 6-point rating scale ranging from zero (never) to five (several times), to assess the frequency of each manifestation per week. To obtain unit in frequency per month, the scales were recoded using the Schredl and Erlacher (2004) methodology.

For *parasomnia* category (PSQI; Buysse et al., 1989), we selected 10 questions about the following: "headaches"; "kicks"; "hypnagogic hallucinations"; "immediate dreams"; "paralysis"; "nightmares"; "coughs"; "gastric burns"; "ruminations"; "narcolepsy." These 10 variables were evaluated on a 6-point frequency scale ranging from zero (never) to six (every day). A total parasomnia score was calculated by summing up the point for each 10 responses.

For *Vividness of Mental Imagery*, we calculated seven scores corresponding to the seven imagery modality subscales "vision," "audition," "smell," "taste," "touch," "body," and "emotion" in 11-point intensity scale (Andrade et al., 2014). A *Vividness of Mental Imagery* score was calculated by summing up the point for each seven subscales score.

RESULTS

Data collection and processing was carried out using SPSS® version 20 for Windows. Non-parametric tests were conducted since the conditions of homogeneity and normality of variances were not met. After exclusion of contributions with missing answers, the statistical analyses concerned 309 participants out of the original sample of 315 individuals.

As shown in **Figure 1**, among participants who have answered the DefQuest ($n = 153$), 81.05% reported having experienced LD at least once. Among participants who answered the AwarContQuest ($n = 154$), 73.38% reported having experienced dream awareness at least once. Concerning the dream control question, 50.65% reported dream control at least once. For the AwarContQuest, among the 113 participants who reported one dream or more with awareness, 79 reported a lower frequency for dream control. Moreover, among the 76 participants who reported one experience of dream control or more, 23 also reported a low frequency of dream awareness (**Figure 2**).

No significant difference was found between LD frequency (DefQuest) and dream awareness frequency (AwarContQuest) on the Mann–Whitney test. However, a significant difference ($p < 0.001$) appeared between LD frequency (DefQuest) and dream control frequency (AwarContQuest). The Wilcoxon signed rank test was significant ($p < 0.001$) between dream awareness and dream control in the AwarContQuest.

Using Mann-Whitney test, we also performed a comparison of scores between the two questionnaires (DefQuest vs. AwarContQuest) and the *Vividness of Mental Imagery* score. For the *Parasomnia* score, we used a chi-Square to perform comparisons. No significant difference was found for all these comparisons, except for *Vividness of Mental Imagery* in vision modality (**Table 2**).

Correlations

We conducted a Holm-Bonferroni sequential correction (Holm, 1979; Gaetano, 2013). Spearman's rho correlation was used to explore the relationship between LD frequency (in DefQuest), awareness and dream control frequencies (in AwarContQuest) and the two factors (*Parasomnia Vividness of Mental Imagery). Parasomnia* score correlated with dream awareness, $r(152) = 0.200$, $p = 0.028$, and dream control, $r(152) = 0.263$, $p = 0.002$, in the AwarContQuest, but not with LD frequency in DefQuest. *Vividness of Mental Imagery* score correlated with dream control $r(152) = 0.189$, $p = 0.019$, in AwarContQuest, but neither with dream awareness frequency in AwarContQuest nor with LD frequency in DefQuest.

DISCUSSION

The present study aims at investigating for possible disparities in LD frequency depending on the type of methodology. We thus investigated the prevalence of LD with two questionnaires: the *DefQuest* contained a definition of LD and a frequency question and the *AwarContQuest* contained two separate questions on two dimensions of LD, one about the frequency of dream awareness and the other about dream control. A series of questions were, however, common to both questionnaires to investigate whether the correlation of certain factors (*Parasomnia* and Vividness of Mental Imagery) with the LD prevalence, could vary depending on the type of questionnaire used.

Prevalence of LD as a Function of the Type of Questionnaire

The prevalence of LD was 81.05% when the definition of LD was given. On the other hand, without a definition, prevalence of dream awareness and dream control, were, respectively, 73.38 and 50.65%. Contrary to our expectations, no major discrepancies on LD frequency were observed using different

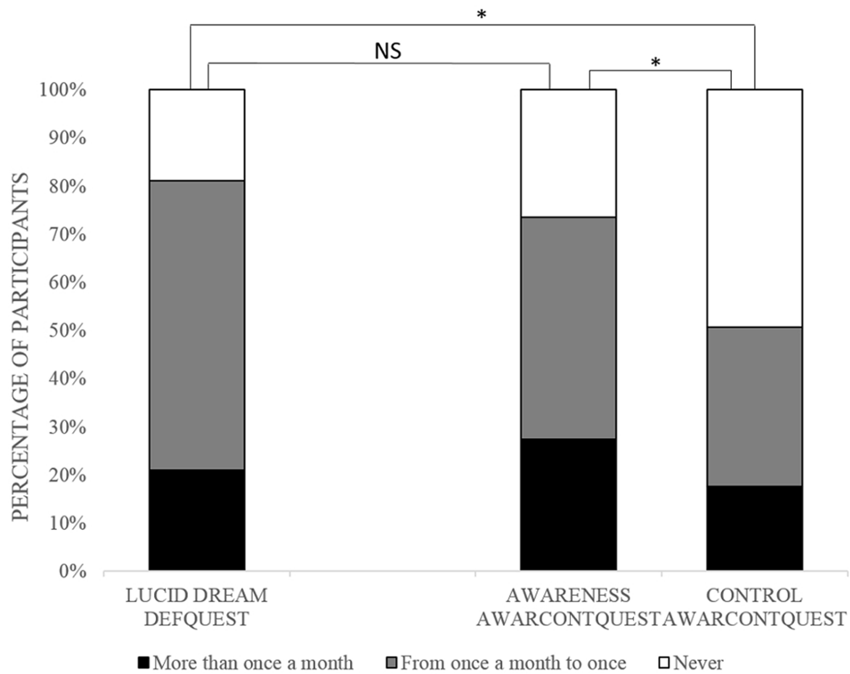

FIGURE 1 | Percentage of participants reporting LD in DefQuest (N = 154) and awareness and control in AwareContQuest (N = 153).

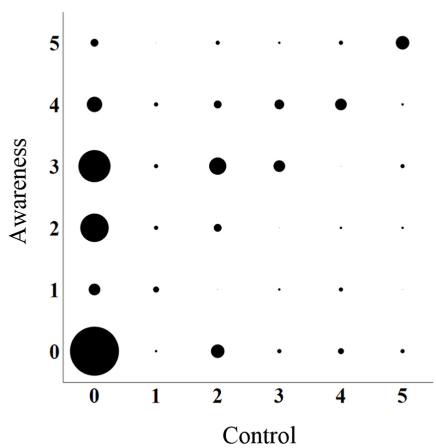

FIGURE 2 | The size of the black circles represents the number of participant responding to both questions (awareness and control) in AwareContQuest. Awareness and control were both evaluated on the same 6-point rating scale (0: never, 1: once, 2: less than once a year but more than once, 3: many times a year, 4: many times a month, 5: many times a week).

methodologies in our study. Indeed, the prevalence of LD obtained with *DefQuest* was not statistically different to the awareness frequency in *AwarContentQuest*. Control frequency was different to awareness frequency in the AwarContQuest. The finding that dream control is not exclusive or systematic to dream awareness, is not a new finding (Voss et al., 2013). It thus seems that these two components of the LD definition, awareness and control, may be at least in part independent features. It is therefore problematic in methodologies such as the *DefQuest*, to identify what the participant has considered in the definition of LD (awareness OR/AND control?).

Authors have advised the use of an example to illustrate LD and to bring clarity to the given definition (Snyder and Gackenbach, 1988; Schredl and Erlacher, 2004). LD is a complex phenomenon, which as in the present study, does not systematically occur along with both awareness and control (Voss et al., 2013). Several proposals have been made for more adequate methodologies to investigate LD. For example, hybrid strategies have been employed, bearing in this way the respective benefits of both types of questionnaires used in our study (DefQuest and AwarConQuest; Snyder and Gackenbach, 1988; Voss et al., 2013). Fingerlin (2013) conducted research in which a definition of LD was presented along with the frequency scale used in Schredl and Erlacher (2004). However, for a more precise measurement of LD prevalence, Fingerlin (2013) also added the following question "*I had one or several dreams meeting only one of the first two criteria.*" In a more recent study, Mota-Rolim et al. (2013) proposed a definition of LD but in addition, they added distinct questions on LD frequency and control frequency. In another study, Mota et al. (2016) used an interesting methodology where LD awareness and dream control are considered separately: "*Can you be aware of dreaming during sleep*?" "*Can you control your dream when this happens*?"

Among the various methods used to investigate dream characteristics, dream mentation report can be an interesting paradigm that could be adapted to LD research (Stickgold et al., 1994; Windt, 2013; Speth et al., 2015; Speth and Speth, 2016a).

TABLE 2 | Descriptive data and significance of the Chi-square and Mann-Whitney tests between the two experimental groups (DefQuest and AwareContQuest).

Type of questionnaire	DefQuest $N = 153$	AwareContQuest $N = 154$	Sig.
Demographic			
Gender women/men	123/30	124/30	NS
Age mean and (*SD*)	20.27 (2.38)	20.11 (1.98)	NS
***Vividness of mental imagery* score**			
Mean and (*SD*)			
"Vision"	7.58 (1.54)	7.34 (1.43)	0.04
"Sound"	7.37 (1.85)	7.04 (1.94)	NS
"Smell"	5.73 (2.4)	5.68 (2.23)	NS
"Taste"	6.15 (2.38)	6.06 (2.47)	NS
"Touch"	6.91 (2.35)	6.94 (2.33)	NS
"Body"	6.74 (2.11)	6.75 (1.99)	NS
"Emotion"	6.96 (1.73)	6.75 (1.9)	NS
Score	47.44 (12.16)	46.56 (12.14)	NS
Parasomnia score			
Mean and (*SD*)			
"Headache"	1.81 (1.57)	1.69 (1.52)	NS
"Kicks"	2.14 (1.88)	2.08 (1.85)	NS
"Hyp. hallucinations"	1.01 (1.60)	1.06 (1.58)	NS
"Immediate dreams"	2.27 (1.95)	2.07 (1.92)	NS
"Sleep paralysis"	0.77 (1.51)	0.82 (1.42)	NS
"Nightmare"	2.29 (1.39)	2.16 (1.34)	NS
"Cough"	1.48 (1.30)	1.79 (1.33)	NS
"Gastric burn"	0.61 (1.14)	0.49 (1.09)	NS
"Rumination"	3.42 (1.44)	3.44 (1.48)	NS
"Narcolepsy"	2.06 (1.82)	1.97 (1.68)	NS
Score	17.07 (6.94)	16.56 (7.23)	NS

Dream mentation report may differ from typical (narrative) dream report by considering broader subjective mentation occurring prior to waking. Mentation report can be elicited by specific questions for instance: "***When you awaken, think back and try to remember what was going on in your mind in the time prior to waking.***" (Speth and Speth, 2016b). Typically, the responses of participants are then analyzed by the experimenter (McNamara et al., 2005).

Adjusting such methodology to the specific case of LD research, would reduce the strong reliance on participants in identifying LD. Indeed, the task of stating whether a dream is lucid or not, would be performed by the experimenter based on his or her definition of LD and not on what the participant would consider as a LD. Moreover, using a double or multiple rating procedure, could further improve the confidence in the identification of LD. The use of dream mentation report could thus be a promising methodology but the generalization of results with such technic, would be possible only if a consensual definition of LD is used in the literature.

However, methodologies such as dream report (or dream mentation report) analysis also trigger new interrogations. By requesting participants to response to specific questions in order to collect information on their dreams, we cannot exclude that their recollections could be affected by these cueing questions.

Various methods are available for investigating LD and other alternatives can also be devised for evaluating this phenomenon. However, it is important to be aware of the forces and weaknesses of each methodology and most importantly, we should also be able to state clearly what a given method measures specifically. Saunders et al. (2016), in a quality meta-analysis, have released a tool for measuring the methodological quality of studies in LD prevalence: the "*LD Incidence Methodological Quality Scale*" (LDIM-Qi). The LDIM-Qi advocates the need of a clear definition that does not focus on control as a necessity. It also advices the adjunction of a LD example, the asking of a narrative recall of LD from the participants, a clear question wording, the control of confounding factor (such as social desirability) and a 7+ point clear scale.

Correlations between LD and Other Factors

We also investigated whether the correlation of *Vividness of Mental Imagery* and *Parasomnia* with the prevalence of LD could vary depending on the type of questionnaire used. LD frequency in the DefQuest did not correlate with neither *Vividness of mental imagery* nor *Parasomnia* score. In the AwarContQuest, both *Parasomnia* score and *Vividness of Mental Imagery* score correlated with control and *Parasomnia* score correlated with awareness.

Differences between LD frequency obtained with DefQuest and AwarContQuest are not apparent but, all things being equal, the interesting information here is that the two types of methodology induced different correlations. If these results can be replicated, future research will have to control systematically if the participant considered the awareness or the control of LD when presenting a multifactorial definition. Historically, the motivation for proposing a definition of LD that encompasses various factors, is to ensure a clear understanding of LD and to avoid confusion with "*morning-after dream recall*" (Snyder and Gackenbach, 1988). However, in the light of the present study, presenting a broad definition to investigate a unique frequency indicator, may induce ambiguity regarding the respective prevalence of awareness and control in LD.

CONCLUSION

In the present study, we measured LD frequency in a sample of French student in order to investigate for possible disparities in LD frequency depending on the type of methodology. We also study links between the prevalence of LD as assessed, respectively, by each methodology with factors such as *Vividness of Mental Imagery* and *Parasomnia*. Results revealed no significant difference between LD frequencies across methodologies. However, with regard to the correlations analysis, links between LD prevalence and factors such as *Vividness of Mental Imagery* and *Parasomnia*, varied across questionnaires. If these findings are confirmed, our study tends to suggest that the type of methodology may affect correlations between LD and other factors (such a mental imagery). Regarding the assessment of LD prevalence, it appears that the type of methodology cannot explain the variability of LD frequency across studies. Others factors such as age (Schredl et al., 2012; Voss et al., 2012), cultural representations toward dream experience (Erlacher et al., 2008; Mota-Rolim et al., 2013) or the fact that retrospective measurement is dependent on memory and meta-cognitive capacity (Mota-Rolim et al., 2013; Aspy et al., 2015), have already been pointed out to possibly explain this discrepancy. However, further studies are still needed to investigate the respective contribution of each of these factors in generating variability in LD frequency. Prior to these investigations, the proposal of a more accurate and consensual definition of LD with the appropriate methodologies, is needed.

AUTHOR CONTRIBUTIONS

VQ supervised the whole research. NR constructed the research protocol and collected all the data. YG participated in the writing of the manuscript and in interpreting the results.

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Tracking Potentiating States of Dissociation: An Intensive Clinical Case Study of Sleep, Daydreaming, Mood, and Depersonalization/Derealization

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This study examined in real time the role of sleep and daydreaming as potentiating states for subsequent dissociation in depersonalization/derealization disorder (DDD). Research and theory suggests that dissociation may be exacerbated and maintained by a labile sleep-wake cycle in which "dream-like" mentation intrudes into waking life and fuels dissociative symptoms. We explore and extend this idea by examining the state of daydreaming in dissociation. Daydreaming is a state of consciousness between dreaming and waking cognition that involves stimulus-independent and task-unrelated mentation. We report the results of a unique intensive $N = 1$ study with an individual meeting diagnostic criteria for DDD. Using experience-sampling methodology, the participant rated (six times daily for 40 days) current daydreaming, mood, and dissociative symptoms. At the start of each day sleep quality and duration was also rated. Daydreaming was reported on 45% of occasions and significantly predicted greater dissociation, in particular when daydreams were repetitive and negative (but not fanciful) in content. These relationships were mediated by feelings of depression and anxiety. Sleep quality but not duration was a negative predictor of daily dissociation and also negatively predicted depression but not anxiety. Findings offer initial evidence that the occurrence and content of daydreams may act as potentiating states for heightened, in the moment, dissociation. The treatment implications of targeting sleep and daydreaming for dissociative disorders are discussed.

Keywords: daydreaming, mindwandering, dissociation, depersonalization, sleep, emotion, experience-sampling methodology, clinical case study

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INTRODUCTION

Detaching from one's immediate surroundings when engrossed in an exhilarating novel or experiencing the energized focus of "flow" at work, are examples of dissociative experiences that can occur in everyday life. Although, typically viewed on a continuum, clinical forms of dissociation are not simply reflective of psychological absorption. Dissociation in dissociative disorders typically involves substantial ongoing problems in integrating thoughts and feelings into consciousness and memory, with associated poor psychosocial functioning (Waller et al., 1996). Prevalence estimates for dissociative disorders range from 4 to 29% of the population and typically involve two common aspects of dissociation: depersonalization (i.e., feelings of disconnection from one's self such as feeling like a robot or automaton) and derealization (i.e., feeling disconnected from ongoing reality, as if the world is distorted or moving in slow motion; van der Kloet et al., 2012b). Recent research and theory proposes that dissociative disorders are maintained and exacerbated by a labile sleep-wake cycle. In this cycle, imaginative, "dream-like," mentation intrudes into waking life, which, in turn, contributes to dissociative experiences and symptoms. In this paper, we present an initial test and extension of this theory by examining the role of daydreaming in dissociation. Specifically, we view daydreaming as a form of dream-like mentation and examine its relationship with sleep, mood, and dissociative symptoms in a unique experience-sampling study with an individual meeting diagnostic criteria for depersonalization/derealization disorder (DDD; American Psychiatric Association, 2013).

Dissociation and a Labile Sleep-Wake Cycle

The etiology of dissociative disorders has historically been proposed to reflect either coping with early childhood adversity/trauma (e.g., Sanders and Giolas, 1991; Gleaves, 1996; Bremner, 2010) or social learning/expectancies (e.g., Lilienfeld et al., 1999). However, more contemporary approaches (e.g., Watson, 2001; Lynn et al., 2012; van der Kloet et al., 2012b; van Heugten–van der Kloet et al., 2014) highlight the important role of sleep experiences for the proximal development and severity of subsequent dissociation. According to this model "sleep-related deficiencies in cognitive control may promote an influx of imaginative, dreamlike mentation in daily life that contributes to dissociative symptoms such as depersonalization and derealization" (van der Kloet et al., 2012b, p. 167). A labile sleep-wake cycle is proposed to promote dissociation by "pushing" sleep-like mentation into waking consciousness, which then fuels fantasy-proneness, and is associated with cognitive failures, and feelings of depersonalization/derealization.

Several studies support the close association between sleep disturbance and dissociative symptoms. Correlational research consistently shows that sleep disturbances (e.g., unusual sleep experiences) are positively correlated with dissociation (e.g., Watson, 2001; Levin and Fireman, 2002; Agargun et al., 2003; Giesbrecht and Merckelbach, 2004; Koffel and Watson, 2009a) and experimental studies demonstrate that dissociative symptoms are heightened by sleep-wake cycle disruptions (Giesbrecht et al., 2007; van Heugten–van der Kloet et al., 2015). Although, this research indicates that sleep disturbances may exacerbate dissociation, research has yet to fully identify and examine the "dream-like mentation" purported to precede and fuel dissociation in daily life. Research has therefore typically focused on the distal relationship between nighttime experiences and daytime dissociation rather than examining how different states of consciousness may be linked to current dissociation as they actually occur during wakefulness. We address this gap by examining the state of daydreaming in dissociation, which can be conceptualized as a state of consciousness in between fully-focused waking thought and sleep mentation (i.e., dreaming). We draw on existing research and theory on daydreaming and emotion to extend theoretical ideas about dream-like mentation (daydreaming) as a potentiating state for heightened dissociation. To ensure external validity and clinical credibility, the theory is tested in an experience-sampling study with an individual meeting diagnostic criteria for DDD (American Psychiatric Association, 2013).

Daydreaming as Dream-Like Mentation

Daydreaming (also variously referred to as mindwandering, spontaneous thought, off-task thinking, stimulus-independent thought) can be defined as mental content that is both stimulus-independent and task-unrelated (Stawarczyk et al., 2011). Daydreaming is stimulus-independent because its content is not directly related to the processing of the immediate environment (i.e., it is internally generated) and it is task-unrelated because its content is unrelated to the progression or completion of the current goal(s) in the external environment. Thus defined, daydreaming is estimated to occupy between a third and a half of waking life (Klinger and Cox, 1987-1988; Killingsworth and Gilbert, 2010), during which thought operates in a more free-flowing, diffuse, and less directed manner than during other kinds of waking mentation (e.g., the deliberate and fully focused thought involved in calculating one's monthly finances; Klinger, 2009).

Several researchers have noted parallels between the daydreaming state and dreaming/sleeping states (e.g., Raichle, 2009; Christoff et al., 2011; Fox et al., 2013; Klinger, 2013; Wamsley, 2013), supporting the notion that daydreaming lies in the middle of the sleep-wake mentation continuum (e.g., Hartmann, 2010; Montangero, 2012). Daydreams show substantial similarities with dreams both in terms of their content and neurophysiological basis (see Fox et al., 2013; Wamsley, 2013, for reviews). Both daydreaming and dreaming involve activation of the default-mode network, which is a core network of regions including the medial prefrontal and cingulate cortex, the medial temporal lobe, the lateral parietal cortex, and areas of the cerebellum and striatum (Buckner et al., 2008). Domhoff and Fox (2015) have recently conceptualized dreaming as an intensified form of daydreaming because of the increased activation in areas of the default mode network that support sensorimotor imagery in REM sleep relative to the "resting" states characteristic of daydreaming. These authors further suggest that "people can indeed drift into dreaming during periods of relaxed wakefulness and mindwandering" (p. 349) which mirrors suggestions that "dream-like" or even dreaming mentation can enter consciousness during wakefulness through daydreaming.

If daydreaming can be one way in which dream-like mentation intrudes into consciousness in dissociative disorders and exacerbates symptoms, then how might these relationships present and unfold in daily life? We propose an initial model of these relationships (shown in **Figure 1**) in which sleep

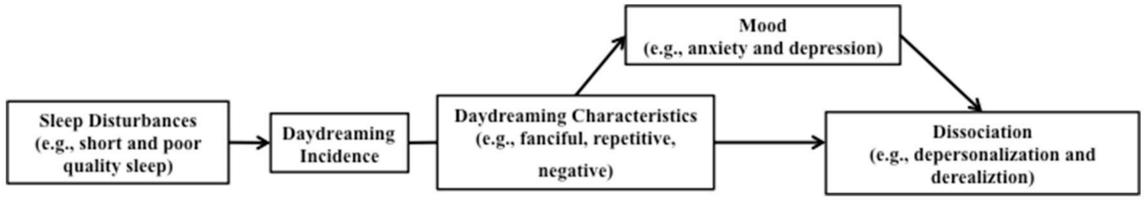

FIGURE 1 | A proposed model of how daydreaming is related to dissociation.

disturbances exacerbate/increase daydreaming; and, in turn, daydreaming (and its characteristics) elicits negative mood and subsequent dissociation. We now review the evidence for each component of this suggested model within existing literature.

Sleep Disturbance and Daydreaming Frequency

Several lines of converging evidence support the proposal that, at least in normative samples, sleep disturbances are related to increased mindwandering/daydreaming. In both laboratory settings and in daily life, daytime fatigue, and sleepiness have been consistently associated with increased momentary mindwandering and daydreaming (e.g., Antrobus et al., 1966, 1967; Manly et al., 2002; McVay and Kane, 2009). Sleep duration has been negatively associated with hours spent daydreaming (Kunzendorf et al., 1983) and sleep deprivation has also been associated with higher rates of later daydreaming (Mikulincer et al., 1990). More recently, daydreaming frequency has been positively associated with various aspects of poor sleep quality (such as sleep latency and disturbances; Carciofo et al., 2014). People who report poorer sleep quality and more unusual sleep experiences (e.g., sleep paralysis and lucid dreaming) also report daydreaming more frequently (Denis and Poerio, 2016).

There are several possibilities for how sleep disturbances might predict the incidence of daydreaming in dissociative disorders. First, as implied by models of dissociation (van der Kloet et al., 2012b), poorer sleep could make the intrusion of dream-like mentation via daydreams more common in dissociation. Second, poorer sleep quality could increase levels of fatigue or reduce metacognitive control which might then be associated with greater daydreaming, in turn increasing the likelihood of a dissociative experience in someone prone to dissociation. Indeed previous research has linked dissociation with increased distractibility and attentional difficulties (Guralnik et al., 2007). Another possibility is that both the labile sleep-wake cycle and daydreaming incidence may be underlined by a latent trait in dissociation characterized by attentional/metacognitive control difficulties (which in itself could make intrusions of sleep experiences into waking thought more likely). Although, we do not test specifically test these possible mechanisms in the present study, we examine for the first time whether the basic association between sleep disturbances and increased daydreaming found in non-clinical samples also occurs in dissociative disorder. Based on the reviewed evidence, we predict that measures indexing sleep disturbance (e.g., sleep duration and quality) would also be associated greater daydreaming incidence in dissociative disorders.

Daydreaming and Dissociative Symptoms

Daydreaming is typically conceived of as state or symptom of both normative (e.g., Butler, 2006) and pathological dissociation (Holmes et al., 2005; Lynn et al., 2012). Indeed, measures of dissociation typically include items related to psychological absorption/daydreaming (e.g., "becoming so involved in a fantasy or daydream that it feels as though it were really happening to you" from the Dissociative Experiences Scale; Carlson and Putnam, 1993). Additionally, cross-sectional research has shown that daydreaming styles are positively associated with both dissociative experiences (Segal and Lynn, 1993) and clinical dissociation (Levin and Spei, 2004). More recent research using a large sample has associated the tendency to daydream more frequently with having more dissociative experiences (Denis and Poerio, 2016). However, the existing research has treated daydreaming as a trait or global variable (e.g., daydreaming style or typical frequency) and has not yet examined whether the state of daydreaming is associated with dissociation. This makes it difficult to ascertain whether daydreaming is a concomitant of dissociation or, as theories might suggest, a state that precedes and fuels dissociative symptoms. Whether momentary daydreams are associated with symptoms of dissociation is therefore an open question. We suggest that rather than daydreams *per se* being associated with worse dissociation, the effect of momentary daydreams on dissociative symptoms will depend on the characteristics of specific daydreams and their relationship with affective states.

Daydreaming Characteristics, Mood, and Dissociation

Although, daydreaming has been previously labeled as a homogeneous experience that has negative effects on emotional well-being (e.g., Killingsworth and Gilbert, 2010), emerging research has consistently supported the view that daydreaming is a heterogeneous experience and that it is through this heterogeneity that certain costs and benefits of the experience emerge (Smallwood and Andrews-Hanna, 2013). With respect to emotional well-being, a number of studies indicate that the characteristics of daydreams (e.g., what people daydream about) determine whether daydreaming has a positive or negative effect on emotional experiences. For example, research has consistently found that daydreams with a positive emotional and social content are associated with beneficial affective outcomes (e.g., greater feelings of happiness, reduced loneliness; Poerio et al., 2013, 2015a,b, 2016). Analogously, other research has identified the specific characteristics of daydreaming related to negative affective outcomes. In particular, repetitive, self-focused, unintentional, and negative daydreams have been linked with poorer emotional well-being and psychological disorder (Ottaviani and Couyoumdjian, 2013; Deng et al., 2014; Marchetti et al., 2014, 2016). This suggests that although daydreaming is likely to be associated with affective outcomes and psychopathological symptomology, this relationship will likely depend on the characteristics of daydreaming.

Drawing on this research and the importance of viewing daydreaming as a heterogeneous experience, we sought to capture pertinent characteristics of daydreaming and their links to mood and dissociation in the present study. Specifically, we measured the emotional valence, repetitive, and fanciful nature of individual daydreams. The first two characteristics were chosen because research in both daydreaming and repetitive thought has consistently associated negative and repetitive thoughts with the occurrence and maintenance of psychopathology (e.g., Segerstrom et al., 2003; Watkins, 2008). In light of this evidence, we expected that daydreams that were more negative in valence and repetitive would be associated with greater dissociation. The fanciful nature of daydreams was chosen as a characteristic of specific clinical relevance to dissociative disorders. Fantasy proneness (i.e., the tendency to engage in vivid imaginative experiences) is a consistent correlate of dissociation in both clinical and non-clinical samples (e.g., Rauschenberger and Lynn, 1995; Giesbrecht and Merckelbach, 2006). Indeed, fantasy proneness is a personality trait that is proposed to map onto dissociation, and fantasy intrusions into waking states are proposed to be a symptomatic and maintenance factor for dissociative disorders (van der Kloet et al., 2012b). To our knowledge, no previous research has examined fantasy as a current state (e.g., in terms of on-going fanciful daydreams) to assess whether such fanciful cognition is associated with dissociation. Based on previous research and theory, we expected more fanciful daydreams to be associated with greater dissociation.

The Present Study

Building on existing theories of sleep disturbances in dissociation and research on daydreaming, we propose an initial model of how sleep and daydreaming interrelate to predict negative mood and dissociative symptoms during dissociative disorder. Specifically, we predict that sleep disturbances will be associated with a greater incidence of daydreaming; and that daydreaming will be associated with greater symptoms of dissociation and negative mood depending on the nature of those daydreams (i.e., the extent to which they are fanciful, repetitive and negative). We tested this model by sampling daydreaming episodes, sleep experience, negative mood (anxiety and depression), and dissociative symptoms of an individual with DDD in an intensive single-case experience-sampling study. Intensive quantitative single clinical case study research has a long and significant heritage and is particularly indicated in the "hourglass model" (Salkovskis, 1995) when there is a lack of evidence for clinical phenomena and a need for associated theory building. Experience-sampling involves reporting on targeted momentary experiences on each occasion participants are signaled over a period of time (Stone et al., 1991). In a clinical context, experience-sampling enables an examination of how fluctuations in everyday experience (e.g., daydreaming) relate to changes in clinical symptoms (e.g., dissociation) within a patient over time, which can be different from between person relationships (Tennen and Affleck, 2002). This method has been found to be particularly useful in $N = 1$ outcome studies (e.g., Totterdell et al., 2012), because it has the advantage of capturing relationships between, and change in, clinical symptoms much closer to their occurrence, compared to traditional retrospective nomothetic outcome measures.

MATERIALS AND METHODS

Participant

The participant was a 24 years old white-British male. The participant had a history of childhood trauma (poor attachment and an assault) and associated attendance in child and adult psychiatric services. Previous psychiatric assessment on three separate occasions had diagnosed a dissociative disorder, with childhood onset. The participant had also been previously diagnosed with Generalized Anxiety Disorder as a child by a psychiatrist. There were no previous episodes of psychiatric admission to an in-patient setting. The participant approached the research team volunteering to participate in research because of his diagnosis and the impact he recognized the dissociation had on his ability to function. Throughout the duration of the study, the patient was taking a low dose of an anti-convulsant and this did not change. Prior to the current study the patient underwent psychological assessment in the form of the (a) Structured Clinical Interview for DSM-IV Dissociative Disorders (SCID-D; Steinberg, 1993) and (b) Clinician Administered Dissociative States Scale (CADSS; Bremner et al., 1998). The SCID-D findings were that the patient met diagnostic criteria for DDD (American Psychiatric Association, 2013) and, on the CADSS, the participant scored 74, which is above the mean for dissociative disorder (Bremner et al., 1998). In brief, the participant described chronic feeling of disconnection from his immediate environment, frequently occupying a cut-off dreamlike state and that he frequently experienced himself as an unreal, disembodied, robot-like figure. Regarding sleep, the participant stated at assessment that he was a vivid dreamer and that his sleep was chaotic and labile; he frequently went to bed much later than the average person (therefore sleeping later in the day) and often had disturbed and broken sleep.

Experience-Sampling Protocol

A signal-contingent experience-sampling protocol (Wheeler and Reis, 1991) was used to obtain repeated data on dissociation, daydreaming, mood and sleep. The participant was signaled on a smartphone via text message six times daily for 40 days with a link to answer online questionnaires regarding dissociation, daydreaming, mood and sleep (see for example, Poerio et al., 2015b, 2016). The six signals were scheduled to occur in three pairs of two signals (separated by between 5 and 10 min) during the following time slots, which were chosen according to the participant's typical waking hours: 12:00-16:30, 16:30-21-30, 21:30-02:30. The first signal in each pair occurred at a random time within each time block with the constraint that pairs of consecutive signals were at least an hour apart. The pairing of signals in each time slot was originally designed to allow an examination of temporal contiguity (by splitting the data into two alternate time-series) over a longer period but the study was curtailed to 40 days due to the participant's new work commitments, so the reduced number of observations meant that this could not be examined.

Procedure

After completing the psychological assessment, the participant met with the researchers on two occasions to discuss the nature of the study and what it would involve. In the first session, the experience-sampling design and appropriate times for signaling were negotiated to fit in with daily routines. We also collaborated with the participant regarding wording of items to ensure that measures of dissociative symptoms were grounded in the participant's daily experiences of derealization and depersonalization (Kellett and Beail, 1997). In the second session, the participant was provided with detailed instructions for completing the study. He was given a written and verbal description of daydreaming and his understanding of the concept was checked and discussed. In line with previous studies (e.g., Poerio et al., 2015b, 2016), a daydream was defined as a series of connected thoughts and/or images where that mental content is not about whatever mental or physical activity one is engaged in at the present moment. Next, the participant was provided with a demonstration of the text message with online questionnaire link and verbal explanation of the meaning and response of each questionnaire item. All instructions for how to complete the study were also provided in written format for later reference. Informed consent was obtained and a start date for the experience-sampling was agreed. At the end of the training session, the participant completed global measures indexing dissociative experiences over the past month. Ethical approval for this study was obtained from the University of Sheffield Psychology ethics committee and was conducted in line with British Psychological Society ethical guidelines.

Global Dissociation Measures

Cambridge Depersonalization Scale (CDS; Sierra and Berrios, 2000). Twenty-nine-items measured the frequency and duration of depersonalization and derealization symptoms associated with depersonalization disorder including: abnormal sensory experiences (e.g., "*Familiar voices (including my own) sound remote and unreal*"), cognitive and emotional complaints (e.g., "*When I weep or laugh, I do not seem to feel any emotions at all*") and space and time distortions (e.g. "*Objects around me seem to look smaller or further away*"). Each item was rated on two likert scales for frequency over the past month (1 = *never*, 5 = *all the time*) and duration of the experience (1 = *a few seconds*, 6 = *more than a week*). Average scores for frequency and duration were calculated with higher values indexing more frequent and longer-lasting symptoms of depersonalization over the preceding month.

Dissociative Experiences Scale (DES-II; Carlson and Putnam, 1993). Twenty-eight-items measured the frequency of dissociative experiences over the past month (e.g., "*Finding yourself in a place and having no idea how you got there*"). Each item was rated using 100-point sliding scales (higher values indicating greater frequency). Scores for each item were summed to create an overall score with higher scores indicative of greater dissociative experiences over the past month. The measure also included three subscales, each with 6-items, indexing amnesia (e.g., "*Finding yourself dressed in clothes that you don't remember putting on*"), depersonalization/derealization (e.g., "*Looking in the mirror and not recognizing yourself*"), and absorption (e.g., "*Sitting staring off into space, thinking of nothing, and not being aware of the passage of time*").

Experience-Sampling Measures

At each signal, the first question always asked about daydreaming and, if applicable, daydreaming characteristics. These questions were followed by items regarding mood and dissociative symptoms, and finally alcohol consumption within the past 3 h. For the first signal of every day, the daydreaming questions were followed by items indexing the previous night's sleep. The set of experience-sampling items was kept brief to minimize participant burden, in line with recommended practice (Bolger et al., 2003; Christensen et al., 2003).

Daydreaming Incidence and Characteristics

The participant was asked "*Right before you were signaled, or within the last 5 min, were you daydreaming?*" (0 = *No*, 1 = *Yes*). When the participant answered affirmatively, he was asked several other questions about the characteristics of that daydream. Each daydream was rated on three 7-point scales according to its fanciful nature (1 = *completely realistic*, 7 = *completely fanciful*), emotional valence (1= *very negative*, 7 = *very positive*), and novelty (1 = very *repetitive*, 7 = *completely novel*). The order of these items was individually randomized for each presentation.

Current Mood and Dissociative Symptoms

In response to the question "*How do you feel right now?*" the participant answered two items concerning mood that indexed anxiety ("*anxious*") and depression ("*depressed*"), and seven items concerning dissociative symptoms that included three items for experiences of derealization ("*Cut off from the world around me,*" "*Detached from my surroundings,*" "*That the world around me seems to look smaller or larger*"), and four items for experiences of depersonalization ("*Emotionally numb,*" "*That I am outside of my body,*" "*That I am robotic,*" "*That I am a detached observer*"). The symptoms of dissociation were taken from the Cambridge Depersonalization Scale (CDS; Sierra and Berrios, 2000) and were adapted to effectively tap into the participant's own experience of dissociation. This "client centered" and idiographic measurement of clinical phenomena is at the methodological heart of $N = 1$ research (Totterdell et al., 2012). Detailed efforts were therefore made to ensure the high face validity of dissociative items with the participant, so that the items were grounded in their daily experience of dissociation. This is in keeping with good practice in the design of $N = 1$ research (Kellett and Beail, 1997). For example, CDS item 1 "out of the blue, I feel strange, as if were not real or as if I were cut from the world around me" was shortened in collaboration with the participant to 'cut off from the word around me' with the stem of I am currently feeling. The order of all these items was individually randomized for each presentation and items were answered on a 5-point scale from 1(*not at all*) to 5(*extremely*). The seven dissociative symptom items were averaged at each time point to create an overall score, where higher values indicated greater current experience of dissociation in general (derealization and depersonalization; $\alpha = 0.81$).

Alcohol and Medication

The participant indicated his recent alcohol consumption ("*Have you consumed any alcohol in the last 3 h?*"; 0 = *No*, 1 = *Yes*) and, using a free text response box, whether there had been any deviations from his medication (of which there were none reported during the study). Alcohol consumption was measured to be included as a control variable in our analyses. This was because the participant indicated during assessment that alcohol typically increased his tendency to dissociate (although there was no evidence of alcohol dependency from the assessment). This is also consistent with previous research suggesting that clinical dissociation is made worse by alcohol consumption (Baker et al., 2003).

Sleep

The participant was asked to provide the previous night's time of sleep onset and wakening ("*What time did you go to sleep/wake up?*"); the total daily minutes of sleep duration was calculated from these values. Sleep quality was assessed with a single item "*How well did you sleep last night?*" ranging from 1(*very badly*) to 7(*very well*).

RESULTS

Analytical Approach

The data were examined with regression and mediation analyses. We modeled the non-independence of the repeated measurement data by first determining the autoregressive structure of each time series using plots of their autocorrelation function and partial autocorrelation function (see Pollock et al., 2014 for a similar time series analysis of ideographic clinical symptoms). The functions indicated the presence of a second order autocorrelation in the time series (probably owing to the pairing of signals), so the second order lag of each dependent variable was included as a predictor in each model to control for its potential influence. For analyses examining associations with sleep variables, we aggregated sampled observations (e.g., individual instances of daydreaming) so that each day of the study was associated with one mean score per variable; we modeled the non-independence of daily data by including the first-order lag of the dependent variable in each regression model. This procedure allowed us to examine associations between sleep and average daily levels of daydreaming, dissociation, and mood. Alcohol consumption was controlled for in all analyses and all regressions were performed with bootstrapping (1000 samples).

Response Rate

All of the experience-sampling data were date and time stamped allowing us to check when the surveys were completed. Only the first answered survey was counted as a valid response if consecutively answered signals were less than 5 min apart. Of the 211 occasions on which experiences were reported, 81 (38%) were considered invalid; this left 130 observations upon which the following analyses were based which corresponds to a 54% valid response rate over the study period.

Descriptive Statistics

At the start of the study, the participant's average level of dissociative experiences according to the Dissociative Experiences Scale was 57.61 (measured on 100-point scale where >30 is considered a clinical cut-off for dissociation). Average values for each subscale of the DES also showed that symptoms of depersonalization/derealization ($M = 73.33$) and absorption ($M = 75.67$) were high; and levels of amnesia were relatively low ($M = 29.83$). Mirroring this, average levels for the Cambridge Depersonalization Scale showed high frequency and duration of dissociative symptoms ($M_{frequency} = 4.03$; $M_{duration} = 4.45$). Daydreaming was reported on 45% of sampled occasions. This frequency of daydreaming is within the range reported by other experience-sampling studies with non-clinical samples (e.g., 26%: Franklin et al., 2013; 30%: Kane et al., 2007; 47%: Killingsworth and Gilbert, 2010; 36%: Poerio et al., 2013; 60%: Song and Wang, 2012).

Sleep Duration and Quality Predicting Daydreaming, Dissociation, and Mood

We examined whether sleep duration ($M = 413$ min; $SD = 240$ min) and quality ($M = 2.00$; $SD = 1.54$) independently predicted daily daydreaming and dissociative symptoms. Neither sleep duration nor quality predicted average daily daydreaming levels (duration: $\beta = 0.005$, $p = 0.710$, $B = 0.00$, $SE = 0.00$, 95%CI: 0.00, 0.00; quality: $\beta = -0.002$, $p = 0.814$, $B = -0.001$, $SE = 0.00$, 95%CI: −0.004, 0.005). However, average daily dissociative symptoms were negatively predicted by sleep quality ($\beta = -0.17$, $p = 0.015$, $B = -0.03$, $SE = 0.01$, 95%CI: −0.06, −0.00), but not sleep duration ($\beta = -0.07$, $p = 0.399$, $B = 0.00$, $SE = 0.00$, 95%CI: 0.00, 0.00). This suggests that although daydreaming incidence was not associated with sleep, dissociative symptoms were greater when sleep quality was poor. We also examined how sleep duration and quality were associated with average daily levels of anxiety and depression. Sleep duration did not predict either anxiety ($\beta = -0.01$, $p = 0.961$, $B = 0.00$, $SE = 0.00$, 95%CI: 0.00, 0.00) or depression ($\beta = -0.07$, $p = 0.427$, $B = 0.00$, $SE = 0.00$, 95%CI: 0.00, 0.00). Sleep quality was a negative predictor of depression ($\beta = -0.17$, $p = 0.022$, $B = -0.05$, $SE = 0.00$, 95%CI: −0.01, 0.00) but not of anxiety ($\beta = -0.14$, $p = 0.115$, $B = -0.04$, $SE = 0.01$, 95%CI: -0.10, 0.03).

Daydreaming Incidence Predicting Dissociation and Mood

Next, we examined whether the occurrence of daydreaming predicted experiences of dissociation, anxiety, and depression. Daydreaming incidence was a significant negative predictor of dissociation ($\beta = -0.28$, $p = 0.001$, $B = -0.25$, $SE = 0.06$, 95%CI: -0.36, -0.13), anxiety ($\beta = -0.43$, $p < 0.001$, $B = -0.73$, $SE = 0.13$, 95%CI: -0.96, -0.46), and depression ($\beta = -0.33$, $p < 0.001$, $B = -0.57$, $SE = 0.14$, 95%CI: -0.83, -0.28) suggesting that experiences of dissociation, anxiety, and depression were more severe when daydreaming had occurred.

Characteristics of Daydreaming Predicting Dissociation and Mood

Given the heterogeneity of daydreaming, we next examined whether the characteristics of daydreaming predicted experiences of dissociation, anxiety and depression. In contrast to our predictions, the fanciful nature of daydreams did not predict dissociation ($\beta = -0.17$, $p = 0.175$, $B = -0.03$, $SE = 0.02$, 95%CI: -0.07, 0.00), anxiety ($\beta = -0.07$, $p = 0.229$, $B = -0.07$, $SE = 0.05$, 95%CI: -0.17, 0.03), or depression ($\beta = -0.22$, $p = 0.110$, $B = -0.10$, $SE = 0.05$, 95%CI: -0.20, 0.02). However, the novelty of daydreaming was a significant negative predictor of dissociation ($\beta = -0.37$, $p = 0.002$, $B = -0.06$, $SE = 0.02$, 95%CI: -0.11, -0.03), anxiety ($\beta = -0.51$, $p < 0.001$, $B = -0.18$, $SE = 0.04$, 95%CI: -0.27, -0.10), and depression ($\beta = -0.45$, $p < 0.001$, $B = -0.17$, $SE = 0.05$, 95%CI: -0.28, -0.07). Likewise, the positivity of daydreams was a significant negative predictor of dissociation ($\beta = -0.50$, $p < 0.001$, $B = -0.10$, $SE = 0.02$, 95%CI: -0.14, -0.05), anxiety ($\beta = -0.58$, $p < 0.001$, $B = -0.24$, $SE = 0.05$, 95%CI: -0.33, -0.17), and depression ($\beta = -0.63$, $p < 0.001$, $B = -0.28$, $SE = 0.06$, 95%CI: -0.40, -0.17). These results suggest that repetitive and negative (but not fanciful) daydreams were associated with more severe experiences of dissociation, anxiety, and depression.

Supplementary Mediation Analyses

Given the significant associations between daydreaming, mood, and dissociative symptoms, we were interested in further exploring whether mood mediated associations between daydreaming (incidence, novelty and emotional valence) and dissociation. To examine the role of mood as a potential mediator we ran a series of mediation analyses using PROCESS (Hayes, 2012) in which daydreaming variables were entered as the predictor variables, dissociation as the dependent variable, and anxiety and depression as the mediator variables. We entered the second order lag of the dependent variable and alcohol consumption as covariates in all models. The results of these mediation analyses are summarized in **Table 1**. Depression and anxiety significantly mediated relationships between: daydreaming incidence and dissociation and the novelty of daydreams and dissociation. Only anxiety was a significant mediator of the relations between the emotional valence of daydreams and dissociation.

TABLE 1 | Summary of mediation analyses.

Model	Path a	Path b	Path c (direct effect)	Indirect (mediated) effect
Daydreaming Incidence-Anxiety-Dissociation	$B = -0.73$, $SE = 0.13$, $p < 0.001$	$B = 0.26$, $SE = 0.04$, $p < 0.001$	$B = -0.04$, $SE = 0.07$, $p = 0.565$	$B = -0.19$, $SE = 0.05$, 95%CI[-0.32, -0.10]
Daydreaming Incidence-Depression-Dissociation	$B = -0.57$, $SE = 0.14$, $p = 0.001$	$B = 0.26$, $SE = 0.04$, $p < 0.001$	$B = -0.08$, $SE = 0.06$, $p = 0.218$	$B = -0.15$, $SE = 0.04$, 95%CI[-0.26, -0.09]
Daydreaming Novelty-Anxiety-Dissociation	$B = -0.19$, $SE = 0.04$, $p < 0.001$	$B = 0.18$, $SE = 0.06$, $p = 0.004$	$B = -0.03$, $SE = 0.02$, $p = 0.253$	$B = -0.04$, $SE = 0.02$, 95%CI[-0.07, -0.01]
Daydreaming Novelty-Depression-Dissociation	$B = -0.19$, $SE = 0.05$, $p < 0.001$	$B = 0.15$, $SE = 0.05$, $p = 0.009$	$B = -0.03$, $SE = 0.02$, $p = 0.132$	$B = -0.03$, $SE = 0.02$, 95%CI[-0.06, 0.00]
Daydreaming Valence-Anxiety-Dissociation	$B = -0.24$, $SE = 0.04$, $p < 0.001$	$B = 0.13$, $SE = 0.06$, $p = 0.032$	$B = -0.06$, $SE = 0.02$, $p = 0.019$	$B = -0.03$, $SE = 0.01$, 95%CI[-0.06, -0.01]
Daydreaming Valence-Depression-Dissociation	$B = -0.28$, $SE = 0.05$, $p < 0.001$	$B = 0.09$, $SE = 0.06$, $p = 0.117$	$B = -0.07$, $SE = 0.03$, $p = 0.017$	$B = -0.03$, $SE = 0.02$, 95%CI[-0.06, 0.01]

B, Unstandardized path coefficients, SE, Standard error. Ninety-five percent Confidence intervals for indirect effects are based on 1000 bootstrapped samples. Path a refers to the effect of the predictor on the proposed mediator (e.g., daydreaming on anxiety), Path b refers to the effect of the mediator on the dependent variable (e.g., anxiety on dissociation), Path c refers to the direct effect of the predictor on the dependent variable considering the mediator. The indirect effect provides an indication of statistical mediation such that 95%CIs excluding zero are considered statistically significant at the $p < 0.05$ level. Alcohol consumption and the second order lag of the dependent variable were entered as covariates in all models.

DISCUSSION

In this intensive clinical case study we used experience-sampling methodology to sample sleep, daydreaming (and its characteristics), mood, and dissociative symptoms in an individual meeting diagnostic criteria for depersonalization/derealization disorder (DDD; American Psychiatric Association, 2013). Based on previous research and theory on both the role of sleep and "dream-like" intrusions in the maintenance of dissociation and the potential role of daydreaming in this process, we proposed an initial model (**Figure 1**) explaining how sleep and daydreaming are linked with mood and dissociative symptoms. The evidence for this model based on the results of the current study are as follows (an updated model based on the present study is presented in **Figure 2**):

First, although we expected sleep disturbances to be associated with greater daydreaming we did not find evidence to suggest that either sleep duration or quality predicted average daily incidence of daydreaming. This finding is unexpected because a range of previous evidence on sleep and daydreaming suggests that sleep disruptions are associated with greater daydreaming frequency (e.g., Kunzendorf et al., 1983; Mikulincer et al., 1990; Carciofo et al., 2014; Denis and Poerio, 2016). We suspect that this null finding may be because the method examining daydreaming incidence (i.e., averaging whether the participant was daydreaming or not across the number of questionnaires answered each day) was unable to accurately characterize daily daydreaming rates. On average, the participant answered 3.7 questionnaires each day (modes = 1, 3), which may not have provided an accurate assessment of the likelihood of daydreaming occurrence. Notably, previous research linking sleep experiences to daydreaming frequency has involved estimates of thoughts over during a brief time period (i.e., a laboratory task; Mikulincer et al., 1990) or has been based on retrospective/global judgments of daydreaming frequency (Carciofo et al., 2014). To appropriately characterize daydreaming incidence with experience-sampling methodology, future research would benefit from more frequent sampling and/or a retrospective daily evaluation of daydreaming frequency. Firmly establishing the link between sleep disturbance and daydreaming in dissociative disorder is important in order to provide empirical evidence to support theoretical ideas that sleep disruptions are associated with an increase of "dream-like" intrusions into waking life (van der Kloet et al., 2012b) often reported in dissociative disorders (American Psychiatric Association, 2013).

Second, poorer self-reported sleep quality (but not sleep duration) was associated with significantly greater severity of dissociative symptoms across the following day. This finding is consistent with research and theory highlighting the importance of sleep disturbance in dissociation (e.g., Watson, 2001; Levin and Fireman, 2002; Agargun et al., 2003; Giesbrecht and Merckelbach, 2004; Giesbrecht et al., 2007; Koffel and Watson, 2009a; van der Kloet et al., 2012b; van Heugten–van der Kloet et al., 2015).

Our study not only confirms this association but it is also the first to provide evidence for a positive association between disrupted sleep and dissociative symptoms using an intensive repeated measures design of a dissociative disorder. Measuring fluctuations in sleep quality over time and assessing accompanying dissociative symptoms "in the moment" overcomes the potential biases involved in using cross-sectional research based on retrospective/global reports (e.g., Bradburn et al., 1987). Our research suggests that the relationship between sleep and dissociation in dissociative disorders over time is important and that poor quality sleep may be a factor that might maintain or exacerbate dissociative symptoms. The finding that sleep quality but not duration was associated with dissociation is of particular interest because previous research has suggested

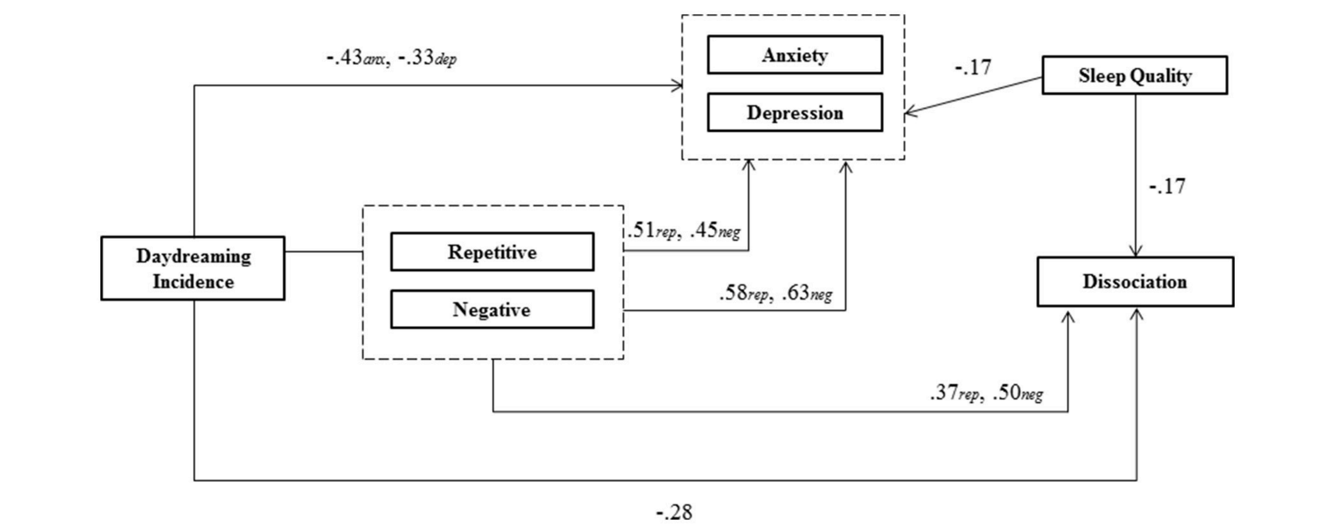

FIGURE 2 | An updated model of how daydreaming is related to dissociation. Values represent regression coefficients for analyses in the current study.

that whereas mood disorders appear to be linked with insomnia, dissociation appears to be uniquely linked to unusual sleep experiences (Koffel and Watson, 2009b; van Heugten–van der Kloet et al., 2014). Our research broadly supports this finding to the extent that subjective sleep quality is a measure that reflects or captures sleep disturbances. Having established the link between sleep quality and dissociative symptoms in an intensive longitudinal design, future research would benefit from more extensive measurement of sleep disturbance across both subjective (e.g., additional measures on the presence/absence of unusual sleep experiences such as nightmares and hallucinations; and dreaming content) and objective measures (e.g., actigraphy). The use of more objective measures of sleep and/or more sensitive self-report measures (e.g., the Pittsburgh Sleep Quality Index; Buysse et al., 1989) would be particularly important in future research because the present study is limited by the use of single items to measure sleep quality and duration.

Third, daydreaming and its characteristics were associated with both mood and dissociative symptoms. In line with our predictions, repetitive and negative daydreams were associated with greater feelings anxiety, depression, and dissociation. This is consistent with previous research on the role of repetitive thought and daydreaming in clinical disorders (e.g., Segerstrom et al., 2003; Watkins, 2008). However, our study extends these ideas beyond depression and anxiety to dissociation, indicating that daydreaming incidence and content are important factors to assess in dissociative disorders. Notably, these findings support theoretical (but until now empirically untested) ideas that dream-like intrusions in daily life are involved in the proximal development and progression of dissociative disorders (e.g., van der Kloet et al., 2012b). Not only was the occurrence of daydreaming associated with dissociative symptoms, but the extent to which daydreaming negatively impacted on mood and dissociation also depended on the characteristics of daydreams. This highlights the need to consider the content (rather than just the occurrence) of daydreaming in clinical disorder and supports a growing body of research showing that in order to determine the positive and/or negative impact of daydreaming on well-being it is vital to measure the heterogeneity of the experience (e.g., Mar et al., 2012; Franklin et al., 2013; Ottaviani and Couyoumdjian, 2013; Poerio et al., 2013, 2015a,b, 2016; Ruby et al., 2013; Smallwood and Andrews-Hanna, 2013).

Fourth, supplementary mediation analyses examined the possibility that mood might mediate the association between daydreaming and its characteristics on dissociation. We found evidence that, in general, feelings of anxiety and depression mediated the positive statistical effects of repetitive and negative daydreaming on dissociative symptoms. This suggests that at least part of the reason why daydreaming is associated with dissociative symptoms arises indirectly from the effect of daydreaming on mood. This is consistent with previous research, which has consistently documented the strong and important impact of various types of imagery on mood in emotional disorders (Holmes and Mathews, 2010) and, in non-clinical samples, the well-established link between daydreaming content and later mood states (e.g., Franklin et al., 2013; Poerio et al., 2013; Ruby et al., 2013). Examining the role of mood in dissociative disorders is important because anxiety and depression are associated with the severity of dissociative symptoms in clinical populations and a previous diagnosis of depression and/or anxiety has been identified as the main risk factor for depersonalization disorder (Baker et al., 2003). This, combined with the present findings, suggests that research examining the development and progression of dissociative disorders would benefit from exploring interactions and the causal relationships between daydreaming, mood, and dissociative symptoms.

One additional and unexpected finding deserves particular mention. We predicted that fanciful daydreaming would be associated with worse mood and greater dissociative symptoms. Not only were the relationships between fanciful daydreaming and feelings of anxiety, depression, and dissociation non-significant but the direction of the relationship between fanciful daydreaming and dissociation was also the opposite of what would be predicted based on previous research and theory. Previous research has consistently identified fantasy-proneness as a correlate of dissociative disorders (Rauschenberger and Lynn, 1995; Giesbrecht and Merckelbach, 2006) and excessive involvement in fantasy is proposed to be a symptom of dissociation (van der Kloet et al., 2012b). To our knowledge, this study is the first to measure fanciful thought as it occurs momentarily in daily life and has failed to find evidence of a link between fanciful mentation and dissociative symptoms. Although, any inferences based on this finding must be considered tentative given our $N = 1$ sample, we suggest that the often-cited link between fantasy and dissociation should be reconsidered and examined in relation to actual daily experiences of fantasy, rather than composite and global tendencies of imaginative involvement (see also Cima et al., 2001; Bremner, 2010). Indeed, it has previously been suggested that the association between fantasy-proneness and dissociation may arise simply because measures assessing both constructs show substantial overlap in item wording (Klinger et al., 2009).

Despite the unique contributions stemming from the present study, it is important to highlight that (a) our results may not be applicable to all individuals with dissociative disorders because this is a single case study specific to DDD and (b) the causal nature of these results should not be overstated. The correlational nature of the study design and the use of self-report measures make it important to emphasize that this study cannot shed light on the causal or temporal nature of the observed associations. For example, it is possible that the participant's own theories about his disorder (of which we have no knowledge) may have affected his reporting (e.g., that negative daydreams should be associated with worse mood and dissociation). It is also likely that the associations observed are bi-directional. For example, although we examined how daydreaming was related to mood because daydreaming was measured as occurring before the signal (or in the preceding 5 min) whereas mood was measured "right now," previous research has shown that prior mood also influences the frequency and nature of daydreaming. Research has revealed that a negative mood (particularly sadness) is associated with increased daydreaming in both laboratory settings (Smallwood et al., 2009) and in daily life (Poerio et al., 2013). This suggests that rather than (or in addition to) daydreaming predicting negative "in the moment" feelings, daydreaming is also preceded or caused by negative mood. Although, we failed to find associations between sleep and daydreaming incidence, other research has suggested that this relationship is also bi-directional (i.e., that daydreaming is linked with subsequent difficulty falling asleep; Ottaviani and Couyoumdjian, 2013). Likewise, dissociation may be a predictor as well as a consequence of daydreaming incidence and content. For example, the daydreaming state may exacerbate symptoms in someone who is prone to dissociation, while states of dissociation could make daydreaming more likely (e.g., dissociation may be linked with the inability to inhibit task-irrelevant thoughts due to a lack of metacognitive control or distractibility; Guralnik et al., 2007). Although, this previous research might be suggestive of alternative explanations to the current results, we suspect that these directions of influence are not mutually exclusive or contradictory. Indeed, considering the bi-directional associations between sleep, daydreaming, mood, and dissociation is likely to represent a more comprehensive account of the cyclical and dynamic nature of moment-to-moment cognition and emotion, particularly within clinical disorders (Borsboom and Cramer, 2013). Future work would profit from examining these variables with more advanced and intensive experience-sampling designs involving multiple participants and in response to intervention. This would enable an examination of the relative strength of different directions of influence (e.g., is the effect of sleep on dissociation stronger than the effect of dissociation on sleep?) and of individual differences that moderate the relationships.

We have argued and provided evidence for the idea that daydreaming is an important state of consciousness relevant to dissociative disorders. However, an important outstanding question involves the precise role of daydreaming in dissociative disorders. Daydreaming has sometimes been conceptualized as a cognitive failure or attention lapse (e.g., Cheyne et al., 2006; McVay and Kane, 2010), or as engagement with fantasy and imagery (e.g., Oettingen and Mayer, 2002), and more recently as an important state of cognition for psychosocial functioning (e.g., Poerio and Smallwood, Submitted). The former two conceptions of daydreaming are of direct relevance to dissociative disorders, with research suggesting that clinical dissociation is linked both with cognitive failures and distractibility (Giesbrecht et al., 2008) and with a preoccupation and absorption with fantasy (Segal and Lynn, 1993). Although, our findings suggests that the fanciful nature of daydreaming may not be as pertinent to the maintenance of dissociative symptoms as previously suggested (at least in this particular individual), future work should further explore relevant characteristics of daydreaming to investigate whether its relationship with dissociation arises from cognitive failure or fantasy immersion. Future work might also examine the less explored aspects of daydreaming and psychosocial functions in relation to dissociation; by, for example, examining how aspects of social cognition (e.g., the ability to distinguish between self and other) during daydreaming are linked with symptoms of dissociation (in particular depersonalization).

There are several potential aspects of daydreaming that might shed light on this issue of whether daydreaming in dissociation reflects cognitive failure or fantasy proneness—taking into account both the nature of daydreaming and the context in which it occurs. First, drawing on methods used to examine daydreaming in laboratory settings (e.g., Konishi et al., 2015), research could investigate whether rates of daydreaming during tasks requiring attention are related to the severity of dissociative symptoms (e.g., as measured by the DES or by comparing clinical and non-clinical samples). Second, experience-sampling research could investigate how the extent of immersion or absorption in daydreams is related to dissociative symptoms with the expectation that these dimensions of daydreaming would be associated with, and possibly exacerbate, dissociative symptoms. Although, daydreaming is a ubiquitous experience, it is possible that daydreaming in dissociation is more "immersive" and so individuals with dissociative disorders struggle to disengage from daydreams and ground themselves in reality. Third and relatedly, an important dimension to be explored would be the controllability and intentionality of daydreaming. Recent research has linked spontaneous (rather than deliberate) daydreaming with clinical disorders (Marchetti et al., 2016) suggesting that they may be more detrimental to mental health. This prediction fits well with the idea that uncontrollable and spontaneous daydreams may be more detrimental to dissociation because they are further toward the dreaming end of the wake-sleep cognition continuum. Indeed, this is mirrored by associations observed in sleeping cognition because uncontrollable sleep disturbances (e.g., nightmares) are typically more strongly associated with dissociative experiences than controllable sleep mentation such as lucid dreaming (Koffel and Watson, 2009a).

Finally our findings motivate the intriguing possibility that sleep and daydreaming are potential intervention targets for dissociative disorders. Research has already demonstrated that improving sleep quality through a sleep hygiene intervention can reduce dissociation (van der Kloet et al., 2012a). Although, the potential for intervention requires future work, we believe that examining the state of daydreaming and its characteristics in dissociative disorders will enrich our understanding of how dissociative symptoms evolve and are potentiated as they occur in daily life. There is scope for targeted interventions aimed at changing the negative aspects of daydreaming whilst maintaining its functional outcomes (e.g., planning, creativity, and social well-being). In terms of the clinical methods to help to change negative aspects of daydreams, use of imagery re-scripting (i.e., actively manipulating negative daydreaming imagery) holds some promise (Wild and Clark, 2011). For more complex patient problems, sleep hygiene, and daydream content interventions could occur in the initial phase of treatment, so that dissociation is reduced and the patient is stabilized, to enable them to engage more effectively in psychotherapeutic work on past trauma. In keeping with the hourglass model of evaluation (Salkovskis, 1995), further $N = 1$ outcome studies offer the opportunity to study, in detail, responsivity to suggested phases of treatment, before proceeding onto larger group studies. In conclusion, this research has shed new light on the relationships between sleep, daydreaming, mood, and dissociation in DDD and highlights exciting avenues for future clinical and research work.

AUTHOR CONTRIBUTIONS

All authors conceived of, and designed, the study. GP collected and analyzed the data with assistance and contributions from SK, PT. GP drafted the manuscript; SK, PT provided revisions. All authors read and approved the final manuscript.

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REVIEW
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Sleep Paralysis in Brazilian Folklore and Other Cultures: A Brief Review

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Sleep paralysis (SP) is a dissociative state that occurs mainly during awakening. SP is characterized by altered motor, perceptual, emotional and cognitive functions, such as inability to perform voluntary movements, visual hallucinations, feelings of chest pressure, delusions about a frightening presence and, in some cases, fear of impending death. Most people experience SP rarely, but typically when sleeping in supine position; however, SP is considered a disease (parasomnia) when recurrent and/or associated to emotional burden. Interestingly, throughout human history, different peoples interpreted SP under a supernatural view. For example, Canadian Eskimos attribute SP to spells of shamans, who hinder the ability to move, and provoke hallucinations of a shapeless presence. In the Japanese tradition, SP is due to a vengeful spirit who suffocates his enemies while sleeping. In Nigerian culture, a female demon attacks during dreaming and provokes paralysis. A modern manifestation of SP is the report of "alien abductions", experienced as inability to move during awakening associated with visual hallucinations of aliens. In all, SP is a significant example of how a specific biological phenomenon can be interpreted and shaped by different cultural contexts. In order to further explore the ethnopsychology of SP, in this review we present the "Pisadeira", a character of Brazilian folklore originated in the country's Southeast, but also found in other regions with variant names. Pisadeira is described as a crone with long fingernails who lurks on roofs at night and tramples on the chest of those who sleep on a full stomach with the belly up. This legend is mentioned in many anthropological accounts; however, we found no comprehensive reference on the Pisadeira from the perspective of sleep science. Here, we aim to fill this gap. We first review the neuropsychological aspects of SP, and then present the folk tale of the Pisadeira. Finally, we summarize the many historical and artistic manifestations of SP in different cultures, emphasizing the similarities and differences with the Pisadeira.

Keywords: sleep paralysis, Pisadeira tale, ethnopsychology, transcultural psychiatry, REM sleep, hypnopompic hallucinations

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INTRODUCTION

Sleep paralysis (SP) is a dissociative state in which an individual, upon going to sleep or waking up, is unable to move (Mahowald et al., 2011). SP is accompanied by frightening, and often fantastic, hallucinations and delusions (Dahlitz and Parkes, 1993), thus different societies interpreted it under a supernatural or metaphysical perspective (Hinton et al., 2005). Interestingly, there is a similarity between these manifestations and the description of nocturnal assaults by the *Pisadeira*, a folk figure typical of Southeastern Brazil, but also found in other regions (Cascudo, 2012). We performed surveys using Google Scholar, as well as the Bireme and Scielo databases, but could not find comprehensive studies wherein the various neuropsychological and sociocultural aspects of SP are described and compared with the Pisadeira tale. The objective of this review is to fill this gap.

SLEEP PARALYSIS: DEFINITION, EPIDEMIOLOGY, NEUROPSYCHOLOGY, AND CLINICAL PICTURE

The term "sleep paralysis" was coined by Wilson (1928). SP is considered a disease when recurrent and disturbing, according to the International Classification of Sleep Disorder – 3rd edition (ICSD-3) (American Academy of Sleep Medicine [AASM], 2014). SP is classified as a parasomnia and characterized by unusual behavior or abnormal physiological events that occur during the transition between sleep and wakefulness. SP episodes are generally accompanied by intense anxiety, inability to perform voluntary movements (even to scream or cry out for help), and, in some cases, fear of impending death (Sharpless et al., 2010; Jalal and Hinton, 2013). SP occurs most commonly in women (Pires et al., 2007; Sharpless and Barber, 2011) and when the body is in supine position (Chilcott et al., 1998; Sharpless et al., 2010). The prevalence of SP among the general population is controversial, ranging from 5 to 62% (Dahlitz and Parkes, 1993). In a sample of nearly two thousand Canadian university students, Burgess et al. (1995) found that 21% of these subjects experienced SP; however, in this sample there was no significant inter-gender difference. In a systematic review, Sharpless and Barber (2011) observed that the prevalence rate of at least one episode of SP in lifetime for the general population, student samples, and psychiatric patients was 7.6, 28.3, and 31.9%, respectively.

Sleep paralysis is associated with either hypnagogic hallucinations (that occur at the onset of sleep) or hypnopompic ones (when waking up) (Dahlitz and Parkes, 1993). Cheyne et al. (1999) grouped the hallucinations associated with SP into three types: (a) "Intruder"; (b) "Unusual Bodily Experiences"; (c) "Incubus." The "Intruder" type is characterized by a feeling of fear or an unpleasant presence, accompanied by auditory and visual hallucinations. The "Unusual Bodily Experiences" involve hovering sensations and out-of-body experiences, in which individuals see the own body from an external perspective, and interpret as if they have left their physical body (Blackmore and Parker, 2002; Blanke et al., 2004; de Sá and Mota-Rolim, 2015). The "Incubus" type refers to feelings of chest pressure and shortness of breath. Cheyne et al. (1999) observed a correlation between types (a) and (c). Cheyne and Girard (2009) consider that out-of-body experiences and SP hallucinations have different neurobiological basis. The former would be caused by altered neural processing in temporoparietal cortex areas, which participate in the integration of visual, auditory, vestibular, and proprioceptive information to encode for body imagery and notion of self (Blanke et al., 2004, 2005; Jalal and Ramachandran, 2014), while the latter have been linked to abruptly going in and out of rapid-eye-movement sleep (REMS).

REMS is strongly associated with the vivid and richly emotional visual events experienced during sleep, which we call dreams (Aserinsky and Kleitman, 1953; Dement and Kleitman, 1957). REMS presents changes in vital signs such as blood pressure, respiratory rate and heart rate. Except for vital organs (e.g., heart and lung muscles) and genitals, the body as a whole is paralyzed during REMS. The absence of myographic activity is known as muscle atonia (Hobson et al., 2000). Muscle tonus decreasing during REMS occurs through the action of a descending inhibitory system from specific brainstem nuclei to the anterior column in the spinal cord, and then to muscles (Jouvet and Delorme, 1965). The main neurotransmitters associated with this network are GABA and glycine (Brooks and Peever, 2012). This system prevents animals from performing "in real life" the imaginary movements that they make when dreaming, which would render them extremely vulnerable, and therefore subject to be preyed upon. This idea derives mainly from the pioneering work of Jouvet (1979), who, upon damaging specific brainstem nuclei, noted that animals exhibited typical behavior such as running, cleaning themselves and masticating during REMS, as they no longer possessed muscle inhibition. These behavior patterns have been readily associated – hypothetically – to dreaming (Jouvet and Delorme, 1965; Jouvet, 1979).

Dahlitz and Parkes (1993) speculate that a lack of synchrony between changes in brain activity and muscle atonia is the mechanism responsible for bodily immobilization during SP. In general terms, during SP the brain falls back to an activity pattern similar to when individuals are awake; however, their muscles remain in the typical REMS atony, thus subjects feel as though they have awakened, and yet are unable to move (Dauvilliers et al., 2007; Nishino, 2007; Mahowald et al., 2011).

Despite sharing a few characteristics, there is an important dissimilarity between SP and dreams (Blackmore and Parker, 2002). When dreaming, we do not know that we are, in fact, dreaming, except in cases of lucid dreams (Van Eeden, 1913; Laberge et al., 1981; Erlacher and Schredl, 2008; Voss et al., 2009; Mota-Rolim and Araujo, 2013; Mota-Rolim et al., 2013; Dresler et al., 2014). On the other hand, during SP subjects know they were asleep but have woken up. In addition, SP experience is usually more aggressive than a normal dream, and there are four times more references to body parts (e.g., feelings of thorax pressure or paralyzed limbs) in the former relatively to the latter (Blackmore and Parker, 2002).

According to Hufford (2005), until recently SP was constantly underdiagnosed as a narcolepsy symptom. Narcolepsy is a disorder characterized by abnormalities in sleep regulation, including abrupt and involuntary sleep attacks associated with cataplexy (sudden loss of muscle tone), which usually follows a strong burst of emotion. Although it may be associated with Narcolepsy, SP can occur separately: the so-called isolated SP (American Academy of Sleep Medicine [AASM], 2014).

OLD, UGLY, AND RAGGED: WHO IS THE *PISADEIRA*?

Ferreira (1986) and Houaiss and Villar (2009) define the Pisadeira as a crone with long fingernails who lurks on roofs at night in order to trample on the chest of those who sleep. Luís da Câmara Cascudo - a renowned folklorist born in the Brazilian state of Rio Grande do Norte - adds further details to this physical description by mentioning Pisadeira's gauntness and unkempt hair (Cascudo, 2012). He states that Pisadeira:

> . . . is the nightmare personified in an old man or woman. The nightmare, or the roman "nocturna oppressio," has always been explained by the evil intervention of an incubus, a demon or a malevolent spirit. In many cultures, the nightmare – also known as the classic oneirodynia, was due to a giant or a dwarf, a terrible woman or man that, taking advantage that one is sleeping, would sit upon their stomach and pressure their thorax, disturbing one's breathing (p. 568).

Cascudo (2012) continues his description of Pisadeira looking for etymological references in other languages. He states that the word for nightmare in Portuguese, *pesadelo*, derives from "peso" or "pesado," which means heavy; in French *cauchemar,* from the ancient verb *chaucer,* from Latin *calcare,* denotes to press or to push; finally, the English word *nightmare* is the night demon, or devil.

In the countryside of the Brazilian states of Minas Gerais and São Paulo, the Pisadeira possesses different physical features: she is a "fat" and "heavy" Afro-Brazilian adept at stepping on the abdomen of those who sleep on a full stomach or belly up. There is also a northeastern variant name for the Pisadeira around the São Francisco River, the so-called "*Pesadeira*." She has the same features of her Minas Gerais and São Paulo state counterparts, except that the Pesadeira wears a red cap. The tale tells that if someone can scrounge it, Pesadeira loses her strength and will grant any wish in return for her cap (Lins, 1983). In Ceará state, this legend is called "*Pisador*" (Portuguese word for the one who steps on something/someone), and, differently from other regions, it is a masculine demon.

Cascudo (2012) believes that the Pisadeira is a direct descendant of the Portuguese myth known as "Fradinho da Mão Furada," literally "Little Hand-Hole Friar." It is said that Fradinho would enter people's bedrooms, and place his "heavy hand" upon their chest, preventing them from screaming:

> From Portugal, however, came the nightmare main elements. J. Leite de Vasconcelos, in his 'Popular Traditions of Portugal,' describes the origin of Pisadeira tormenting their hillbillies and rednecks. In Algarve, it is the "Little Hand-Hole Friar." The Friar enters late at night in the alcoves, through the door keyhole. He has a red cap on his head, and straddles at ease upon the people, to assign them the worst nightmares. He goes away only when the person wakes up (p. 289). '..' The nightmare is the devil, which has a cowl and a very heavy hand. When people sleep with the belly full, the nightmare puts his hand on the chest of the sleeper and leaves no possibility to shout (p. 290).' From Portugal, of course, came the Pisadeira. But from where has Portugal received the 'night oppressio?' The influence of Provence on Portuguese land was long and powerful. Provencal people spread rhythms for the early verses. For Provencal culture, nightmare is an old woman, with the tricks of Pisadeira. Only in Provence and Portugal, she comes down the chimney, and goes to the sleeper chest (p. 569).

Cascudo (2012) also described an equivalent of Pisadeira for the native Brazilian Indians: "she was an old woman who, along with her procession of unspeakable agonies, would visit an individual" (p. 568). The native Brazilian tribe of the Tupi called her Kerepiiua. There was also the figure of the Jurupari, who, following catholic catechesis, was ascribed the meaning of "nocturnal demon," its name a contraction of "i-ur-upá-ri" (she who comes to, or upon, the bed).

The Pires (2002) quotation below, taken from a dialog with a country bumpkin sitting at a bonfire, resembles descriptions of Pisadeira:

> It's a woman, this one, real skinny, got haseff' dose real long, bony fingas with big ol' nails! She got stubby legs, ratty hair, chin all pointed up and a nose real bent-like, bushy brows and eyes all a-glowin'... When, we finish our suppa an' go sleep on our backs, she'll come down from the roof an' sit right on ya'chest, camberin'... camberin' down... right on ya'belly! Now that's why ya ought not let ya young-uns sleep on their backs (Pires, 2002, p. 89).

The Pisadeira also starred on the verses of Cora Coralina, a pseudonym of the Brazilian Goias-State poetess Anna Lins dos Guimarães Peixoto Brêtas (1889–1985). Despite her status as one of the greatest writers ever to grace Brazil, Cora Coralina had her very first book – *Poems from the Goias alleyways and other stories* – published only when she was 75 years old. In this book, Coralina makes the following reference to the *Pisadeira*:

> That night it came to pass that Mrs. Jesuína was awakened by grunts, moans, almost, coming from the placemat. She scolded: "quiet, you imp, let us sleep..." All fell silent, and the night continued its spin in space and time. In the alcove, the yellow circle of the old oil lamp. The paintings of Saints, immovable on the walls. Then again, a renewed grunt and a few little moans, a thing of the underage. Once again uttered the old woman in all her nobility: "turn to the darn side, girl, that's the Pisadeira, don't you piss on that mat..." And then there was silence. The old woman went back to sleep, but woke up in the wee hours of the morning. "Jesuína, Jesuína." No reply. She commented: "Tis how it goes, you fill up your breadbasket, the Pisadeira comes, won't let you sleep, and in the morning you're broken like hell" (Coralina, 2014, p. 32).

Unfortunately, Pisadeira – as well as other figures in Brazilian folklore, such as Saci and the headless Mule – is at a risk of being forgotten. Passed on from generation to generation in the Brazilian countryside, these oral traditions are losing their strength. One of the policies for the preservation of this heritage of Brazilian legends and myths is to give them their proper value (Moreira et al., 2009).

From what has been seen so far, it is possible to say that both the Pisadeira tale and SP share many features, such as a malevolent supernatural presence, feelings of chest pressure, difficulty to breath and to scream, and sleeping in supine position with full stomach. In the next sessions, we will review historical aspects of SP as well as its manifestation in other cultures.

A HISTORICAL OUTLOOK ON SLEEP PARALYSIS

Before the development of sleep science, there have been a series of magical and religious-based interpretations of SP throughout the history of human civilization, such as the Ancient Roman *nocturna oppressio* mentioned above (Cascudo, 2012). The first known description of SP comes from Hippocrates (∼400 BC), and the Greeks named it "ἐφιάλτης" (ephialtes), roughly translated as "to pounce upon someone." Artemidorus of Daldis (2nd century) in his book *Oneirocritica* – translated as "The Interpretation of Dreams" – associated *ephialtes* with the god Pan. The horned god of the woods and flocks could have sex with the dreamer during an *ephialtes*, and such was viewed as a promise of a great future income (Stewart, 2002).

This positive link with the sexual act would eventually change with the arrival of the Christian era of the Middle Ages. The *incubi* and the *succubi*, demons who sexually harassed their victims at night, would then emerge. The Latin name *incubus* would initially be a direct translation of *ephialtes*. However, it quickly acquired sexual connotations, given its proximity to *concumbere*, "to sleep (with)," and *concubinus*, a concubine. Much like the *incubus* was a male demon prone to abuse women, the *succubus* was a female demon who took advantage of men during sleep, and the origin of its name (*succubus*) means "to lie under." Stewart (2002) comments that it was the Christianity that first negatively associated nightmares with erotic dreams, as its tenets were built upon the strict control of sexual instincts.

In early Enlightenment, with the beginning of scientific revolution, there is what appears to be the first medical description of an SP episode accompanied by hypnagogic hallucinations: Dr. Isbrand van Diemerbroeck (1609–1674) diagnosed a 50-year-old woman suffering from repeated spells caused by a *nightmare*, or incubus (Kompanje, 2008). Regarding the etymology of the word *nightmare*, Stewart (2002) describes its Scandinavian origins: *mare* comes from *mara*, a spirit that, in the Northern mythology, was said to torment or suffocate sleepers. The woman investigated by Diemerbroeck exhibited chest pressure, shortness of breath, inability to move, and an association of this experience with sleeping in the supine position (Kompanje, 2008), just like those visited by the Brazilian Pisadeira (Cascudo, 2012).

There is a major source of confusion between the *nightmare* and SP. Before the 15th century, a "nightmare" was synonymous to spiritual attack, believed to be orchestrated by a witch. However, under the influence of Enlightenment, the "nightmare" became grouped under a larger category of "bad" dreams, and lost its specificity to SP characteristics (Hufford, 1982). Nevertheless, Henry Fuseli depicted the overlap between nightmare and SP in his most famous painting, "The Nightmare" (1781) (**Figure 1**). In this painting, an elf sits upon the chest of a lifeless-like woman draped in white over the end of a bed. In the upper left corner of the painting, just behind scarlet curtains, stands the ghostly head of a horse (Myrone, 2001). This painting has been interpreted as a "classical" pictorial representation of SP, of which the painter himself might have been victim, according to Kompanje (2008).

In the literary domain, Guy de Maupassant's "Le Horla" is viewed by Cheyne (2001, 2015) as a case of SP. In the first version of the tale, Dr. Marrande introduce to his fellow scientists one of his patients, dubbed as "the strangest and most unsettling case" in his career as an alienist. The protagonist narrates his misfortunes from a first-person perspective, describing that an invisible being torments him every night. He is assaulted in his sleep by a "dreadful feeling of a crushing weight on my chest, and of a mouth that was eating up my life." He blames his mysterious visitor – whom he names "Horla" – for his insomnia and loss of weight. In the final version of the tale, the narrator describes an episode in which, as he lies and sleeps, he also feels someone "approaching me, looking at me, feeling me, climbing into my bed, kneeling on my chest, taking my neck in his hands and squeezing" (Maupassant, 2009, p. 250), similarly to the Pisadeira (Cascudo, 2012). Curiously, the protagonist attributes his mental illness to a Brazilian ship he saw, believed to have spread an "epidemic madness," in which people were possessed by a kind of vampire that feeds of their lives while they sleep.

Contemporary SP Manifestation

A modern day retelling of SP would correspond to the so-called "alien abductions" (Shermer, 2011). Mack (1997) defines these cases as narratives (conscious or aided by hypnosis) describing the abduction by aliens, which are recorded in the absence of altered mental states – such as those induced by psychotropic substances. According to Shermer (2011), the appearance of aliens in the popular imagination took place after the supposed crash landing of an unidentified flying object in Roswell, New Mexico, in 1947. Shermer (2011) believes that the abduction narratives have their origin in a special broadcast by NBC in 1975, based on the extraordinary accounts by Barney and Betty Hill. The Hill couple described experiences that have become a standard for thousands of people who have experienced the same phenomenon: lights in the middle of the night, body paralysis, dissections, examinations, etc. The "classic" look of extraterrestrial kidnappers – bald, bigheaded humanoids with elongated eyes – was in fact a product of NBC artists. Following the dissemination of these accounts in newspapers, tabloids and TV programs, abduction reports rose exponentially. Shermer (2011) cites Strieber's (1987) Communion and Mack's (1997) Abduction as examples of literary landmarks that helped perpetuate the belief in the supposed veracity of alien abductions.

Clancy et al. (2002) and McNally et al. (2004) questioned the veracity of such reports – most of them extracted via hypnosis. According to McNally and Clancy (2005), human memory is malleable: false memories can be implanted by the suggestion of therapists. After conducting a survey with ten individuals that had been "abducted," Clancy and McNally (2005) have found a substantial occurrence of SP episodes in this group compared to a control group. These authors additionally noted the similarity between alien abduction experiences and SP: immobility, feeling of a threating presence, feeling of levitation, flashing lights, bright objects, and other hallucinations.

FIGURE 1 | The Nightmare (1871) by Henry Fuseli.

SLEEP PARALYSIS IN OTHER CULTURES

Sleep paralysis represents a fairly strong evidence of how a given neurobiological phenomenon can be interpreted and shaped by different cultural contexts. Field studies conducted in many different parts of the world detected the same phenomenon occurring under a myriad of ethnic and religious perspectives. In these cases, the few seconds, or minutes, of an SP episode – a veritable mish-mash of terrifying sensations – give rise to supernatural interpretations (Hinton et al., 2005).

The closest language to Portuguese is Spanish; interestingly, SP in Mexico is known as "se me subió el muerto," translated as "a dead body climbed on top of me" (for comprehensive review, see Sharpless and Doghramji, 2015). The idea of a "phantasmagoric weight" is also found in the Pisadeira tale. In Catalonia, the Pesanta is a black animal (usually a dog or a cat) that invades houses at night and steps over people's chests, disturbing their breath and causing nightmares, similar to the Pisadeira. Curiously, both Pesanta and the Fradinho da Mão Furada (who originated the Pisadeira, as mentioned above) have holes in their hands.

Beyond Latin cultures, Kirmayer and Law (2005) studied the Inuit people, who are Eskimos living in Canada's subarctic region. They refer to SP as *uqumangirniq*, an experience closely linked to the spiritual world, which courses with compromised motor functions (inability to move, talk, and/or scream), hallucinations, and the frightening manifestation of a shapeless, or faceless, presence. The Inuit believe that the *angakkuit* (shamans) are the main responsible for the *uqumangirniq*. Although the shamans exert a benign influence by organizing activities ranging from rites of passage to the interpretation of dreams, some shamans involved in power disputes cast spells (*ilisiiqsijuq*) on their opponents. One type of *ilisiiqsijuq* consists of attacking the enemy as they sleep, since at this moment the connection between body and soul (*tarniq*) is fragile. If a shaman can permanently separate the *tarniq* from its body, that individual dies.

In the Japanese tradition, the 金縛り (*kanashibari*) is the cultural equivalent of SP (Fukuda et al., 1987). Translated as "the state of being totally bound, as if constrained by metal chains," the *kanashibari* may emerge through the spell of a summoner, who uses a vengeful spirit to suffocate his enemies. The *kanashibari* is a popular phenomenon in the Far East, often represented in *mangas*, the Japanese comic books. Despite the fact that the phenomenology of SP in both Inuit and Japanese is very similar to the "Pisadeira," they attribute to SP a human origin - from spells of shamans or summoners – which does not happen in the Brazilian tale.

Through interviews with one hundred Cambodian refugees in an American psychiatric clinic, Hinton et al. (2005a) observed a high incidence of SP among survivors of the Pol Pot dictatorial regime (1975–1979): 42% of the subjects reported at least one SP episode per year. These patients referred to SP as *khmaoch sângkât*, "the ghost that pushes you down." According to them, a supernatural being, or a ghost, would put their hands on the chest or neck of the victim while sleeping in supine position, making it difficult to breathe. There are four ways the supernatural beings could look like: (i) a tall, black shadow lacking a defined outline; (ii) a red-eyed, canine-toothed being, dressed in a Khmer Rouge cloak who brandishes a knife or club; (iii) a simian-like demon; (iv) an *ap* – a grotesque creature embodied solely by the head of a woman and her bowels. Regarding the ghosts, when someone is killed violently, or buried without the proper funeral rites – something recurrent during the Pol Pot period – the spirit would be doomed to walk the Earth and haunt the living by showing them the afterlife state of penury.

The Asian immigrants from the Hinton et al. (2005b) sample exhibited high levels of post-traumatic stress disorder (PTSD). These subjects had certain physical SP symptoms associated with the severe, traumatic experiences they went through under the yoke of the Khmer Rouge. For example, they associated dyspnea with near-drowning experiences during monsoon periods typical to Southeast Asia, or with their witnessing executions in which victims wore a bag over their head. Chest pressure, a typical SP feature, was associated with the chest pain resulting from heavy loads they were forced to carry in rice farms run by their tormentors. The association of SP with PTSD in Cambodian people does not appear in the Pisadeira tale; however, there are no systematic studies of SP in the Brazilian society.

Sleep paralysis appears in many other cultures around the world with regional variances. In Thailand, the ผีอำ (*phi am*) is a ghost that haunts subjects when half-asleep and unable to move (Cassaniti and Luhrmann, 2011). Egyptians believe that SP is caused by the الجن (*Jinn*), who are malevolent spirit-like creatures (Jalal and Hinton, 2013). Sharpless and Doghramji (2015) report that Ethiopians consider the ዱካክ (*dukak*) an evil spirit that haunts the sleep. Similarly to the Brazilian Pisadeira, the Hmong people – an ethnic group from the mountain regions of Vietnam and Laos – believe that a "pressing spirit" sits on the chest of the sleepers and tries to asphyxiate them (Adler, 2011), while Chinese traditional people also believe that a type of "ghost oppression" causes SP (Yeung et al., 2005). Furthermore, the Yoruba people from Southwest Nigeria believe that the *Ogun Oru* is a female demon who possesses body and mind during dreaming (Aina and Famuyiwa, 2007), and in Newfoundland (a province of Canada) the *Old Hag* is a witch who sits on the sleeper (Firestone, 1985).

FINAL CONSIDERATIONS

Sleep paralysis is characterized by body immobility, chest pressure, seeing scary figures, and/or feeling a frightening "presence," which tend to happen during awakening in supine position. As described along this article, the interpretation of SP rebirths in different eras and cultures, such as the Greek "ephialtes" (ἐφιάλτης), the *nocturna oppressio* of Ancient Roman, Fuseli's "The nightmare," the Japanese *kanashibari* (金縛り), the Egyptian *Jinn* (الجن), and the modern "alien abductions," among others. Here, we report that SP in Brazil is usually described as Pisadeira attacks (Corso, 2002; Pires, 2002; Cascudo, 2012). Cascudo (2012) investigates Pisadeira etymology and relates it to the Portuguese word "pesadelo" (nightmare), akin to its original meaning, the Spanish *pesadilla* ("heavy" or "weighed").

Since the Enlightenment, the "supernatural" experiences associated to SP have been interpreted as pathological. However, there are few connections between SP and other neuro-psychiatric disorders (Hufford, 2005) with the exception of Narcolepsy, as mentioned earlier (American Academy of Sleep Medicine [AASM], 2014). Yet, if SP episodes occur too frequently and/or intensely as to induce any physical, psychological or social suffering, the subject must be examined by sleep clinicians.

Noteworthy, there is a tendency to associate the Pisadeira and similar phenomena to a "superstition" believed by naïve, uneducated people. However, Hufford (2005) observed that a "spiritual" component of SP exists independently of social class or education level. Despite offering an alternative socio-biological interpretation to such episodes, here we do not intend to belittle this spiritual component. Instead, the goal of this work is to enrich the knowledge about these experiences and their psychological and cultural aspects.

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All authors listed, have made substantial, direct and intellectual contribution to the work, and approved it for publication.

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HYPOTHESIS AND THEORY
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Consciousness across Sleep and Wake: Discontinuity and Continuity of Memory Experiences As a Reflection of Consolidation Processes

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The continuity hypothesis (1) posits that there is continuity, of some form, between waking and dreaming mentation. A recent body of work has provided convincing evidence for different aspects of continuity, for instance that some salient experiences from waking life seem to feature in dreams over others, with a particular role for emotional arousal as accompanying these experiences, both during waking and while asleep. However, discontinuities have been somewhat dismissed as being either a product of activation-synthesis, an error within the consciousness binding process during sleep, a methodological anomaly, or simply as yet unexplained. This paper presents an overview of discontinuity within dreaming and waking cognition, arguing that disruptions of consciousness are as common a feature of waking cognition as of dreaming cognition, and that processes of sleep-dependent memory consolidation of autobiographical experiences can in part account for some of the discontinuities of sleeping cognition in a functional way. By drawing upon evidence of the incorporation, fragmentation, and reorganization of memories within dreams, this paper proposes a model of discontinuity whereby the fragmentation of autobiographical and episodic memories during sleep, as part of the consolidation process, render salient aspects of those memories subsequently available for retrieval in isolation from their contextual features. As such discontinuity of consciousness in sleep is functional and normal.

Keywords: sleep, dreaming consciousness, autobiographical memory, memory consolidation, continuity theory

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CONTINUITY IN ITS GENERAL FORM

The continuity hypothesis (1) posits that there is continuity, of some form, between waking and dreaming. A recent body of work [e.g., Ref. (1–10)] has provided convincing evidence for the characteristics of specific aspects of continuity, for instance that some salient experiences from waking-life feature in dreams over others. Five factors have been proposed to account for the incorporation of waking-life experiences into dreams (11): the emotionality of the waking-life experience; the type of waking-life activity; personality traits; time intervals; and time of night. Emotional arousal consistently seems to accompany these experiences, both during waking (original experience) and while dreaming [for a review, see Ref. (10)].

Continuity between dreaming and waking, therefore, appears to provide a framework for studying and measuring the extent of overlap, or shared variance, between different states of consciousness (11). This holds appeal in that—hypothetically—scholars could build models predicting dream content and characteristics given knowledge about specific predictor parameters, such as the emotionality of past experiences and time spent asleep. Previous attempts to conceptualize variability in dream behaviors such as dream recall (12) left 91.6% variance unexplained. As such the task at hand is ambitious. It also assumes that any as yet explained variance may be problematic, or simply, "error." Indeed, discontinuities have been somewhat dismissed as being either a product of activation-synthesis [for instance, see Ref. (13)], an error within the consciousness binding process during sleep, a methodological anomaly, or simply as yet unexplained. Furthermore, the concept of continuity remains somewhat ill-defined (14). This paper presents a conception of discontinuity within dreaming and waking cognition for the first time, arguing that disruptions of consciousness are as common a feature of waking cognition as of dreaming cognition, and that processes of sleep-dependent memory consolidation of autobiographical experiences can in part account for many of the discontinuities of sleeping cognition in a functional way. By drawing upon evidence of the incorporation, fragmentation, and reorganization of memories within dreams, this paper proposes a model of the fragmentation of autobiographical and episodic memories during sleep, which manifest as discontinuity during sleep, rendering salient aspects of those memories subsequently available for consolidation in isolation from their contextual features.

In sum the discontinuities of cognition in dreams have previously been recognized as being both typical of normal sleep mentation behavior, and possibly indicative of problematic dissociative symptoms, such as schizophrenia [e.g., Ref. (15, 16)]. This paper summarizes the elements of continuous and discontinuous processing across sleep and wake, recognizing that discontinuities in form, of cognition and of consciousness are typical and indeed functional of waking processing as well as in dreams (i.e., sleeping processing). At first glance, this may appear to be at odds with literature and evidence demonstrating that dreaming cognition, as a reflection of rapid eye movement (REM) sleep (13, 17), is dissociative and, therefore, symptomatic of psychosis. However, this paper will conceptualize discontinuity independently from concepts of continuity and dissociation in order to clarify this standpoint.

The continuity and discontinuity of dreaming mentation has to date been explored in a handful of studies, with the latter in part being related to the experience of bizarreness. This paper provides an alternative account of such discontinuities and attempts to conceptualize dreaming cognition as being functionally discontinuous for the first time, while offering theoretical accounts of continuity and discontinuity across sleep and wake.

There has thus far been little agreement over a definition of the term, "continuity," when it refers to the carryover of aspects of waking life into dreams and dreams into waking life (14). This paper attempts to clarity this and proposes a workable conception of continuity, with reference to the retrieval of prior experiences into consciousness at any given time.

CONTINUITY OF CONSCIOUSNESS

The field of sleep science well recognizes that sleep is a heterogeneous state. As distinct stages of sleep are defined by specific patterns of neural activity, measured using electroencephalogy, we assume that cognition during sleep changes also. What is less clear is how consciousness, usually measured using sleep or dream "mentation" reports, changes in line with this. This is less clear because it is difficult to access reports of conscious experience from sleep, as recall of those experiences is poor and changeable as an individual wakes from sleep.[1] Perhaps, due to this methodological challenge, there has been relatively little interest in consciousness during sleep within the field of sleep science. Dream researchers, on the other hand, use a variety of methods to capture fragments of conscious experience from sleep, including at times relying on spontaneous awakenings or the "most recent dream" method of recall and report, which likely bias findings to a sample of REM sleep dreams. Dreams sampled from REM are, indeed, typically easier to recall than dreams from other stages of sleep (18) and are also more bizarre, lengthy and emotionally intense. Comparable changes have also been documented from dreams sampled across the night, shifting from early (more coordinated) to late (more bizarre and discontinuous) (7, 19, 20). This seems somewhat different to the traditional view of waking conscious thought as focused, under control, and efficient. To illustrate this, Hartmann (21) depicted a model of consciousness as a dimension ranging from focused thought in wake at one end, to looser, hyperassociative cognition in REM sleep at the other, with a variety of intermediate states such as daydreaming and non-REM sleep featuring some degree of both control and bizarreness.

However, it seems vastly over-simplistic to think of waking consciousness as being homogeneous. It also seems somewhat optimistic to characterize waking thought as consistently focused and efficient. Take for example the metacognitive awareness of realizing that you have been trying to read the same paragraph of text for some time, without really having processed any of it. Or the conscious act of daydreaming: a part-focused activity perhaps with a pleasant goal but one that requires fantasy, mind-wandering and a loss of engagement with reality. Other examples combining high-level metacognitive functioning with a loss of engagement with reality include experience deja-vu, having involuntary autobiographical memories (AMs) interrupt focused thought, and meditation. During wake, we often appear not to notice events in our immediate environment (for a more dramatic example consider change blindness, in which observers often fail to notice major visual changes to a stimulus). As such, consciousness is extremely discontinuous, particularly with its focus sometimes being on the external environment and sometimes detaching

[1] It is assumed, here, that dreaming is considered to be a reflection of conscious activity during sleep and that, as such, it is not different to sleeping cognition or even reflective of specific stages of sleep. Indeed, several studies demonstrate that dreams can be successfully sampled from sleep onset, non-REM as well as REM stages under appropriate systematic conditions [e.g., Ref. (18)]. As such, the definition of dreaming preferred here is *a report of a mental activity experienced during sleep*.

from this almost completely, with the conscious awareness being directed toward internal states of reflection. Furthermore, most theories of consciousness distinguish between the more essential and automatic processes of responding to environmental needs, and the high-order cognitive processes of awareness of self in place and time [e.g., Ref. (22, 23)].

While there seems to be change in the manifestation and perhaps function of consciousness both across sleep and wake, and within each of those states, there also exists continuity. Continuity across sleep and wake to some extent is unsurprising as the same neurophysiological and cognitive system (i.e., the person) functions across these states. Across wake, dreaming and daydreaming, for example, we are also able to recall our past experiences, to demonstrate awareness of moments when we somewhat lose engagement with reality and transport our present conscious awareness to the future in the form of planning and setting goals. Thus, consciousness in part involves the activation and awareness of memory. Memories for our own personal experiences, AMs (24–26) may provide a framework for such continuity over time. Indeed, the AM system acknowledges that a personal life story changes over time, with memories for specific experiences being updated and constructed in accordance with long-term goals and identities (25).

One way of conceptualizing continuity then is in terms of the activation of memories across time. Indeed, a dream that is continuous with waking life should, in theory, feature real experiences, or AMs. Continuity, therefore, would be high if AMs were activated and recalled accurately and in full. Conversely discontinuity, or low continuity, would prevail if AMs were activated partially or inaccurately. The problem with this view is that very rarely are AMs recalled in full and accurately. To recall an experience fully, with many details as featured in the original experience, would be to recall an episodic memory (24, 27, 28). Very rarely do we recall episodes in this way. Rather, we remember part-details and at times fill in the blanks, creating a narrative that aligns well with a goal or identity (26). Furthermore, this seems characteristic of sleeping mentation as well as wake (8, 29). As such, we can present two arguments: (i) consciousness is varied across both sleep and wake, yet (ii) in both states continuity of memory may not prevail.

Previous studies have explored the overlap, or continuity, of cognitive processing style from waking life to dreaming. Hobson et al.'s (13) activation-input-modulation (AIM) model of dreaming assumes that dreaming is illogical and lacks self-reflective awareness and directed thought, and it points to neurophysiological changes in REM sleep as the correlate for that mode of thought (30). However, empirical explorations of the continuity of cognition across sleep and wake have reflected more similarities than differences in cognition and metacognition (31), on measures of internal commentary, public self-awareness, frequency of emotion, self-reflection, and thwarted intentions. The only measure of cognition on which the two states differed were choice, event-related self-reflection and affect, with dreams being more emotional but having fewer feelings of volition, suggesting that dreaming and waking cognition are largely comparable in many respects (31). It is widely reported that the dorsolateral prefrontal cortex is relatively attenuated during REM sleep (32–34), which may well account for the reduced volition during REM sleep. However, we must be careful not to over-simplify these findings, recognizing that volition is still possible during sleep, as evidenced by the wealth of empirical work into the experience of lucid dreaming. Taken together, there is much evidence for comparable cognitive processing across sleep and wake. Kahan and LaBerge (35) suggest that differences between waking and dreaming cognition may be quantitative; there being more of certain cognitions in waking than dreaming and *vice versa*, but not qualitative, since there were incidences of the different types of cognitions sampled from both states.

Another way of accounting for the processing styles across wake and dreaming has been evidenced by Kahn and Hobson (36), who distinguished between thinking within dreams, which they argue was similar to waking thought states, and thinking about dreams, which they argued differed. Here, the authors compared cognitive functioning in dreams with that of wake, by asking participants questions about specific dream experiences. They highlighted that thinking within the dream is similar to thinking when awake even though some implausible activities and events within dreams are accepted without question ("thinking *about* …"), whereas in wake we are aware of the source of events. This awareness of the origin of events as being either internal, such as a thought or a dream, or external in that it is truly perceived, is known as reality monitoring (37). Reality monitoring is known to be deficient during dreaming, when we accept surrounding circumstances without question, with the exception of experiencing lucidity, when we become aware that we are dreaming (36, 38). Nevertheless we have further evidence that dreaming and waking cognition is largely comparable, with dreaming reflecting a sleep state in which reality monitoring is typically reduced. This gives rise to the possibility that the dreamer can process, or think about, scenarios that would not be encountered in waking life, perhaps as a rehearsal strategy of some kind [e.g., Ref. (39)].

This view is reiterated by Kozmová and Wolman (40), who point out that the differences between the findings of cognitive researchers and neurophysiological researchers may be explained by the fact that while Kahan and colleagues are focused on cognition within a dream, Hobson and colleagues in theories like the AIM model of dreaming focus more on features of dreaming such as uncertainty about people and places, and incongruous imagery. Nevertheless, the specific features of dreams as compared to waking memories may reflect the cognitive processing capacities at the time of being experienced and recalled, and consequently it is difficult to separate out cognition from features. In their study, Kozmová and Wolman (40) identified thought units as featuring cognitive or metacognitive processing, such as being analytical or operational, and in doing so illustrated the complexity of cognitions available in dreaming, concluding that the content of the dream (be it bizarre or not) does not preclude the application of rational thought, much like one would in waking life, and in fact the thought processes applied to a dream situation have much in common with those applied to a situation experienced in waking life. Any differences in cognitions between sleep and wake may be exemplified by the generation of bizarre scenarios, than how the mind approaches those scenarios, in line with Kahn and Hobson (36) views.

Kahn and Hobson (36) further account for the lack of reality monitoring during REM sleep dreaming by the reduced activity of the dorsolateral prefrontal cortex and precuneus, as well as the functional disconnect between these structures (32–34), meaning the brain cannot distinguish between who, where and what we are within a given context. This can account for not only the poor reality monitoring during dreaming, but also the typically disorganized or bizarre string of memory sources that comprise our dreams (41). As such, the way in which our cognition operates across different states may be largely continuous, but there seems to exist differences in the *organization* of our memories between sleep and wake. Given the complexities of the characteristics of continuity between sleep and wake and even across sleep (7, 19), it is unsurprising that efforts to account for continuity have thus far been limited.

WHAT MIGHT BE THE FUNCTION OF CONTINUITY?

If we proceed with our definition of consciousness as a holistic experience of the present, brief past, long-term past (*via* memory retrieval) and the future (goal directed), we may assume that the ability to recall prior experiences, i.e., for continuity to function, would allow focus to be maintained in reaching future goals. In addition, as with the function of any memory system, the ability to recall prior experiences is the consequence of successful learning and allows those experiences to shape our interaction with the world in light of them. The activation of prior experience in a truly continuous manner would mean that we need to access all aspects of that prior experience. As we have seen, prior experiences are rarely recalled episodically, and so perhaps only salient aspects are particularly accessible at any one time, depending on need. Similarly, during sleep prior experiences may be activated either in full [rarely; see Ref. (8)] or in part and the activation of those salient aspects may strengthen them for future accessibility (42).

Ordered, controlled, and focused consciousness is also deemed to be a marker of psychological health, with authors such as Llewellyn (16) suggesting that a less structured or continuous consciousness may reflect elements of psychosis. Psychosis is characterized by disorganized cognition, seemingly leaping from one thought to another. The breakdown of holistic conscious experience is also reflected in dissociation; detachment from either the perception of reality or separation of the experience of the past. The essential feature of Dissociative Disorders is defined as "a disruption of and/or discontinuity in the normal integration of consciousness, memory, identity, emotion, perception, body representation, motor control, and behaviour" (43). The DSM-5 positions the dissociative disorders next to the trauma- and stressor-related disorders, to reflect the close relationship between these diagnostic categories (44). Dissociation can be exacerbated by sleep loss (45) and sleep disturbances are symptomatic (or perhaps even causal) of virtually all mental disorders as listed in the DSM-5 (43). This implies that sleep serves an integrative function for the mind and body. Indeed, in cognitive terms during sleep, we activate and re-activate experiences from the past (in particular the recent past), giving rise to the experience of dreams when we can recall the mental activation upon awakening. However, as we have already seen, when we explore the characteristics of dreams it is evident that consciousness is rarely continuous [e.g., Ref. (7, 18)]. As such while sleep may help to maintain order of consciousness and overall mental health, it apparently does not reflect continuity of it.[2]

WHAT IS DISCONTINUITY?

If continuity refers to the ability to retrieve the past, and the future where relevant (goals), in the context of present awareness (consciousness), then it would follow logically that discontinuity is the opposite of this, whereby discontinuity would be the inability to retrieve the past or future in the context of the present. Also, if continuity involves recalling past experiences holistically, discontinuity could refer to recalling them in a fragmentary manner. As we have noted, such discontinuity seems characteristic of both waking and sleeping cognition.

However, discontinuity may not always be conceptualized in opposition to continuity. Both Hobson and Schredl (14) and Malinowski and Horton (5, 6) acknowledge that the continuity-discontinuity spectrum may be a gradient, rather than discrete entities. For example, recalling a dream (continuity of dreaming memories to wake) may involve accessing a number of features of the original experience, but with some added appraisal of the experience and with some features being omitted from memory. This appears both continuous and discontinuous at the same time. Similarly dreaming of an upcoming social event (from waking life) may seem largely continuous in the manner of reflecting concerns, characters involved and the general setting, but could be discontinuous in that the actual future event could never happen. Here, then dream–wake (or wake–dream) continuity would perhaps rarely be clearly either continuous or discontinuous, but comprising features of both.

This presents a challenge with conceptualizing continuity and discontinuity in operational terms. Future work should aim to characterize dream–wake continuity in specific ways, noting trends for specific memory features to be either largely continuous or discontinuous.[3] This may help to alleviate concerns with

[2]It is necessary to mention here that in these discussions that acknowledge the changeable nature of consciousness, we are referring to continuous and discontinuous functioning as a state, rather than a trait. Explorations of dissociative tendency typically refer to individuals who experience discontinuity more readily and frequently than others. However, my own work has noted that, despite these individual differences, there exists great variability within people's dreaming tendencies. As such experiencing a particularly discontinuous dream, for instance, should not necessarily indicate problematic cognition or experiences, especially of a clinical nature. Furthermore, therapists and clinicians should always be wary of relying on dreams as part of any clinical diagnosis, unless sampled reliably and systematically. Great biases exist in dream reports, with some individuals much more likely to recall dreams generally than others [e.g., see Ref. (46)]. As such, encouraging anyone to try to recall a dream could over-rely on creative or imaginative processes, rather than capturing a valid dream memory. Similarly, some individuals seemingly very ready to report a dream could be particularly susceptible to creating the report without apparent effort, falsely believing that their report is true (47).

[3]One present project within my own lab is exploring this, by creating a dream memory database and charting the likelihood of individual memory fragments (objects, characters, place, sounds, etc.) as being continuous or discontinuous.

discontinuity as being merely unexplained variance in models of continuity that aim to predict dreaming behavior.

As we have noted, continuity can take many forms. Discontinuity could present as disjointed cognition, with absences or lapses in attention (i.e., consciousness being interrupted). Alternatively discontinuity could present, in extreme cases, as dissociation in waking, or bizarreness in dreams (consciousness during sleep). REM dreams are typically bizarre (48, 49), featuring sudden changes and eliciting feelings of strangeness, curiosity or mystique upon awakening. As we have seen, dreams very rarely feature memories from waking life in a truly episodic form (8, 29) and so are, by definition, discontinuous. Indeed, it seems likely that the only instances in which memories are replayed in their precise manner as they were originally experiences, is when they are so emotionally intense and negatively valenced that they were traumatic to the individual (50). In sum, full continuity here may reflect a maladapted system, while discontinuity is the norm.

Indeed several fields of study indicate the central role of the emotionality of a (waking) experience as being important for its subsequent recallability (51, 52), consolidation [e.g., Ref. (53, 54)]; and, perhaps relatedly, its likelihood of being dreamed about [(55, 56); see also Ref. (10) for a review]. Furthermore, some studies have implied that there exists a relationship between continuity and emotional intensity, such that the more intensely emotional the experience, the more highly continuous it is, especially if it is traumatic in nature [e.g. Ref. (57), see also (58)]. A somewhat emotional experience will likely be dreamed about, but in a less continuous manner [e.g., see Ref. (7, 19, 55)]. An experience low in emotional intensity may be unlikely to require processing or be dreamed about (55). Thus, there may be just cause to further explore relationships between continuity and emotionality in dream studies. Indeed, in order to explore discontinuities across sleep and wake, Kunzendorf et al. (59) reported that dreams were more bizarre, more "dream-like," and more emotional than daydreams. Hartmann et al. (60) found that the contextualizing images in dreams were more emotionally intense than those in daydreams, and also that dreams had mostly fear/terror and helplessness/vulnerability as their contextualizing emotion, whereas daydreams had no particularly dominant emotions. Thus, consciousness during sleep appears to be more bizarre and emotional than daydreams, although emotionality and bizarreness (perhaps representing discontinuity) is related across all states. It is also interesting to note that daydreams generated under the influence of extreme emotional intensity are more "dream-like" and more symbolic than any other kind of daydream (61). This again illustrates that the content of dreams may be different to waking thought, but, as above, the cognitions about that content may be more similar.

An interesting caveat to the generalization about dreams versus daydreams comes from Kunzendorf et al. (59) who found that participants with "thin boundaries," i.e., people who blur the lines between various aspects of life (including waking and dreaming) more than those with "thick boundaries" who see things in more clear-cut, black-and-white terms, had daydreams that were equally as bizarre as nocturnal dreams, reinforcing the idea that there may exist strong individual differences between people who experience continuity and those who do not. The assumptions within this paper on the whole refer to patterns of general cognitive activity irrespective of any such trait effects. However, both the fields of dream science and psychopathology indicate that there exist differences between individuals in the extent to which they may experience continuity or not. For instance, some individuals are more susceptible to nightmares than others, which often feature more episodic incorporations of waking-life episodes (57). Furthermore and not unrelatedly, some individuals are more vulnerable to experiencing dissociation than others. This raises questions concerning the extent to which continuity and discontinuity may be "normal" in terms of being psychologically healthy. As stated earlier, continuity may reflect maladaptive processing. However, severe discontinuity, as in the case of experiencing dissociation, reflects a disorganized and interrupted sense of reality and as such is clearly maladaptive also. Thus, part of the role of characterizing the extent and frequency of experiencing discontinuity should help to address the issue of, "*how much discontinuity is normal*?"

A POSSIBLE FUNCTION OF DISCONTINUITY?

If discontinuity is the norm, rather than indicating a disordered system as previous literature has implied, it may have a function. A number of theories of dreaming and of consciousness have attempted to account for discontinuity in the past, and a brief review of these will follow.

Hobson et al.'s (13) AIM model of dreaming focuses on dreaming occurring during REM, which has not been empirically supported as dreams can be sampled easily from non-REM sleep and REM does not always lead to dream recall. Nevertheless, the model proposes that with correct activation and cognitive input, dreaming will result. A dream report is deemed to be the result of a "synthesis" of activations, which taken together are neither meaningful nor functional. As such according to this model, discontinuity is the norm during REM sleep and is taken to reflect the lack of order and purpose of the epiphenomena of dreams.

Somewhat relatedly, models, such as Schredl's (1, 62), attempt to characterize the likelihood of recalling dreams and even dreaming of specific material. However, unexplained variance remains so high (91.6%) that these models have many more factors yet to uncover in the pursuit of understanding the nature of dreaming. The as yet unexplained variance may reflect discontinuity, which is difficult to conceptualize let alone predict using existing methods and the continuity hypothesis as a theoretical underpinning (1), though of course this does not imply necessarily that such discontinuity is unimportant. Rather just that dream scientists have much work to do!

An alternative set of views concerns the style of cognitive processing that seems typical of REM, or late-night, sleep. As Hartmann (21) suggested, but did not test empirically, REM sleep cognition may be *hyperassociative*, in that the links from one activated thought to another are more tenuous than in waking. Indeed, this is one way of thinking about discontinuity as illogical or surprising links from one processing sequence to another. In cognitive psychology, this would represent a weak semantic association rather than a strong one, with the latter typically reflecting focused thought and goal-oriented processing. Hartmann, however, did not speculate as to what the function of such hyperassociativity may have been, although he was a psychoanalyst and so believed that dreams had a language that could be uncovered therapeutically. Implicit in that view was the notion that manifest dream content was merely only part of a dream's make-up, meaning that some degree of interpretation was required on Hartmann's part. Such a view is largely at odds with more contemporary approaches to dream science, in which memory sources of dreams are deemed to reflect more explicitly the activation of waking-life experiences that may be processed during sleep, perhaps as part of a memory consolidation process (2–4).

An alternative body of work from both the sleep and dreaming fields explore the creativity associated with REM sleep (in particular). The hyperassociative processing style, or "loose" connections in Hartmann (21) terms, provide a mental space for creativity and novel solutions to become conscious. A great deal of evidence shows the relationships between REM sleep and creativity [e.g., Ref. (63)]. However, evidence also demonstrates the relationships between creativity and dissociation, with the latter in part being increased with sleep disturbances, as we have already seen (64), reinforcing the complex relationships between psychopathology and creativity.

Nevertheless the relationship between REM sleep and novel ideas has been shown in a number of empirical investigations exploring not only creativity but also problem solving and insight. Thus there seems to be something about the activity in REM sleep, or at least following several iterations of preceding non-REM sleep cycles, that promotes the formation of new concepts and ideas. Merely re-activating previous experiences episodically, i.e., continuity, would not logically facilitate such novelty. Rather, then discontinuity may involve the reactivation of some elements of previous experiences, but perhaps in parallel with additional experiences or in quick succession to dissimilar, or weakly associated, experiences—we do not yet know whether such hypothesized hyperassociativity operates in parallel or sequentially. We may assume that discontinuity involves the activation of memory fragments taken from a number of memory sources that are bound together into a conscious uniform experience, as dream images seem to comprise such condensed imagery (4, 65). If this is the case discontinuity, comprising hyperassociative processing, could be evidenced by the analysis of the memory sources of dreams. For example, one dream image featuring several identified memory sources, such as a character that we recognize from recent waking life, a familiar place in which the dream is set, the content of a conversation in the dream, as well as additional specific features, such as objects, people, or activities, can each be rated in terms of the dreamer's familiarity with them, their age or time since being experienced (if at all), as well as more general features such as counting the number of memory sources in dream images across the night or sampled from different stages of sleep. Llewellyn (65) illustrates this in detail with her "quicksand dream," showcasing how various different elements of waking life had been recombined and synthesized into a single, composite dream event. Llewellyn postulated that this process in dreaming operates to create episodic "landmark junctions" at a neural level. However, such discontinuity could have many purposes, not least to decontextualize each of the composite memory sources, rendering each individual contribution memorable in its own right. Such studies of discontinuity could inform much about the activation of autobiographical experiences across different states of consciousness.

To this end, discontinuity seems to allow novel insights and creative possibilities. However, very few individuals wake from a dream experiencing a sudden moment of clarity or enhanced understanding into a problem. As such, we cannot assume that discontinuity functions to make revelations conscious. Rather, discontinuity in sleep, and likely in wake also though perhaps to a lesser extent, may reflect offline processing that maintains the organization and consolidation of experiences within a neurocognitive system that is constantly being updated. During wake the human brain perceives a great wealth of novel information that requires processing and integration with existing structures. Much of this information will be superfluous to requirements and processing will cease very shortly after sensation. However, some will be salient enough to require consolidation into long-term memory networks, to be accessible for future use and to require prior knowledge to be updated. Such consolidation and re-consolidation likely occur constantly, though sleep seems to be the time when much of this consolidation occurs (66–70). Furthermore, sleep appears to afford opportunities for the reorganization of memory networks (22, 65, 71, 72) and thus the integration of newer experiences into pre-existing cortical structures (70, 73–75).

In order to evidence the idea that discontinuity engenders consolidation and integration of novel experiences with more established memory networks, we should be able to identify a change in the organization and representation of memory sources over time, as they become increasingly integrated. This should be mapped on to changes in the continuity, or order, of the conscious manifestation of that experience. A handful of dream studies have been able to map the activation of a specific memory source over time, although unfortunately these studies are varied in their methodological approach. Some short-term approaches have looked at the organization of memory representations across the night, with early-night sleep being rich in non-REM, slow-wave sleep, and later night sleep being richer in REM (7). More recently, we (19) have also demonstrated changes in the continuity of memory representations across the night, with dreams being sampled from later night sleep being more bizarre yet more integrated with older memory sources. Thus, to evidence a change in the organization and representation of a memory over time we may expect to see a memory source, appearing in a dream in a decreasingly literal manner as it is consolidated. Some postulate that the representation may become increasingly metaphorical (10), although this is difficult to evidence empirically. Hopefully in the future sleep study technology will afford the more accurate monitoring of this with neural mapping of the activation of the original memory engram along with a representation of the extent to which it has been integrated into long-term cortical structures. At present, we can rely on subjective dream reports and an analysis of their memory sources.

Long-term approaches have typically explored emotionally charged experiences being incorporated into dreams and have documented corresponding changes in the characteristics of those emotional memory representations over time [e.g., Ref. (62, 66, 76)]. Convincing evidence of relations between emotional waking-life experiences and dreams comes from studies with victims of trauma [for reviews, see Ref. (10, 77)]. For example, individuals with direct military experience of war have direct, unambiguous, and sometimes apparently veridical dream incorporations of their experiences; civilians, on the other hand, have "indirect" or "symbolic" incorporations (78). Thus, it may be that the more traumatic the experience, the more direct the incorporation of the experience into dreaming, as is also the case with posttraumatic stress disorder symptomatology. Cartwright (76) also reports of her studies with divorcees, who dreamed of their divorce process over time, and the shift from dream reports being more accurately reflective of current concerns and experiences, to being more symbolically represented as the divorce process was appraised and comes to terms with by the dreamer.

Indeed, these emotional experiences may be particularly pertinent. Several theories of sleep-dependent memory processing emphasize the role of emotion, either in identifying a particular aspect of a memory to be processed (79) or in signaling heightened activity during the consolidation process in sleep (80). Stickgold and Walker (42) presented a "triage" model of sleep-dependent memory consolidation, whereby salient aspects of an experience are tagged as requiring processing during sleep. Emotional intensity likely acts as this triage indicator. Concurrently, a growing number of studies now indicate that emotional waking-life experiences are more likely to feature in dreams compared to neutral experiences (9, 19, 55, 62, 81).

The consequence here is that experiences that have been well integrated into a memory network and that have been processed emotionally, would not manifest in dreams in a manner that largely reflects their original experience in waking life. In this way, the more discontinuous the representation of the experience, the more integrated and perhaps the more accepted (emotionally) it has become. Thus discontinuity can reflect a healthy cognitive system, rather than being a sign of psychopathology, as has been implied in previous accounts of consciousness. This may appear counterintuitive but suggests that discontinuity is a functional end-point of a cognitive process of integration and consolidation.

THE CHARACTERISTICS OF MEMORY EXPERIENCE ACROSS SLEEP AND WAKE

Horton and Malinowski (4) proposed a model of AM consolidation in sleep, whereby memories for waking experiences can appear in dreams in largely fragmentary forms and as such differ from conventional manifestations of episodic memory. AMs in dreams can be sampled from non-REM as well as REM periods, which contain fewer episodic references and become more bizarre across the night (41, 82). Salient fragmented memory features are activated in sleep and rebound with fragments not necessarily emerging from the same memory, thus de-contextualizing those memories and manifesting as experiences that differ from waking conceptions. The constructive nature of autobiographical recall further encourages synthesis of these hyperassociated images into an episode *via* recalling and reporting dreams. This model of sleep-dependent memory consolidation accounts for the discontinuity within REM sleep mentation, and perhaps in elements of non-REM sleep reports and in aspects of waking also, as the fragmentary activation of specific memories being coupled with other memory fragments, giving rise to a new image, illustrates discontinuity clearly. Here, we can synthesize the characteristics of discontinuity with the activation of fragments of memory sources in sleep.

In sum the discontinuities of cognition in dreams have been recognized as being both typical of normal sleep mentation behavior, and possibly indicative of problematic dissociative symptoms, such as schizophrenia [e.g., Ref. (16)]. In this paper, I summarized the elements of continuous and discontinuous processing across sleep and wake, recognizing that discontinuities in form, of cognition and of consciousness are typical and indeed functional of waking processing as well as in dreams (i.e., sleeping processing).

The behavioral outcome, i.e., what is consolidated and/or consciously experienced is, more often than not, unclear upon awakening and usually later following dreaming. As the dream memory fades so quickly and it is only in the case of the few avid dreamers who may engage in consideration of their dream experiences that they claim to have an understanding of what their dream "meant" or represented, we cannot assume that a clear purpose of dreaming is to have conscious clarity or insight following the dream experience. The discontinuity of a dream and the associated feelings of bizarreness may contribute to this perception that dreams are perhaps not there to be understood as such. Nevertheless, discontinuity within and across dreaming and waking may still be functional if the activated memory fragments in sleep, manifesting in dream reports, remain accessible over and above other, non-incorporated memories at a later date.

CONCLUSION

Discontinuity as we have conceptualized it here is the fragmentation of experiences as we tend to perceive them in the present. That may refer to dreaming of an event from waking life in a very different way to the original experience, or it may refer to simply recalling an experience in a different way to its original occurrence. Thus, discontinuity could refer to the change of a memory representation over time, whether that be in a dream or when recalled at a later time in waking.

In this paper, I have argued that discontinuity is typical of both waking as well as sleeping cognition as in waking it is a normal characteristic of autobiographical remembering. During sleep, as evidenced from dream reports from across the night, experiences from our waking lives are particularly discontinuous as specific constituent features of autobiographical experiences are selected for processing. However, under the backdrop of continuous consciousness, whereby the stream of thoughts, images, and cognitions are sewn together into a coherent narrative, individual memory fragments are bound together to create a new "episode," which is certainly discontinuous from waking life as it may be implausible, incongruous or impossible (e.g., dreaming of talking to someone who has recently passed away).

The consequence of this is that the dream product may provide insight via consideration of novel experiences, but may not have been composed in a deliberately metaphorical or symbolic manner.

This leads us to present some testable hypotheses for future work in this field, linking sleep-dependent memory consolidation, the characteristics of dreams (of prior waking experiences) and the recallability of AMs over time. Experiences from waking life (AMs) that have been dreamed about in a discontinuous manner would likely be less emotionally intense than those that are continuous. Also the memory fragments that were rebound with another memory (source) during dreaming should lead to enhanced recallability of both the original source of the memory fragment as well as the memory source that appeared in the dream, relative to memories and fragments that had not been dreamed about, due to all these aspects having been activated during sleep. A recent study (83), documented the incorporation of recent autobiographical experiences into dreams that had been documented in a 14-day diary. Memory for those original experiences was tested *via* recall and recognition. Those experiences that had been incorporated into dreams were better recalled and recognized later. While this may seem unsurprising as the act of reporting a dream could be seen to rehearse those original experiences, the representation of the experience in the dream was often far different to the original episode. This provides a starting framework for exploring links between (dis)continuity and memory consolidation of declarative experiences.

These predictions present exciting opportunities for the collaboration of dream and sleep scientists with memory consolidation scholars, to explore the nature of sleeping mentation as a reflection of the cognitive processes of memory reorganization over time. They also should not detract from the contributions and efforts of continuity theorists, who may, in part, aim to predict dream behaviors given certain parameters. Rather, discontinuity needs to be characterized in relation to continuity to help us to appreciate further the wonderful changing state of consciousness, what it might tell us about the activation of memories during sleep; something that neuroimaging methods are not yet able to do in a detailed manner.

Furthermore, scholars should continue attempting to identify whether patterns of discontinuity and continuity are consistent or varied across individuals. For instance, some existing work has identified benefits of a labile sleep–wake pattern in terms of the number of cycles through sleep stages upon knowledge awareness tasks (84, 85) and recent work has identified that lucid dreaming training benefits performance in field independence tasks (86). As such identifying patterns of cognitive functioning and discontinuity of consciousness that seem optimal for both mental health and memory consolidation could pave the way for similar training or intervention studies, if patterns of discontinuity may be changeable across individuals.

AUTHOR CONTRIBUTIONS

As sole author CH prepared the manuscript and ideas therein in full.

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Sex-Related Differences in the Effects of Sleep Habits on Verbal and Visuospatial Working Memory

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Poor sleep quality negatively affects memory performance, and working memory in particular. We investigated sleep habits related to sleep quality including sleep duration, daytime nap duration, nap frequency, and dream content recall frequency (DCRF). Declarative working memory can be subdivided into verbal working memory (VWM) and visuospatial working memory (VSWM). We hypothesized that sleep habits would have different effects on VWM and VSWM. To our knowledge, our study is the first to investigate differences between VWM and VSWM related to daytime nap duration, nap frequency, and DCRF. Furthermore, we tested the hypothesis that the effects of duration and frequency of daytime naps and DCRF on VWM and VSWM differed according to sex. We assessed 779 healthy right-handed individuals (434 males and 345 females; mean age: 20.7 ± 1.8 years) using a digit span forward and backward VWM task, a forward and backward VSWM task, and sleep habits scales. A correlation analysis was used to test the relationships between VWM capacity (VWMC) and VSWM capacity (VSWMC) scores and sleep duration, nap duration, nap frequency, and DCRF. Furthermore, multiple regression analyses were conducted to identify factors associated with VWMC and VSWMC scores and to identify sex-related differences. We found significant positive correlations between VSWMC and nap duration and DCRF, and between VWMC and sleep duration in all subjects. Furthermore, we found that working memory capacity (WMC) was positively correlated with nap duration in males and with sleep duration in females, and DCRF was positively correlated with VSWMC in females.

Our finding of sex-related differences in the effects of sleep habits on WMC has not been reported previously. The associations between WMC and sleep habits differed according to sex because of differences in the underlying neural correlates of VWM and VSWM, and effectiveness of the sleep habits in males and females.

Keywords: dream content remembering frequency (DCRF), nap duration, sleep duration, verbal working memory capacity (VWMC), visuospatial working memory capacity (VSWMC)

INTRODUCTION

Poor sleep quality has a negative affect on memory performance, particularly working memory (Valdez et al., 2008). Considerable evidence suggests that sleep habits, such as sleep duration, daytime nap duration, nap frequency, and dream content recall, are related to the quality of sleep. Less than 7 h per night affects cognitive function (Banks and Dinges, 2007) and working memory (del Angel et al., 2015). Daytime naps increase alertness and cognitive performance (Milner and Cote, 2009) and, thus, improve learning and memory. Importantly, the benefits of a brief (5–15 min) nap are almost immediate but short lasting (1–3 h), and although longer naps (>30 min) may produce a short period of sleep inertia, cognitive performance is improved for several hours after waking (Lovato and Lack, 2010). Habitual napping improves alertness (Milner and Cote, 2009). Thus, the duration and frequency of daytime naps have an impact on memory performance. Furthermore, because one can memorize the contents of dreams, the act of recalling a dream must involve memory operations. Specifically, the recall of dream content may involve two steps: recalling the dream experiences and considering the dream content by associating it with personal memories (Nielsen and Stenstrom, 2005). The most important variable related to dream recall may be individual differences in memory ability (Cory and Ormiston, 1975). Dream content recall may be enhanced by increasing the capacity of short-term memory and imaginal life (Martinetti, 1985). Moreover, high dream content recall frequency (DCRF) is associated with higher visuospatial IQ (Butler and Watson, 1985) and absorption in imagery, according to the results of a subjective questionnaire (Schredl et al., 1997). However, several studies have been unable to replicate these findings or have reported contradictory results (Dumel et al., 2015).

Declarative working memory can be subdivided into verbal (VWM) and visuospatial (VSWM) working memory. VWM is used for speech, reading, and writing, whereas VSWM is used for spatial processing, drawing, and mathematics (Valdez et al., 2008). It is likely that sleep habits affect VWM and VSWM differently because their neural correlates differ considerably. VWM is lateralized in the left hemisphere, most notably in the frontal and parietal lobes, whereas VSWM is lateralized in the right hemisphere, particularly in the frontal and temporal cortices (Nagel et al., 2013). A reduction in daily sleep duration has been shown to decrease accuracy in VWM (Jiang et al., 2011) and VSWM (Kuriyama et al., 2008) tasks in healthy young adults. Moreover, a previous study in healthy young subjects found that VSWM function was better in subjects who had a nap than in those who did not (Lau et al., 2015). Based on these findings, we hypothesized that the duration and frequency of daytime naps and DCRF would have different effects on VWM and VSWM. To our knowledge, no previous study has investigated the effects of nap duration and frequency and DCRF on VWM and VSWM simultaneously. Thus, we investigated the relationships between daily sleep habits and working memory.

A previous review of studies investigating sex differences in working memory found that males performed better than females on tasks that required transformations in VSWM, whereas females performed better on tasks that used phonological and semantic information (Halpern, 1997). Furthermore, a study in university undergraduates found that males performed better than females on a high cognitive load spatial working memory task (Lejbak et al., 2011). Based on these findings, we further hypothesized that the associations between VWM and VSWM and sleep habits would differ according to sex. Thus, we investigated the associations among working memory and sleep habits according to sex.

MATERIALS AND METHODS

Subjects

Our study included 779 (434 males and 345 females; mean age, 20.7 ± 1.8 years) healthy right-handed individuals with normal vision who were part of an ongoing project investigating associations between brain imaging, cognitive function, aging, genetics, and daily habits (Takeuchi et al., 2010, 2011a). Our findings will be made available to researchers investigating other psychological and behavioral phenomena, such as chronic fatigue and fatigability. All subjects were university, college, or postgraduate students who had graduated from their respective institutions within 1 year of the initiation of our experiment. Japanese schools typically provide annual health checkups. The medical checkup for first-year students is performed in early April, before classes start. The screening items gather general information and include height and weight measurements, a blood/urine test, and a chest X-ray[1]. After participants have completed the health examination, the Health Administration Center is available to help with retesting, explaining the results, providing health-related guidance and hospital referrals, and so on. As described previously (Takeuchi et al., 2015b), we also distributed self-report questionnaires to potential subjects to assess their history of psychiatric and physical illness as well as their recent drug use. The questionnaires required subjects to provide a detailed list of any recent drugs used. The assessments performed during and after recruitment were

[1] http://www.health.ihe.tohoku.ac.jp/eng_front/medical_checkup/

voluntary and self-reported. As we described in our previous study (Takeuchi et al., 2015a), we did not control the menstrual cycle of the female participants. Thus, the associations reported by the female participants in this study represent the average of the associations experienced across the various stages of the menstrual cycle. During the recruitment procedure, the exclusion criteria, including a restriction on individuals with physical or mental health conditions, were explained to all subjects. Potential subjects were reminded of the exclusion criteria after the preliminary contact to prevent individuals who should have been excluded from the study from arriving at the laboratory to participate. Subjects who met the exclusion criteria and arrived to participate in the experiment were asked to return home. Accordingly, none of the subjects included in our study had a history of neurological or psychiatric illnesses. As we described in our previous study (Takeuchi et al., 2015a), subjects were instructed to get sufficient sleep, maintain their physical condition, eat an adequate breakfast, and consume their normal amounts of caffeinated food and drink on the day of cognitive testing. Additionally, subjects were instructed to avoid alcohol the night before the assessment.

Written informed consent was obtained from each subject prior to participation in the study in accordance with the Declaration of Helsinki (1991), and the study protocol was approved by the Ethics Committee of Tohoku University.

Psychological Outcome Measures

Assessment of VWM Capacity (VWMC)

Computerized forward and backward digit span tests were used to assess VWM capacity (VWMC). These tests were used to adjust for the effect of individual psychometric measures of VWMC on brain activities during VWM processes. Subjects were asked to view a progressively increasing number of random digits, starting at two digits, visually presented at a rate of one digit/s on a computer screen. They were then asked to repeat the sequence by pressing numbered buttons on the screen in the order presented (digit span forward) or in the reverse order (digit span backward). Three sequences were presented at each level until the participants responded incorrectly to all three sequences, at which point the task was ended. The score of each test was the sum of the number of digits correctly repeated in the digit span forward and backward tasks (Takeuchi et al., 2011a).

Assessment of VSWM Capacity (VSWMC)

In the VSWM task, circles were presented one by one at a rate of one/s in a four-by-four grid-like interface. Participants were required to remember the location and order of the stimuli. After the stimuli were presented, participants were instructed to indicate the location and order presented (forward VSWM task) or reverse order (backward VSWM task) of the stimuli by clicking the grid-like interface on a computer screen using a mouse. The number of items to be remembered started with two items and progressively increased. Three sequences were presented at each level until the participants responded incorrectly to all three sequences, at which point the task was ended. The score of each test was the sum of the number of items correctly repeated in the forward and backward VSWM tasks (Takeuchi et al., 2011b).

Assessment of Sleep Habits

We used the Japanese version of the Sleep Habits Scale developed at the Tokyo Metropolitan Institute of Medical Science (Ishihara et al., 1986). The questionnaire is a widely used self-report measure of individual sleep habits. The responses are compiled into a single score, in which higher scores indicate longer duration and greater frequency of the respective measures. Both the original and Japanese versions of the Sleep Habits Scale have high reliability (Ishihara et al., 1986; Anderson et al., 1991). We assessed daily sleep and nap duration, nap frequency, and DCRF. Daily sleep duration was assessed using a 15-point scale ranging from <4 h (1) to >10 h (15) in 30 min increments. Daily nap duration was assessed using a four-point rating scale (1. ≤ 15 min, 2. $>15 \leq 30$ min, 3. $>30 \leq 60$ min, 4. >60 min), and nap frequency was measured using a four-point rating scale (1. seldom, 2. sometimes, 3. often, 4. habitual). DCRF was assessed using a six-point rating scale (1. seldom, 2. rarely, 3. a few, 4. sometimes, 5. often, 6. always).

Behavioral Data Analyses

All statistical tests were conducted using the IBM Statistical Package for the Social Sciences 22.0 (SPSS, IBM Corp., Armonk, NY, USA). Sex-related differences in age, VWMC and VSWMC scores, and sleep habits were tested using Mann–Whitney U tests with a Bonferroni correction ($P < 0.05/7 = 0.0071$) for multiple comparisons to determine statistical significance. Spearman correlation coefficients were used to test relationships between VWMC and VSWMC scores and sleep habits. P-values <0.0071 (0.05/7, two-tailed corrected using the Bonferroni method) were deemed to indicate statistical significance.

To identify the factors associated with VWMC and VSWMC scores, we conducted a stepwise regression analysis using VWMC and VSWMC scores as dependent variables and age, sex, sleep duration, nap duration, nap frequency, and DCRF as independent variables. P-values <0.05 (two-sided probability) were deemed to indicate statistical significance. Furthermore, we performed separate step-wise regression analyses in males and females, using the same method, to investigate sex-related differences in VWMC and VSWMC using VWMC and VSWMC scores as dependent variables and age, sleep duration, nap duration, nap frequency, and DCRF as independent variables.

Structural equation modeling (SEM) is useful for the assessment of mediation because it offers several alternatives for exploring mediation effects (Preacher and Hayes, 2004). Thus, we used SEM to test our hypothesis that the interactions between VWMC and VSWMC are mediated by individual differences in sleep duration, nap duration, and DCRF. All factors that made significant independent contributions to the VWMC and VSWMC scores were entered into a linear structural equation system using analysis of moment structures (AMOS 18) to explore the interrelationships of working memory capacity (WMC) with sleep duration, nap duration, and DCRF. We constructed a model in which VWMC and VSWMC interactions were mediated by sleep duration, nap duration, and DCRF based on the results of the multiple regression analysis. We also constructed a model in which interactions between VWMC and

VSWMC were mediated by the aforementioned sleep habits, and sex (male and female) was treated as a covariate.

RESULTS

Verbal working memory capacity and VSWMC score distributions according to sex are shown in **Figure 1**. The histograms in **Figure 2** show the distributions of sleep habits in both sexes. The VWMC and VSWMC scores and sleep duration and nap frequency values were significantly greater in males than in females (Mann–Whitney *U* tests with Bonferroni correction, $P < 0.05/7 = 0.0071$; **Table 1**). We found significant positive correlations between VSWMC and VWMC scores and nap duration ($P < 0.05$, two-tailed corrected using the Bonferroni method; **Table 2**).

The VWMC and VSWMC scores were used as dependent variables in a stepwise regression analysis (Entry; $P < 0.05$, Removal; $P < 0.10$) to identify the sleep variables independently associated with WMC (**Table 3**). The regression analysis revealed that nap duration and DCRF were significantly associated with VSWMC in all subjects, whereas sleep duration was significantly associated with VWMC. Nap duration was significantly correlated with VWMC and VSWMC in males, whereas sleep duration was significantly correlated with VWMC and VSWMC in females. Moreover, DCRF was significantly associated with VSWMC in females.

Figure 3A shows the SEM of interactions among VWMC and VSWMC mediated by individual differences in sleep duration, nap duration, and DCRF. The model provided a good fit for the data (goodness of fit index [GFI] = 0.997, adjusted goodness of fit index [AGFI] = 0.984, comparative fit index [CFI] = 0.980, and root mean square error of approximation [RMSEA] = 0.045). **Figure 3B** (male) and **Figure 3C** (female) show the SEMs of interactions between VWMC and VSWMC scores mediated by individual differences in sleep duration, nap duration, and DCRF. The model including sex as a covariate also provided a good fit for the data [GFI = 0.997, AGFI = 0.962, comparative fit index (CFI) = 0.987, and RMSEA = 0.037].

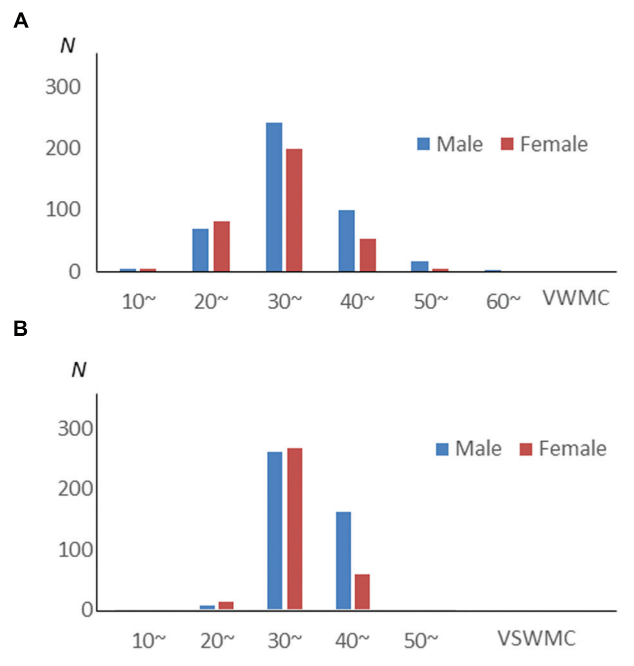

FIGURE 1 | VWMC and VSWMC score distributions according to sex. Histograms showing the distributions of verbal working memory capacity (VWMC, **A**) and visuospatial working memory capacity (VSWMC, **B**) scores for males (Blue bars) and females (Red bars).

DISCUSSION

To our knowledge, our study is the first to investigate associations between WMC (VWMC and VSWMC) and sleep habits according to sex. We found that nap duration was correlated with VSWMC in all subjects, and we identified sex-related differences in the associations among VWMC, VSWMC, and sleep habits (i.e., nap duration in males and sleep duration and DCRF in females). Our finding of sex-related differences in the effect of sleep habits on WMC has not been reported previously.

Our finding that nap duration was significantly related to VWMC and VSWMC in males is in partial agreement with a previous study in which females showed greater improvement than males in declarative memory tasks, regardless of whether they had had a nap (Backhaus and Junghanns, 2006). Moreover, a previous study found that males performed significantly better on a memory consolidation task after a nap, whereas females did so only in the mid-luteal phase of their menstrual cycle (Genzel et al., 2012). These findings may explain the sex-related differences in our study. Furthermore, the accumulated effect of naps may be related to frequency and duration. Thus, the fact that the males in our study napped more frequently than females may account for the effect on WMC. Our finding that DCRF was significantly correlated with VSWMC in females is consistent with a previous meta-analysis, which found that females tended to recall their dreams more often than males (Schredl and Reinhard, 2008).

Our finding that DCRF was associated with VSWMC, but not VWMV, is supported by several lines of evidence. First, dream recall can be enhanced by increasing the capacity of short-term memory (Martinetti, 1985), and higher DCRF is associated with higher visuospatial IQ (Butler and Watson, 1985). Furthermore, DCRF is thought to be associated with VSWMC because the dreamer often portrays wishes, conflicts, or current problems in terms of visuospatial representations (Katz, 2005). Interestingly, the cortical region responsible for visuospatial integration, which includes the inferior parietal cortex, is selectively activated during REM sleep (Hobson, 2004; Pace-Schott, 2011). Thus, DCRF may be associated with improved VSWMC.

Our finding of a significant positive association between nap duration and VSWMC, but not VWMC, in all subjects is in partial agreement with that of a previous study in healthy young subjects showing that naps improved VSWMC (N-back task; Lau et al., 2015). Spatial working memory is

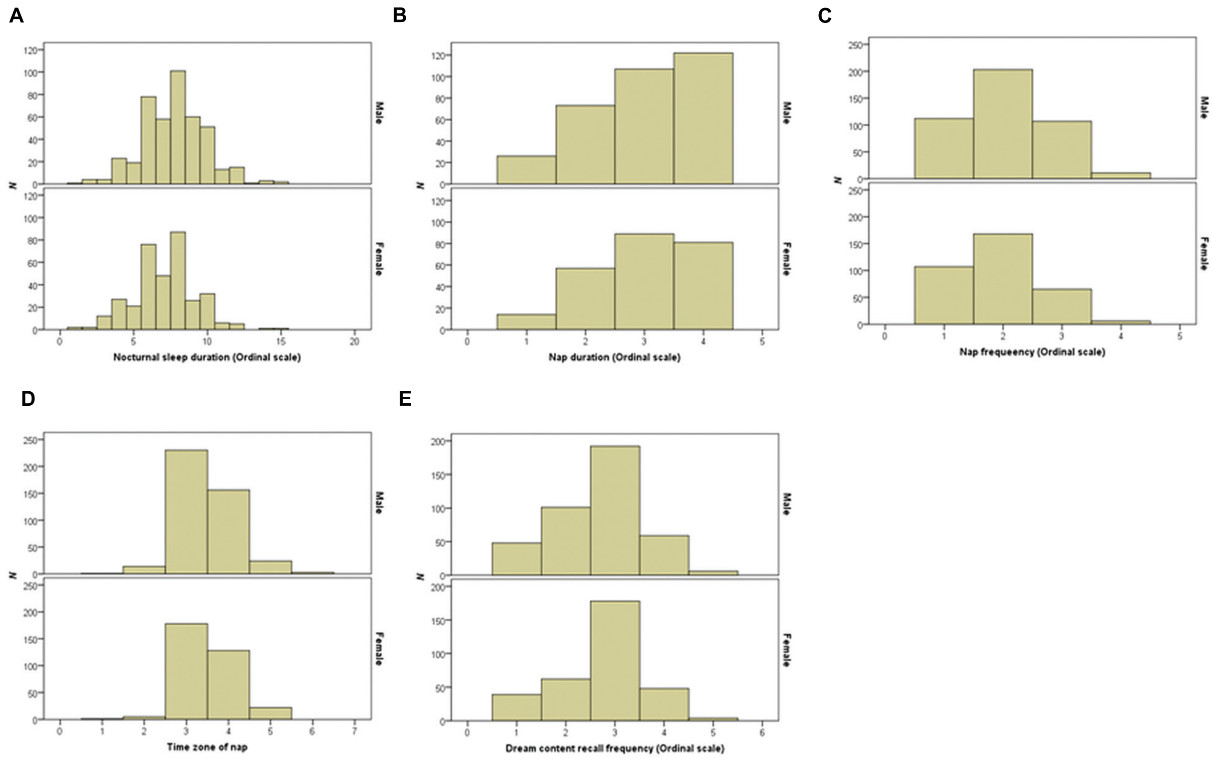

FIGURE 2 | Distributions of nocturnal sleep duration, nap duration, nap frequency, time zone of nap, and dream recall frequency in both sexes. Histograms show the distributions of nocturnal sleep duration **(A)**, nap duration **(B)**, nap frequency **(C)**, time zone of nap **(D)**, and dream recall frequency **(E)** in both sexes.

TABLE 1 | Age, VWMC, and VSWMC scores, and sleep habits according to sex.

	All subjects		Males		Females		*P*-value	*Z*
Variable	**Mean**	***SD***	**Mean**	***SD***	**Mean**	***SD***		
Age	20.7	1.8	20.8	2.0	20.6	1.7	0.42	0.82
VWMC	35.7	7.1	36.7	7.2	34.5	6.8	<0.0001*	3.99
VSWMC	28.3	4.3	29.3	4.1	27.1	4.2	<0.0001*	7.25
Sleep duration	7.5	2.2	7.7	2.2	7.1	2.1	<0.0001*	4.13
Nap duration	3.0	0.9	3.0	1.0	3.0	0.9	0.752	0.32
Nap frequency	2.0	0.8	2.0	0.8	1.9	0.7	0.024	2.26
DCRF	2.7	0.9	2.7	0.9	2.8	0.9	0.283	1.07

**P* < 0.05/7 = 0.0071 (Mann–Whitney U test with Bonferroni correction). DCRF, dream content recall frequency; SD, standard deviation; VWMC, verbal working memory capacity; VSWMC, visuospatial working memory capacity.*

TABLE 2 | Correlations between age, VWMC, and VSWMC scores, and sleep habits.

	Age	VWMC	VSWMC	Sleep duration	Nap duration	Nap frequency
Age	–					
VWMC	0.204	–				
VSWMC	0.007	0.308*	–			
Sleep duration	0.048	0.090	0.089	–		
Nap duration	−0.152*	0.049	0.164*	0.124*	–	
Nap frequency	−0.081	−0.02	−0.031	0.035	0.116*	–
DCRF	−0.018	0.019	0.067	−0.016	0.071	0.066

**P* < 0.05/7 = 0.0071 (Spearman correlation coefficients corrected using the Bonferroni method). DCRF, dream content recall frequency; VWMC, verbal working memory capacity; VSWMC, visuospatial working memory capacity.*

TABLE 3 | Factors associated with VWMC and VSWMC: Multiple stepwise regression analyses in all subjects, males, and females.

Subjects	Dependent variables	Independent variables	*R*	Adjusted R^2	*F*	β
All	VWMC	Sex	0.186	0.031	9.51***	0.144
		Sleep duration				0.103
	VSWMC	Sex	0.315	0.094	19.49***	0.236
		Nap duration				0.162
		DCRF				0.119
Males	VWMC	Nap duration	0.113	0.009	3.90*	0.113
	VSWMC	Nap duration	0.199	0.036	12.55***	0.199
Females	VWMC	Sleep duration	0.205	0.038	9.95**	0.205
	VSWMC	Sleep duration	0.256	0.057	7.91***	0.204
		DCRF				0.184

**P* < 0.05, ***P* < 0.01, ****P* < 0.001. *DCRF, dream content recall frequency; VWMC, verbal working memory capacity; VSWMC, visuospatial working memory capacity.*

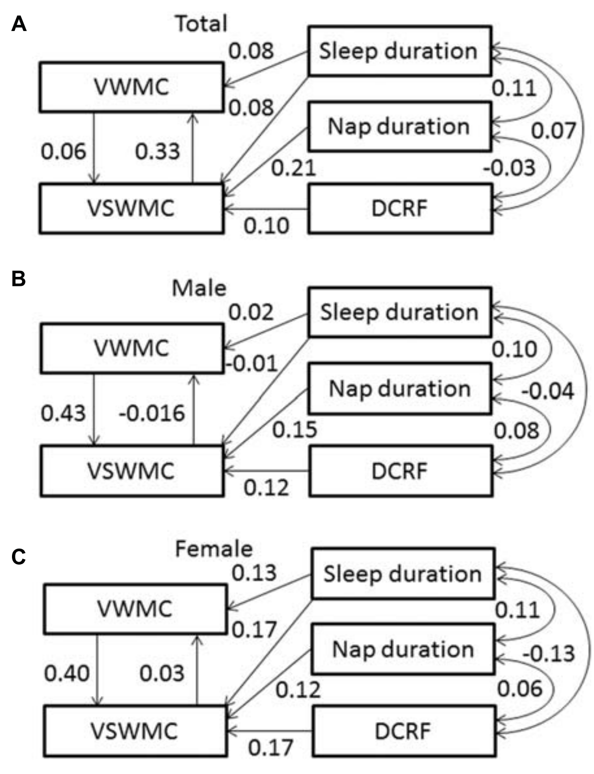

FIGURE 3 | Structural equation model showing associations between VWMC, VSWMC, sleep duration, nap duration, and DCRF in total (A), male (B), and female (C) subjects. Sleep duration increased VWMC and VSWMC, whereas nap duration and DCRF increased only VSWMC. VWMC and VSWMC interact with each other. The one-headed arrows indicate the direction of the observed effect. The numbers on the arrows are standardized regression coefficients. Error components are omitted for simplicity. DCRF, dream content recall frequency; VSWMC, visuospatial working memory capacity; VWMC, verbal working memory capacity.

impaired by acute (Olver et al., 2015) and chronic stress (Conrad, 2010) and the slow-wave sleep achieved during long naps has a stress-reducing effect (Faraut et al., 2013). Furthermore, previous studies have found that subjective feelings of anxiety decreased among participants in a nap group compared with a no-nap group (Takeyama et al., 2005), and that anxiety selectively disrupted the accuracy of spatial but not VWM performance (Shackman et al., 2006). Interestingly, brief meditation training sessions designed to maintain a relaxed state of mind, which is similar to napping, improved visuospatial processing (Zeidan et al., 2010), suggesting that longer naps may improve VSWMC by reducing stress and anxiety. It is important to explain why nap duration is correlated with better working memory function. Given the higher probability of being awakened from slow-wave sleep as nap duration increases, we would expect that the risk of sleep inertia (which transiently impairs working memory functions) would also increase as a function of nap duration (Tassi and Muzet, 2000). However, the duration of sleep inertia rarely exceeds 30 min in the absence of nocturnal sleep deprivation (Tassi and Muzet, 2000). VWM and VSWM were seldom measured during sleep inertia.

It is important to note that, in most time zones, naps occurred from noon to 3 p.m. (value 3, 53.5%) and from 3 p.m. to 6 p.m. (value 4, 37.3%). These data differ from the results of a previous study with university students in Madrid, Spain, which found that most naps (90%) took place later, after lunch or in the early afternoon (Vela-Bueno et al., 2008). This difference might be due to the fact that, unlike the situation in Japan, in the Mediterranean, including Spain, taking an afternoon nap forms part of the culture and is considered to be a healthy habit (Masa et al., 2006).

Our finding that sleep duration was positively correlated with VWMC in all subjects is consistent with those of previous studies showing a positive relationship between working memory and sleep duration (Banks and Dinges, 2007; del Angel et al., 2015). However, this outcome may be restricted to young adults because a systematic review found that self-reported extreme sleep duration was a risk factor for cognitive aging, including WMC in older adults (Lo et al., 2016).

It is important to explain why nap duration and sleep duration were positively correlated. This outcome is consistent with data demonstrating that self-reported long-duration sleepers reported both longer nocturnal sleep and longer naps compared with normal-duration sleepers (Patel et al., 2012). Interestingly, short-duration sleep may be of more concern than long-duration sleep among university students (Steptoe et al., 2006). Accordingly, it is not surprising that longer nocturnal sleep duration was related to longer nap duration in young adults.

Finally, our study has some limitations. We used a cross-sectional design; thus, we were not able to establish causal relationships between the independent variables and WMC. It was not possible to determine the number of potential subjects who were excluded or who dropped out during the various stages of the recruitment process because we did not have access to the informal preliminary contacts and were not privy to the reasons why particular subjects were excluded. Furthermore, our subjects were young, healthy, highly educated university students; thus, our findings may not be generalizable to populations with a different educational background. This limitation is inherent in investigations using a cohort of college students (Song et al., 2008; Jung et al., 2010; Takeuchi et al., 2010). Thus, studies using larger and more representative samples are needed to confirm our results. Despite these limitations, our study furthers understanding of the association between sleep habits and WMC and provides insights for improving working memory by controlling sleep habits in individuals with impaired working memory and learning.

AUTHOR CONTRIBUTIONS

SN, HT, YT, and RK designed the study. SN, HT, RN, AS, YK, CM, KI, RY, TS, YY, SH, TA, KK, and YS collected the data. SN and HT analyzed the data and prepared the manuscript. All authors reviewed the manuscript.

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frontiers in Psychology

METHODS
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Bizarreness and Emotion Identification in Grete Stern Photomontages: Gender and Age Disparities

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Although the International Affective Picture System (IAPS) is used to evaluate emotions (valence, arousal, and dominance evoked by a large set of photographs), bizarre images in works of art have not been assessed with the IAPS procedures. Understood here as strange, non-sense, and absurd mental contents or expressions accompanied by surprise and confusion emotions, bizarreness was assessed after healthy adult volunteers assigned this specified variable to 140 Grete Stern's photomontages overtly intended to illustrate strange, absurd, and non-sensical contents in dream reports. The images were presented to 21 Young Males (YM) and 30 Young Females (YF) who were instructed to use the IAPS Self-Assessment Manikin, along with an additional bizarre-to-normal scale, to evaluate their response to them. The valence and the bizarre-to-normal ratings showed a dissimilar pattern of distribution between genders. Ratings of scales were different, and a greater variation in scales occurred according to gender. When bizarreness was appraised, gender differences became more evident especially for YF, who rated half of the images as bizarre, and with a diminished feeling of control, while the neutral and normal images were deemed more pleased and controlled. Valence, bizarreness, and dominance formed a different component than arousal in both groups. Negative correlations between valence and dominance, and between valence and bizarreness were also found in both groups, plus a positive one for dominance and bizarreness in YF, along with curvilinear relationships among all scales. On a second experiment, 10 photomontages evaluated by YF as *bizarre* or as *normal* were administered to 18 Old Males (OM) and 28 Old Females (OF). OF's arousal showed less neutral evaluations than OM's. In OF the bizarre images evoked either more excitation or calmness than in OM. The distribution of the bizarre-to-normal scale was significantly different across the evaluations in YM, YF, OM, and OF. The use of this extended IAPS instrument to explore bizarreness and emotional variables in response to art images seems suitable and potentially valuable to characterize bizarre, absurd, or non-sensical mental states and their brain correlates.

Keywords: bizarreness, emotion, art, Grete Stern, gender, age

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INTRODUCTION

Mental or expressive "bizarreness" is an important but complex and vague concept, difficult to define and measure. This alleged property of some mental processes and pictorial or verbal expressions has not been clearly identified and characterized (Cermolacce et al., 2010). Recently the term "bizarre delusions" in psychotic disorders has been eliminated in the DSM-V (Tandon et al., 2013; Manual of the American Psychiatric Association, 2014). Nevertheless, since multiple features and expressions, such as incongruities, contradictions, and paradoxes occurring in natural and human domains prevent subjects to engage in credible representations and appropriate actions, the concept of mental bizarreness still constitutes a relevant empirical and theoretical challenge.

Hall and Van de Castle (1966) specified the following words in dream reports to identify mental confusion: surprised, astonished, amazed, awestruck, mystified, puzzled, perplexed, estranged, bewildered, doubtful, conflicted, undecided, and uncertain. Domhoff (2007) define bizarreness as distorted settings, metamorphosed characters, or feelings of confusion and surprise resulting from unexpected events. Cermolacce et al. (2010) identify bizarreness in contrast with congruous ordinary experience as non-sense, incongruity, physical or logical impossibility, implausibility, and incomprehensibility. In a book about non-sense, Cappuccio and Froese (2014) emphasize that the disturbing feeling of the unfamiliar, strange or bizarre usually directs attention and self-monitoring functions toward the generation of action-oriented representations. In a chapter of this book, González (2014) further stipulates that a perceived non-sense defies the agent's rationality to transform the non-sensical into sense-making and meaningful experience.

Following the cognitive/affective conception of bizarreness derived from these approaches and previous evidence in the present investigation we tentatively define mental bizarreness in the following three-fold manner: "(1) perceptions of non-sense, incongruity, distortion and physical or logical impossibility, implausibility or incomprehensibility, (2) involving feelings of confusion, surprise and strangeness, that (3) are identified in contrast with habitual, congruous, logical and meaningful experiences." In the present study we demonstrate that a first-person method extending the IAPS emotion system to evaluate bizarreness in photomontages crafted to depict dream scenes is a valuable tool to compare this otherwise elusive phenomenon between human genders and age groups, and to correlate it to emotional variables such as valence, arousal, and dominance.

Several instruments have been applied to measure incongruous, non-sensical, and bizarre mental states in psychopathology and cognitive psychology. The *Dissociative Experiences Scale* is a self-report assessment that evaluates absorption, depersonalization/de-realization, and amnesia (Bernstein and Putnam, 1986; Van Heugten-van der Kloet et al., 2014). The *Examination of Anomalous Self-Experience* (EASE) is a 57-item semi-structured interview focusing on self-affection, hyper-reflectivity, "disturbed" hold on the world, or confusion with others (Parnas et al., 2005; Sass, 2014; Sass and Byrom, 2015). In the classic Hall and Van de Castle (1966) analysis of dreams, the emotion of confusion is categorized apart from a group of distorted places, characters, creatures, and metamorphoses. Domhoff (2007) considers both of these categories as "bizarre."

Allan Hobson's group has analyzed dream bizarreness as content incongruity, discontinuity, or uncertainty in three cognitive categories: (1) bizarreness of place, plot, object, character, time, and action, (2) bizarreness of thought, and (3) bizarreness of emotion (Williams et al., 1992; Merritt et al., 1994; Scarone et al., 2008; D'Agostino et al., 2010). While incongruity and discontinuity were found to be the most frequent, followed by uncertainty of thought (Williams et al., 1992; Scarone et al., 2008), uncertainty of plot and thought were difficult to distinguish (Williams et al., 1992). In a study of dream contents judged for bizarreness, Revonsuo and Salmivalli (1995) found that dream emotions had a lower rate of incongruity (11.8%) than animate objects (15.1%), persons (15.2%), objects (16.1%), events (23.2%), language (31%), and cognition (34.7%). Compared to similar waking episodes, "bizarre" experiences occurring during Rapid Eye Movement (REM) phases emerge in an involuntary manner, and occur more frequently, in contrast with Non REM dream mentation (Fosse, 2000; Fosse et al., 2001; Corsi-Cabrera et al., 2003). Moreover, scenes and items are not usually perceived as bizarre or non-sensical during the original dream experience, but judged as such during their wakeful recollection and narration (Díaz, 2015).

It has been difficult to distinguish "bizarreness" among dream reports of normal subjects and waking mentation of schizophrenics (Noreika et al., 2010) and major depressives (Cavallotti et al., 2014). "Bizarreness" understood as a wakeful-dreaming pathological state, has been induced by images evoking projective interpretations in order to measure psychotic mentation. Using this approach, Scarone et al. (2008) found that seven Thematic Apperception Test (TAT) pictures elicited a higher percentage of "bizarre" responses in schizophrenic compared to normal subjects. When the habitual knowledge of the world is tested, "bizarre" answers have been more frequently found in frontal-damaged patients vs. patients with lesions of posterior areas (Shallice and Evans, 1978; MacPherson et al., 2014). Bizarreness and emotion have been reported as decreased in patients with basal ganglia bilateral damage (Leu-Semenescu et al., 2013). Cognitive studies have employed deformed images or impossible sentences to originate bizarre feelings and judgments in healthy people. The "bizarreness effect" phenomenon obtained with these techniques refers to the fact that unexpected, distinctive or bizarre items, sentences and images are remembered more easily than common ones (Von Restorff, 1933; Hunt, 2006; Geraci et al., 2013; Gounden and Nicolas, 2015).

We propose now that Grete Stern photomontages inspired in dream reports can be used to specify and measure mental bizarreness. Grete Stern, a German artist, crafted 140 photomontages that were published between 1948 and 1951 in the weekly magazine *Idilio* of Argentina. The magazine requested female readers to submit written accounts of dreams. Salient scenes of the dream reports selected for psychoanalytic interpretation were illustrated by the artist (Stern et al., 2012).

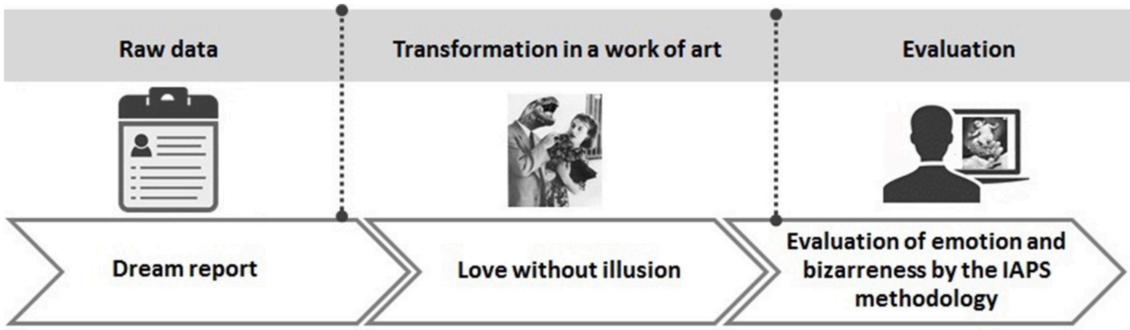

FIGURE 1 | Dream reports were interpreted by trained psychoanalysts and rendered into photomontages by Grete Stern and collaborators. Next, the evaluation of bizarreness and emotions by young students and later by old adults was carried on. Photomontages from Stern et al. (2012) are reproduced with permission.

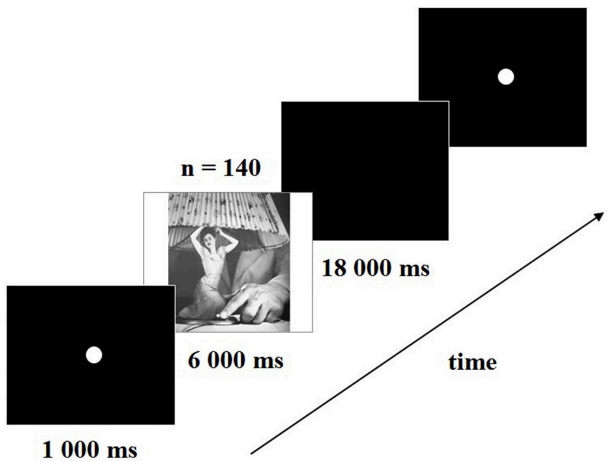

FIGURE 2 | Presentation timing of the task. A Stern photomontage is preceded by a fixation point. After the image, a black screen appears and ratings using the modified Self-Assessment Manikin format are requested.

These photomontages usually depict non-sensical and absurd disproportions, fragmentations, and other logical and/or factual incongruities typical of dreams (Díaz, 2015). In order to evaluate not only emotion, but also bizarreness, in the present study we extend the methods employed by the International Affective Picture System (IAPS, Lang et al., 2005; **Figure 1**). The IAPS has been previously extended to measure compassion in both men and women (Mercadillo et al., 2007) and in the present experiments, one scale was added in which, in accord with the above definition, the IAPS manikin exhibited an expression of strangeness in contrast to a neutral gesture.

With the application of this novel instrument, we explored possible dissimilarities between genders since the frequency of distorted places or metamorphoses found in dream reports is about double in women vs. men (Hall and Van de Castle, 1966; Domhoff, 2007), and gender differences have been found in several emotions evaluated with the IAPS methodology (Bradley et al., 2001; Lang et al., 2005; Mercadillo et al., 2007; Silva, 2011), Moreover, we analyzed bizarreness in young and old people because dreams (Giambra, 1980), daydreaming activity (Grenier et al., 2005; Guénole et al., 2010), and the "bizarreness effect" (Smith, 2006) have been reported to decrease with age. In order to explore the bizarreness evoked by the selected graphic material in young and old men and women, intra and intergroup gender and age differences were studied in terms of frequencies, relationships, comparisons of means, and principal component analysis.

METHODS

Experiment 1

Participants

The images were evaluated by 51 college students (21 Young Males, YM, and 30 Young Females, YF, 21.86 $\pm$ 2.64 years of age with no significant difference between genders) from the Gerontology program of the *Universidad Autónoma del Estado de Hidalgo* in the city of Pachuca, México. The experiment was part of these students' field practices. Students were told that their evaluations of the images had to be immediate, as the instructions of the IAPS demands, so no relation to an age-study bias seemed to occur. A letter of consent was read and signed by all subjects. This research was part of a larger project called "Design of tests to pre-diagnose and diagnose Old Adults of Hidalgo at the bio-psycho-techological areas" and received the approval of the research Ethics committee.

Images and Task

From the original set of Grete Stern's photomontages (Stern et al., 2012), some were substituted by later versions of the artist (i.e., "Love without illusion" an improved version of "Idilio 64"; "Made in England"; or "Paintbrush dreams" instead of "Idilio 101") and others discarded because they were not fully discernable in the computer screen (i.e., "Extrañamiento"). A total of 140 Grete Stern photomontages (see Supplemental Material) were presented on the center of a 64 $\times$ 113 cm computer screen. Following a 1 s fixation point period, each image was presented during 6 s, and evaluated on four scales during an inter-trial black screen of 18 s (**Figure 2**).

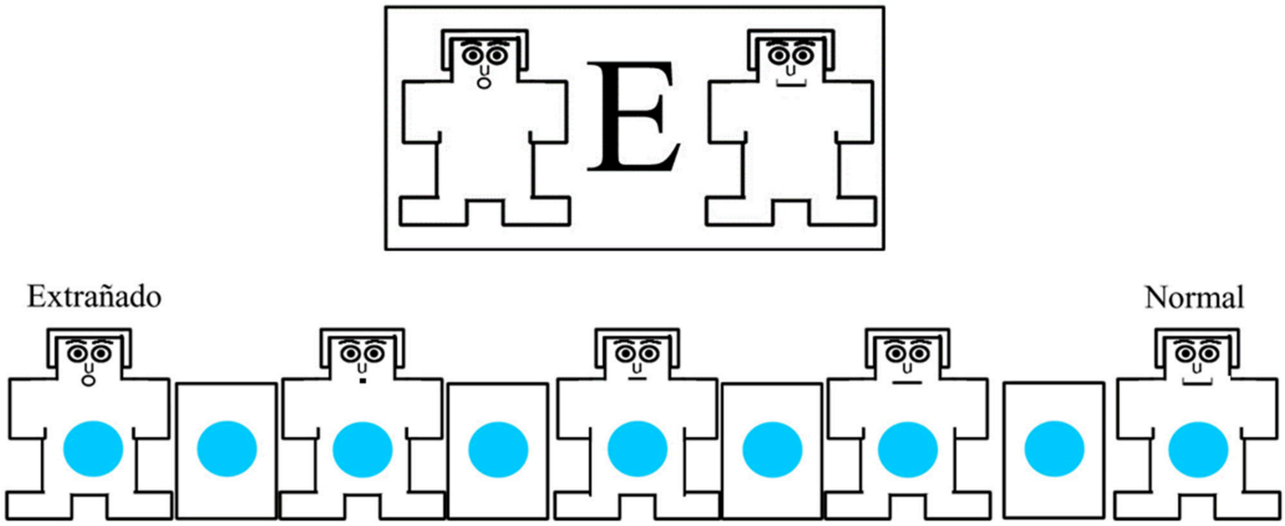

FIGURE 3 | Modified sheet format of the Self-Assessment Manikin of the International Affective Picture System for Young Adults with the additional bizarreness scale. For the 140 Stern photomontages, 10 per sheet were rated for *Valencia* (Valence), *Alertamiento* (Arousal), *Dominancia* (Dominance), and *Extrañeza* (Bizarreness).

TABLE 1 | Mean and standard deviation of age; education MMSE, Mini-Mental State Examination; GDS, Geriatric Depression Scale; SATS, Short Anxiety Screening Test and Katz scale for Old Aged subjects.

	Old males	Old females	*t*	*p*
Age	68.12 (7.45)	68.41 (8.19)	1.35	0.90
Education (years)	7.5 (6.24)	6.7 (5.23)	0.88	0.81
MMSE	26.69 (4.01)	25.41 (3.79)	−0.38	0.35
GDS	5.47 (4.72)	4.83 (3.86)	0.38	0.64
SATS	19.55 (4.01)	20.83 (2.5)	−0.54	0.29
Katz	0.62 (1.66)	0.21 (0.54)	−0.45	0.32

Level of significance set at $p < 0.05$.

Procedure

The traditional IAPS written instructions were administrated along with this phrase (translated from Spanish): "We are interested in how people respond to pictures that represent different events that can or cannot occur in life." Since the IAPS allows for explanations of the instructions to assess emotions, the bizarreness-to-normal category stated: "You will see four sets of five figures, and you will use these figures to rate how you felt while viewing each picture. You will make four ratings for each picture that you observed. The manikins show four different kinds of feelings: Joy vs. Sad, Excited vs. Calm, Controlled vs. In-Control, and *Extrañado* vs. Normal." The latter and added scale was explained in this way:

> "The last of the scales is about the feeling of bizarreness, strangeness or perceiving an absurd (*extrañado, sorprendido o percibiendo algo absurdo*). In such events you will be putting an X on the figure on the left, like this (demonstrate with the manikin). If you felt completely normal, as having a familiar and common experience you will indicate it with an X on the figure on the right (demonstrate with the manikin). Note the figure on the left has a bizarre or surprised expression and that on the extreme right a neutral expression. If you did neither feel "*extrañado*" nor "normal," put an X in the middle figure."

According to the original IAPS system, the subjects had to rate Valence (glad vs. sad), Arousal (excited vs. calmed), Dominance (being dominated vs. dominate) using the usual manikins, plus a rating of Bizarreness with the aid of an additional manikin. The introduced manikin had a round-open mouth to indicate "*extrañado*" (ratings 1, 2, 3, and 4 to indicate bizarreness) and another one with a neutral expression to indicate a usual or "normal" condition (ratings 6, 7, 8, or 9) while 5 meant neither one nor the other (**Figure 3**). A sheet contained the four scales for 10 images. To balance the conditions of valence, arousal, dominance, and the bizarre scales, four orders of the manikins were placed on the format.

Statistical Analysis

Means and standard deviations were obtained for each of the 140 pictures in the scales of valence, arousal, dominance, and bizarre-to-normal. Afterwards, percentages to visualize how the ratings were distributed, and chi-squares to compare frequency of choice between groups were used. To know which relationships were followed by the variables, linear correlations among the possible six combinations of variables from the 140 means across images and curvilinear regressions were tested. Since the data followed a normal distribution and in order to compare the means, ANOVAs with gender and emotional variables as factors were implemented. Tukey *post-hoc* tests for comparisons of means were then used. A PCA was done to reduce the

FIGURE 4 | Stern photomontages evaluated with the extreme values of 3 as "bizarre" or 7 as "normal" by most of the four groups. Of the 10 photomontages rated by young and old subjects, "Idilio 16" was bizarre for young adults. Only "Idilio 20" was bizarre for old and young women. Old male subjects rated neither of them as extremely bizarre or normal. Photomontages from Stern et al. (2012) are reproduced with permission.

number of variables. As the variable of interest, the bizarreness scale was used to discriminate images within each gender using dependent Student *t*-tests and later between gender groups with independent Student *t*-tests.

Experiment 2

Participants

The sample of older people from the city of Pachuca and nearby locations (administrative university workers, grandparents, or

TABLE 2 | Means and standard deviations (in parentheses) of "bizarre" (mean of 2 or 3 in bold) and of "normal" photomontages (mean of 7 in plain text) rated by YM.

Young Males					
Name	**Slide no.**	**Valence**	**Arousal**	**Dominance**	**Bizarreness**
"ATH"	7	3.94 (2.86)	6.75 (2.82)	5.69 (2.15)	7.50 (1.86)
"Idilio 1"	12	3.67 (2.20)	5.95 (2.64)	5.65 (1.84)	**3.86 (2.52)**
"Idilio 8"	18	3.75 (2.62)	6.69 (2.73)	5.27 (2.12)	7.19 (2.37)
"Idilio 16"	26	5.14 (2.50)	6.35 (2.48)	4.75 (2.38)	**3.67 (1.62)**
"Idilio 23"	33	5.00 (3.16)	6.53 (2.10)	5.67 (1.63)	7.13 (2.96)
"Idilio 27"	37	5.95 (2.16)	4.20 (1.85)	5.15 (2.35)	**3.86 (2.39)**
"Idilio 34"	44	5.10 (2.72)	6.38 (2.50)	6.29 (2.92)	7.33 (1.93)
"Idilio 36"	46	3.71 (2.51)	4.86 (2.33)	6.24 (2.21)	**3.90 (2.83)**
"Idilio 46"	55	4.67 (2.48)	4.86 (2.76)	5.24 (2.76)	**3.57 (2.11)**
"Idilio 55"	64	5.80 (2.28)	4.45 (2.24)	5.35 (2.37)	**3.85 (2.74)**
"Idilio 83"	88	6.10 (2.85)	4.37 (2.43)	4.40 (2.91)	**3.65 (2.56)**
"Idilio 121"	123	5.52 (1.12)	5.62 (1.88)	4.19 (1.99)	**3.86 (2.17)**
"Idilio 124"	126	3.43 (1.80)	5.19 (2.80)	5.90 (1.55)	7.24 (2.28)

"ATH", "At this hour."

TABLE 3 | Same as Table 2 rated by YF.

Young Females					
Name	**Slide no.**	**Valence**	**Arousal**	**Dominancee**	**Bizarrenesss**
"LWI"	1	4.43 (1.70)	6.30 (2.39)	4.41 (2.40)	**3.30 (2.74)**
"OTP"	6	5.55 (2.13)	4.43 (2.43)	4.30 (2.42)	**3.27 (2.56)**
"Idilio 3"	14	6.13 (2.26)	4.55 (2.47)	4.69 (2.32)	**3.14 (2.56)**
"Idilio 7"	17	3.41 (2.47)	7.41 (2.35)	6.03 (2.11)	7.13 (2.10)
"Idilio 16"	26	5.24 (2.50)	5.60 (3.11)	4.41 (2.32)	**3.79 (2.48)**
"Idilio 20"	30	5.62 (2.27)	5.03 (2.34)	4.28 (2.49)	**3.66 (2.36)**
"Idilio 25"	35	5.14 (2.26)	4.69 (2.55)	5.66 (2.51)	**3.79 (3.42)**
"Idilio 35"	45	6.23 (2.34)	4.93 (2.26)	3.90 (2.58)	**2.87 (2.87)**
"Idilio 45"	54	5.37 (2.63)	4.93 (2.75)	5.23 (2.22)	**3.67 (3.03)**
"Idilio 46"	55	6.70 (2.37)	4.86 (2.61)	3.97 (2.41)	**3.20 (2.75)**
"Idilio 50"	59	5.83 (2.38)	4.93 (2.38)	4.83 (2.00)	**3.73 (2.49)**
"Idilio 51"	60	7.23 (2.19)	4.50 (2.42)	4.00 (2.60)	**3.53 (2.83)**
"Idilio 55"	64	6.07 (2.02)	4.83 (2.68)	3.77 (2.22)	**3.30 (2.48)**
"Idilio 61"	69	5.07 (2.49)	5.07 (2.49)	3.93 (2.66)	**3.87 (3.15)**
"Idilio 67"	73	6.77 (1.81)	5.20 (2.37)	2.97 (2.11)	**2.90 (2.50)**
"Idilio 68"	74	5.33 (2.35)	6.03 (2.50)	4.30 (2.02)	**3.80 (2.91)**
"Idilio 71"	77	5.73 (2.60)	4.73 (2.50)	5.07 (2.60)	**3.67 (3.03)**
"Idilio 73"	79	3.57 (2.97)	5.20 (3.25)	4.33 (2.01)	7.37 (2.58)
"Idilio 74"	80	5.90 (2.38)	5.23 (2.28)	4.73 (2.16)	**3.67 (3.08)**
"Idilio 84"	89	6.67 (1.97)	5.00 (2.46)	4.17 (2.76)	**3.90 (2.76)**
"Idilio 86"	91	5.03 (1.63)	4.93 (2.30)	5.13 (2.30)	**3.33 (3.07)**
"Idilio 88"	93	7.67 (1.69)	6.33 (2.75)	4.20 (1.86)	**3.13 (2.57)**
"Idilio 89"	94	5.73 (1.70)	4.73 (2.66)	4.70 (2.42)	**3.77 (2.78)**
"Idilio 92"	96	6.30 (2.02)	4.80 (2.75)	3.87 (2.76)	**3.77 (2.92)**
"Idilio 97"	101	2.87 (2.34)	6.87 (2.83)	6.07 (2.33)	7.07 (2.80)
"Idilio 99"	103	4.33 (1.92)	4.93 (2.32)	4.40 (1.98)	**3.87 (3.14)**
"Idilio 100"	104	2.87 (2.52)	5.07 (3.22)	5.37 (1.79)	7.30 (2.51)
"Idilio 105"	108	5.47 (2.15)	5.60 (2.24)	3.73 (2.20)	**3.97 (2.93)**
"Idilio 115"	117	5.63 (2.50)	5.13 (2.67)	4.53 (2.15)	**3.13 (2.67)**
"Idilio 121"	123	5.97 (2.14)	5.30 (2.67)	4.21 (2.13)	**3.07 (2.80)**
"Idilio 124"	126	3.40 (1.71)	5.73 (2.85)	5.87 (2.34)	7.83 (1.70)
"Idilio 128"	130	2.77 (2.25)	5.47 (2.96)	5.83 (1.82)	7.27 (2.39)

"LWI", "Love Without Illusion"; "OTP", "On The Platform."

acquaintances of participant students) was made of 28 Old Females (OF; 68.41 ± 8.19) and 18 Old Males (OM; 68.12 ± 7.45). There were no significant differences between the two groups concerning age, education, or results of the Mini-Mental State Examination (MMSE), Geriatric Depression Scale (GDS), Short Anxiety Screening Test (SATS), or Katz Daily Activities Scale in their Spanish versions (Ugalde, 2010; **Table 1**). Education ranged from 3 analphabet subjects to 15 years of education. Some of the subjects wore glasses or auditory devices.

Images and Task

Black and white Stern photomontages were exhibited on a computer screen. Old Adults (OA) viewed similar manikins as in **Figure 3** with the four scales. In contrast to Young Adults (YA), OA evaluated one image per sheet of paper, but the scales were enlarged in order to facilitate visualization and evaluation. Depending on the individual capacity for execution or proneness to become tired, 10–40 pictures were shown. These were selected from the study with the college students with mean evaluations of 2, 3, or 4 (bizarre) or 6 or 7 (normal). The values for the first 10 images are presented. The photomontages judged as bizarre by YF were "Love without illusion," "On the platform," "Idilio 3," "Idilio 16," "Idilio 20," and "Idilio 25." The "normal" images were "At this hour," "Idilio 8," and "Idilio 23" by the group of YM and "Idilio 7" by YF (**Figure 4**).

Procedure

The instruction manual and the format for evaluating IAPS were used, both modified to include the bizarreness scale. After instructions, each one of the Stern photomontages was presented on the center of the screen, but was not time restricted to avoid visual or speed difficulties. Two different sequences balanced the position to a particular series of images. To diminish possible effects of unfamiliar settings and techniques (Lupien et al., 2007), OA were evaluated at their homes and photomontages were shown on personal computers or laptops.

Statistical Analysis

Since a differential evaluation was observed for each image considering valence, arousal, dominance, and the bizarreness scales, analyses were carried out according to the mean of each of the 10 images for the two groups and each variable and their frequencies were submitted to Pearson's chi-square tests. Later, chi-square tests were used for each scale to compare the distribution of responses along the four groups.

RESULTS

Experiment 1

In **Tables 2, 3**, the mean ratings and standard deviations in YM and YF for "bizarre" and "normal" photomontages are shown. When submitted to chi-square tests, frequencies of valence $\chi^2_{(5)} =$

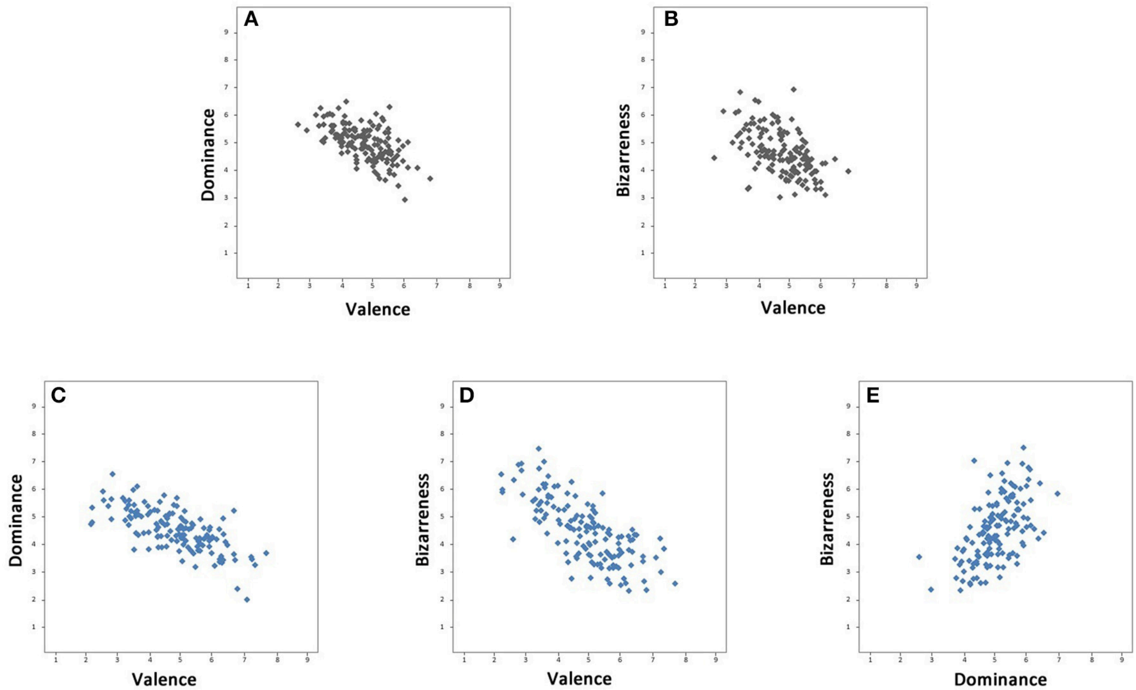

FIGURE 5 | Negative correlations in Young Males are shown in black between (A) valence and dominance and **(B)** valence and bizarreness. The same correlations for Young Females **(C,D)**, and a positive one for dominance and bizarreness **(E)**.

TABLE 4 | Significant quadratic regression analyses for emotion and the bizarreness scale by images in Young Males and Young Females.

	F	df	R^2	p
YOUNG MALES				
V-D	36.25	2, 137	0.35	**<0.001**
V-B	24.51	2, 137	0.26	**<0.001**
A-B	12.94	2, 137	0.15	**<0.001**
D-B	17.19	2, 137	0.20	**<0.001**
YOUNG FEMALES				
V-A	4.33	2, 137	0.07	**<0.001**
V-D	64.73	2, 137	0.48	**<0.001**
V-B	82.79	2, 137	0.54	**<0.001**
A-D	8.74	2, 137	0.11	**<0.001**
A-B	13.82	2, 137	0.16	**<0.001**
D-B	32.05	2, 137	0.31	**<0.001**

Data are based on the mean score for each picture (n = 140).
Valence (V), Arousal (A), Dominance (D), and Bizarre (B) scales. Numbers in bold indicate significant probability levels.

20.94, $p = 0.0003$, and the bizarre to normal scale $\chi^2_{(5)} = 15$, $p = 0.01$, were significant. Stern's images in YF evoked more extreme ratings on the valence and the bizarreness scale than YM. Thus, from the 140 images, YM rated none as extremely bizarre ($M = 2$) and 5.71% as moderately bizarre ($M = 3$), while YF rated 1.4% ($M = 2$) and 18.57% ($M = 3$). YM rated 13.57% as normal ($M = 6$) or moderately normal 1.42% ($M = 7$), while YF evaluated 15 and 4.2% as normal or moderately normal. When the means of 2, 3 and 4 for bizarreness were considered, the result for YM was 45.71%, while for YF was 50%. The figures for normality (6 or 7) were 15% for YM, and 19.28% for YF. "Idilio 16," "Idilio 46," and "Idilio 55" were considered bizarre by both sexes. Only "Idilio 124" showed normal ratings between genders. "Idilio 23," a picture of a woman watching a flying tree from her window, was rated as *normal* by YM. Similarly "Idilio 7," showing a woman playing a piano with typewriter keys was rated as *normal* by YM.

Considering the six combinations of the four variables and the means of subjects for each one of the 140 photomontages, significant negative correlations were found between valence and dominance; and valence and the bizarreness scale for both sexes; for YM [$r_{(138)} = -0.59$, $p < 0.001$; $r_{(138)} = -0.51$, $p < 0.001$, respectively]; for YF [$r_{(138)} = -0.69$, $p < 0.001$; $r_{(138)} = -0.73$, $p < 0.01$, respectively], and YF associated positively dominance and the bizarreness scale, $r_{(138)} = 0.56$, $p < 0.001$. **Figure 5** shows the scatter plots of the significant correlation values for YM and YF.

Quadratic regression analyses resulted in further evidence for associations of valence and dominance, valence and the bizarre scale, arousal and the bizarreness scale and dominance and the bizarreness scale in YM. All variable relationships were significant for YF and are presented in **Table 4**.

A mixed ANOVA (2 × 4) was employed to test the effects of gender, scales, and to compare whether there was an interaction between gender and scales. Although the evaluation of young men and women was not different [$F_{(1, 278)} = 0.67$, $p = 0.58$)], scales [$F_{(3, 834)} = 43.20$, $p < 0.001$)] and their interaction [$F_{(3, 834)}$

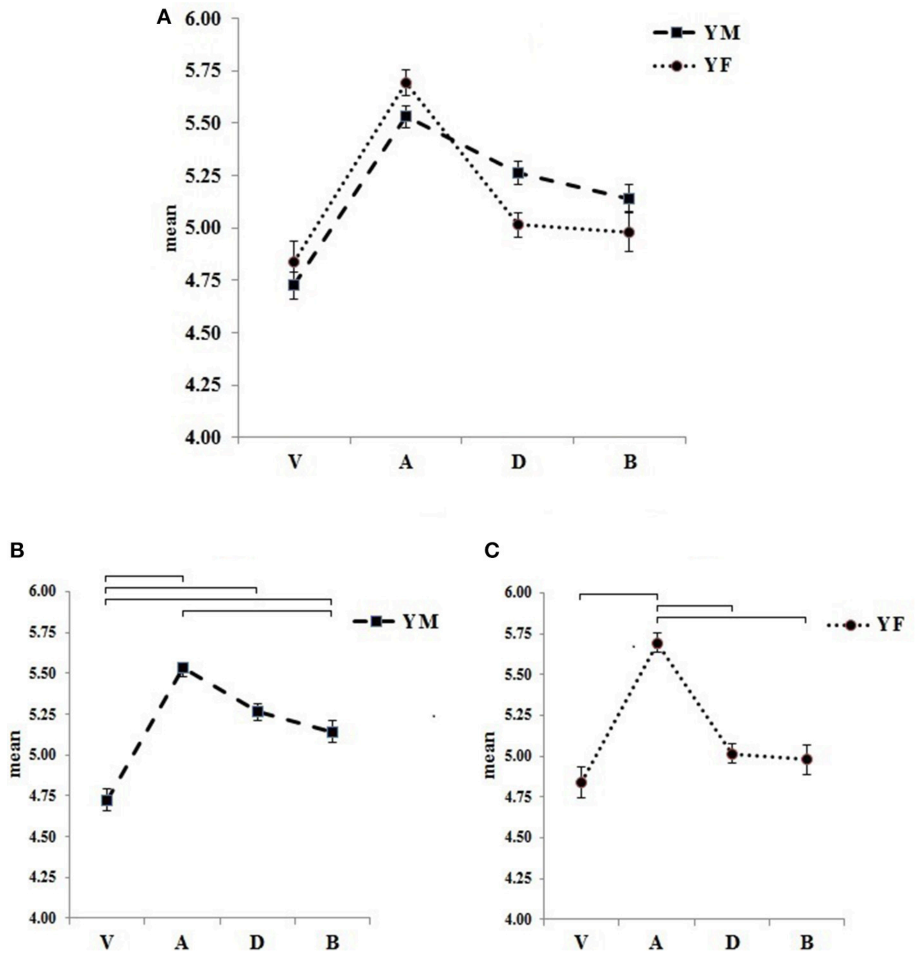

FIGURE 6 | Means and standard errors of the four scales: Valence (V), Arousal (A), Dominance (D), and the Bizarreness scale (B) according to gender for the 140 Stern photomontages. YM (Young Males) and YF (Young Females) demonstrated an interaction between scales and gender **(A)**. In both YM (**B**, left) and YF (**C**, right) V-A and A-B differed. In YM, V-D and V-B; in YF, A-D. Significant results ($p < 0.05$) are indicated in brackets according to Tukey tests.

$= 3.76$, $p < 0.01$] reached the probability threshold. Both sexes showed a peak in arousal at the middle of the scale in the neutral location (YM: $M = 5.53$, $SD = 0.62$; YF: $M = 5.69$, $SD = 0.73$), while valence and the bizarreness scales had the lower values (valence: YM: $M = 4.72$, SD $= 0.77$; YF: $M = 4.84$, $SD = 1.15$; the bizarreness scale: YM: $M = 5.14$, $SD = 0.78$; YF: $M = 4.97$, $SD = 1.08$). Tukey *post-hoc* tests revealed differences within genders, for valence and arousal; and arousal and the bizarreness scale varied significantly. These results confirm there is a specific effect of gender according to the evaluations: both YM and YF considered Stern photomontages to evoke joy, with a trend in YF to rate them as bizarre, while both groups indicated a neutral evaluation of arousal and dominance. Interestingly, arousal and dominance for YM were similar, a result not observed for YF (**Figure 6**).

In order to reduce variables, responses of both genders for the images were subjected to a Principal Component Analysis (PCA). Two components that explained 71.18% of the total variance PCA were identified. The first component explained 53.4% of the variance and was formed by valence, dominance, and the bizarreness scale. The second component explained 17.77% of the variance and was integrated by arousal (**Table 5**). According to the previous results, both genders differed among their variables from the arousal scale.

Furthermore, since the mean values of Stern images at the bizarre scale ranged from 2 to 7, and there was an interaction between gender and scales, pictures were split in two groups considering bizarre images as one group, and normal or neutral as a non-bizarre group of images. **Figure 7A** shows the scatter plots only for bizarre images in YM ($M = 2$, 3, and 4) and for every mean of valence, arousal, dominance, and the bizarreness scale (i.e., 64 bizarre images $\times$ 4 variables in YM $= 256$ means). In **Figure 7C**, the respective YF scatter plot is presented (70 bizarre images $\times$ 4 variables $= 280$ means). Means of 5, 6, and 7 (normality and neutrality; **Figures 7B,D**) for each gender group and each variable (76 normal or neutral images $\times$ 4 $= 304$ means for YM; 70 normal or neutral images $\times$ 4 $= 280$ means for YF) are found.

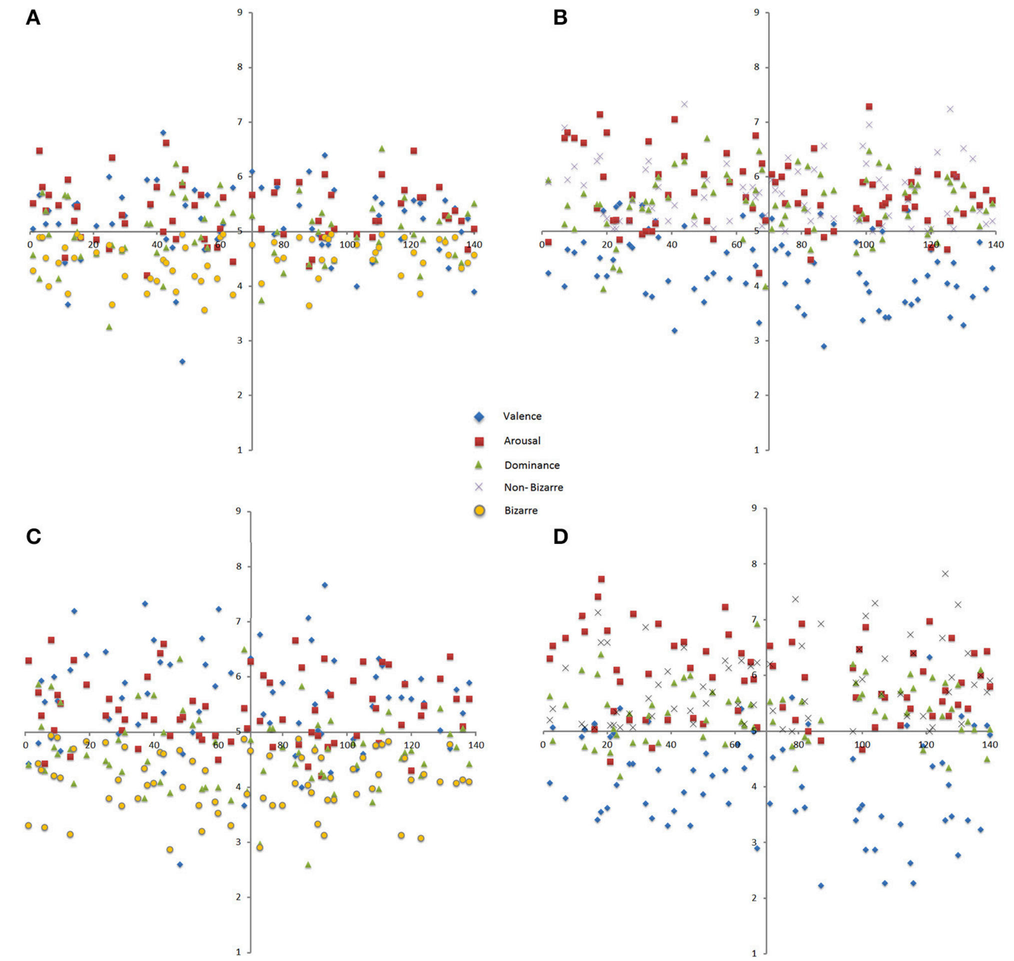

FIGURE 7 | Means of Stern images scatter plots split according to bizarreness (left) and to neutral-to-normal (right) evaluations in Young Males (A,B) and Young Females **(C,D)**.

There were significant differences in Student *t*-tests for every couple of variables according to gender. Valence of the bizarre images, $t_{(132)} = 2.96, p = 0.003$; valence of the normal and neutral images, $t_{(144)} = 2.02, p = 0.04$; arousal of the normal and neutral images, $t_{(144)} = 2.42, p = 0.01$; dominance of the bizarre images, $t_{(132)} = 2.78, p = 0.006$; dominance of the normal and neutral images, $t_{(144)} = 3.83, p < 0.001$; and the bizarreness scale of bizarre images, $t_{(132)} = 4.6, p < 0.001$, with the exception of arousal for the bizarre images [$t_{(132)} = 0.79, p = 0.43$] and the bizarreness scale for the normal and neutral images [$t_{(144)} = 1.49, p = 0.14$]. As previously observed, higher scores for arousal ranging at the neutral score were also visualized, especially for non-bizarre images. As the continuous line shows, neutral and normal images are more happily rated (YM: $M = 4.35, SD = 0.64$; YF: $M = 4.10, SD = 0.88$) than those perceived as bizarre of the dotted lines (YM: $M = 5.17, SD = 0.69$; YF: $M = 5.58, SD = 0.91$), a more evident result for YF. Also, YF are more dominated by bizarre images than YM (YM: $M = 4.98, SD = 0.59$ vs. YF, $M = 4.67, SD = 0.69$). Bizarre images for YM were less bizarre ($M = 4.48, SD = 0.38$) than for YF ($M = 4.10, SD = 0.55$) than non-bizarre ones. Black lines (YM) come closer to the neutral rating of 5 than YF in red lines (**Figure 8**).

Experiment 2

From the Pearson's chi-square tests for the 10 images in the OA groups, arousal was significant ($\chi^2 = 19.95$, $df = 3$, $p < 0.001$). While OM followed a normal distribution, choosing more neutral and calmer evaluations, OF followed an "L"- like distribution. Only "Idilio 3," a woman falling, produced alertness in OM. "Love without illusion," "At this hour," "Idilio 7," "Idilio 8," and "Idilio 23" frequencies evoked greater calmness in OM. Although the bizarre scale was not differently distributed by sexes in old adults, of the 10 photomontages rated by young and old male and female subjects, considering extreme values (2, 3 or 7, 8), "Idilio 16" was bizarre for YA. Only "Idilio 20" was bizarre for OF and YF. OM subjects rated neither of them on the extremes as bizarre or normal, but they rated "Idilio 3" and "Idilio 16" with a mean of 4; and the other seven images with a mean of 5. "On the platform" was rated with the mean of 6. OF rated three of them with the mean of 4 ("Love without illusion," "Idilio 3," and "Idilio

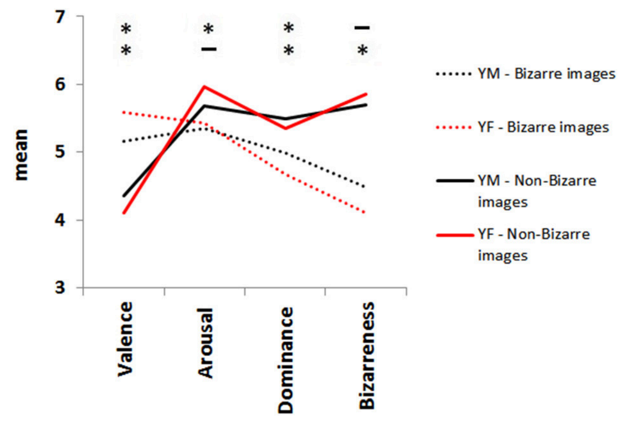

FIGURE 8 | Means of the data of the scatterplots in Figure 7. Mean ratings in Young Males (in black) and Young Females (in red) separated Stern images into: bizarre (dotted lines), and neutral and normal images (continuous lines). Asterisks indicate significant differences between means. Level of significance set at $p < 0.05$.

TABLE 5 | Principal Component Analysis of Grete Stern photomontages in both genders.

Eigenvectors		1st	2nd
Adjectives		Valence, Dominance, Bizarre	Arousal
YOUNG MALES			
Alegre-triste	(joy-sad)	**−0.88**	0.07
Excitado-tranquilo	(excited-calm)	0.10	**0.86**
Ser dominado-dominar	(be dominated-dominate)	**0.74**	0.05
Extrañado-normal	(bizarre-normal)	**0.68**	0.43
YOUNG FEMALES			
Alegre-triste	(joy-sad)	**−0.90**	−0.14
Excitado-tranquilo	(excited-calm)	0.14	**0.87**
Ser dominado-dominar	(be dominated-dominate)	**0.72**	0.31
Extrañado-normal	(bizarre-normal)	**0.80**	0.31
Eigenvalues		3.78	1.91
% of variance explained		53.4%	17.77%

Varimax rotated values from Principal Component Analysis. Factor loadings higher than 0.5 are in bold. Eigenvalues higher than 1 and percentage of the total variance explained by eigenvectors are shown. Emotion adjectives were provided to subjects in Spanish and the English equivalents are shown in parenthesis.

25"); "At this hour," "Idilio 7," and "Idilio 23" with the mean of 6, and the other 2 pictures as more bizarre. "Idilio 8" and "Idilio 16" were rated as neutral. When a Pearson's chi-square test for the four groups of YM, YF, OM, and OF was done for the 10 images, the bizarre distributions were different across the groups ($\chi^2 = 3.85$, $df = 12$, $p = 0.01$), showing a similar pattern for YM and OF, more bizarre values for YF and more neutral ratings for OM (YM: 10, 30, 20, 40, and 0%; YF: 60, 10, 0, 20, 10%; OM: 0, 20, 70, 10, and 0%; OF: 20, 30, 20, 30, and 0%, for ratings of 3, 4, 5, 6, and 7, respectively). In **Table 6**, means and standard deviations of the most bizarre and normal images are shown for OA and YA.

TABLE 6 | Mean and Standard Deviations in parenthesis of "bizarre" (bold) and "normal" images (plain text) evaluated with the extreme values of 3 as "bizarre" or 7 as "normal" by the four groups.

Group	Name	Valence	Arousal	Dominance	Bizarreness
OLD MALES					
YOUNG MALES					
	"Idilio 16"	5.14 (2.50)	6.35 (2.48)	4.75 (2.38)	**3.67 (1.62)**
OLD FEMALES					
	OTP	5.29 (2.42)	5.25 (2.61)	4.79 (2.45)	**3.64 (2.88)**
	"Idilio 20"	6.04 (2.86)	4.46 (3.08)	3.69 (2.40)	**3.24 (2.85)**
YOUNG FEMALES					
	"LWI"	4.43 (1.70)	6.30 (2.39)	4.41 (2.40)	**3.30 (2.74)**
	"OTP"	5.55 (2.13)	4.43 (2.43)	4.30 (2.42)	**3.27 (2.56)**
	"Idilio 3"	6.13 (2.26)	4.55 (2.47)	4.69 (2.32)	**3.14 (2.56)**
	"Idilio 7"	3.41 (2.47)	7.41 (2.35)	6.03 (2.11)	7.13 (2.10)
	"Idilio 16"	5.24 (2.50)	5.60 (3.11)	4.41 (2.32)	**3.79 (2.48)**
	"Idilio 20"	5.62 (2.27)	5.03 (2.34)	4.28 (2.49)	**3.66 (2.36)**
	"Idilio 25"	5.14 (2.26)	4.69 (2.55)	5.66 (2.51)	**3.79 (3.42)**

"LWI", "Love Without Illusion"; "OTP", "On The Platform."

DISCUSSION

The present study was designed to assess emotion and bizarreness in response to Grete Stern's dream representations in photomontages by the application of the IAPS system extended to include bizarreness. Such first-person rating of mental states defined as strange, non-sensical, and absurd showed that it is possible to measure and standardize bizarreness originated from the inspection of pictorial stimuli. The overall results indicate that the experience of bizarreness encompasses both cognitive and emotional elements giving support to the first two components of our initial definition. Furthermore, the differential statistical profile of the images selected as bizarre and those chosen as normal or habitual reinforce the third part of our definition asserting that the stipulated array of cognitive and emotional characteristics of bizarreness stands in opposition to normal, habitual, and congruous expressions and experiences.

The distribution of the evaluation of images differed between young males and females in valence and bizarreness. When images were either separated or considered as a whole, YF registered more extreme ratings than YM in terms of joy, sadness, and bizarreness. The same applied to OF who rated images more at the extremes than OM. Males provide more neutral ratings, and this is more evident in OM. OF showed a different evaluation pattern than OM in the arousal scales, tending to be more responsive to the stimuli, reporting more excitement for some pictures and more calmness for others. The positive associations of dominance and bizarreness, and the negative associations of valence with dominance, and of valence and bizarreness summarize the mental effects of these images in YA. Calmer emotions and neutral ratings in the arousal scale seem to be evoked in YA. The evaluations of Stern photomontages follow a quadratic relationship similar to the boomerang-shaped distribution found for images of the IAPS

(Lang et al., 1998). After the separation of photomontages by the bizarreness scale, the images split according to bizarreness. The more bizarre ones were deemed neutral and sadder and evoked a feeling of being controlled, while half of other images, rated as neutral and normal, were happier and evoked more dominance, especially in YF.

Both the gender and age effects found with the present instrument are consistent with the reports of higher frequency of dream bizarreness in YF (Hall and Van de Castle, 1966; Domhoff, 2007) and with the evidence obtained using the IAPS system that while men are more activated by erotica, women respond with greater defensive reactivity to aversive pictures (Bradley et al., 2001; Silva, 2011). It has also been found that the encoding of selected art stimuli has a gender and age effect, suggesting an attenuation of distinctiveness in OM (Smith, 2006). Old people seem to be less reactive and sensitive to anomaly, and spend less effort in attempting to resolve violations of expectancy.

Domhoff (2007) reported that bizarreness occurs in about half of the dreams reports if sudden changes, juxtapositions, uncertainty, confusion, and distension are considered in the evaluation. Using a similar definition, our results indicate that approximately half of Stern's images are evaluated as bizarre. Revonsuo and Salmivalli (1995) compared waking bizarreness to dreaming bizarreness and found the former was an adequate baseline of dream mentation, a hypothesis that could be tested using Stern's photomontages in future studies.

The present first-person method differs from written dream reports assessed by trained judges and constitutes an easier way, albeit less specific, to measure bizarreness. Certainly, formal analysis of written reports considers more information, but is less reliable than content analysis (Voss et al., 2011), and also requires independent judge agreement (Hall and Van de Castle, 1966). Alternatively, the IAPS method allows the control of the selection of emotional stimuli and facilitates the comparison and replication of results across different studies (Lang et al., 2005).

A larger and wider sample of subjects should be used in order to achieve a better understanding of the effects of these and other purportedly bizarre images such as Fineman's (2012) photoshop presentations. The present procedure can be employed to study bizarre and emotional states in response to diverse graphic or other art-related pictures. Furthermore, the technique may advance the knowledge of non-sensical or bizarre mentation in both psychopathology (Lang et al., 1998; Scarone et al., 2008) and neuroscience (see De Gennaro et al., 2011; Fox et al., 2013; Benedetti et al., 2015).

ETHICS STATEMENTS

The study was approved by the Direccion de Investigacion de la Universidad Autonoma del Estado de Hidalgo, Oficio ICSa. GER/CAT/024/2015, 23/09/2015. Number: UAEH-DI-ICSA-GE-CF-008. Also, the ethics committee has approved the study. Bizarreness and Emotional Evaluations were carried out with the grandparents and friends of the students and did not imply any danger to them.

AUTHOR CONTRIBUTIONS

JD contributed most to the idea about identifying bizarreness with Grete Stern images and rewrote the manuscript. AR implemented the overall evaluation, the methodology, and wrote the original article. CM and PP helped to gather the students to measure Grete Stern photomontages. CM also designed the sheet for the older adults and corrected the correlation figure. EM helped with the scatter plots of the results.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: http://journal.frontiersin.org/article/10.3389/fpsyg.2017.00414/full#supplementary-material

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Developmental Trajectories of Sleep Problems from Childhood to Adolescence Both Predict and Are Predicted by Emotional and Behavioral Problems

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Although the prevalence rates of sleep disorders at different stages of childhood and adolescence have been well established, little is known about the developmental course of general sleep problems. This also holds true for the bidirectional relationship between sleep problems and emotional as well as behavioral difficulties. This longitudinal study investigated the general pattern and the latent trajectory classes of general sleep problems from a large community sample aged 5–14 years. In addition, this study examined the predictive value of emotional/behavioral difficulties (i.e., anxiety/depression, attention problems, and aggressive behavior) on sleep problems latent trajectory classes, and vice-versa. Participants ($N = 1993$) were drawn from a birth cohort of Western Australian children born between 1989 and 1991 who were followed until 14 years of age. Sleep problems were assessed at ages 5, 8, 10, and 14, respectively, whereas anxiety/depression, attention problems, and aggressive behavior were assessed at ages 5 and 17 years. Latent growth curve modeling revealed a decline in an overall pattern of sleep problems during the observed 10-year period. Anxiety/depression was the only baseline factor that predicted the longitudinal course of sleep problems from ages 5 to 14 years, with anxious and depressed participants showing faster decreasing patterns of sleep problems over time than those without anxiety or depression. Growth mixture modeling identified two classes of sleep problem trajectories: *Normal Sleepers* (89.4%) and *Troubled Sleepers* (10.6%). Gender was randomly distributed between these groups. Childhood attention problems, aggressive behavior, and the interaction between gender and anxiety/depression were significantly predictive of membership in the group of *Troubled Sleepers*. Group membership in *Troubled Sleepers* was associated with higher probability of having attention problems and aggressive behavior in mid-adolescence. Boys and girls with behavioral difficulties, and girls with emotional difficulties were at increased risk of having sleep problems during later childhood and adolescence. Developmental trajectories of sleep problems were also predictive of behavioral difficulties in later life. Findings from this study provide empirical evidence for the heterogeneity of sleep problems and their development, and emphasize the importance of understanding sleep problems and their relationship to children and adolescents' mental health.

Keywords: sleep problems, childhood and adolescence, latent trajectory classes, anxiety/depression, attention problems, aggressive behavior, CBCL, Raine study

INTRODUCTION

Sleep problems in children and adolescents are common (Kahn et al., 1989; Owens et al., 2000b; Goodnight et al., 2007). Estimates of the prevalence of sleep problems vary depending upon differences in definitions and methods of assessment (O'Callaghan et al., 2010). Furthermore, these disturbances can take many forms, including dyssomnias (such as insomnia) and parasomnias (such as sleep walking). Moreover, the classification of such disorders varies, depending on the system being followed – the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5, American Psychiatric Association, 2013) or the third edition of the International Classification of Sleep Disorders (ICSD-III, American Academy of Sleep Medicine, 2014). Sleep problems often co-occur with a wide range of psychiatric and neurodevelopmental problems like autism (Allik et al., 2006; Richdale and Schreck, 2009; Cohen et al., 2014; Brand et al., 2015a), epilepsy (Pereira et al., 2012; Carotenuto et al., 2014), and tic disorders (Kirov et al., 2007; Ghosh et al., 2014).

Sleep problems not only affect children and adolescents' psychological functioning as well as their academic, neurocognitive, and behavioral performance, but can also have a negative impact on family functioning and the well-being of family members (Curcio et al., 2006; Kheirandish and Gozal, 2006; Mitchell and Kelly, 2006; Martin et al., 2007; Meltzer and Mindell, 2007; Bell and Belsky, 2008; Kalak et al., 2014; Brand et al., 2015b). However, many parents tend to overlook or ignore sleep problems, or possibly underestimate the importance of healthy sleep habits for good daily psychological functioning of their children (Stein et al., 2001). Disturbed sleep during childhood seems to be an invisible phenomenon to many parents, and often fails to receive attention until it interferes with the child's well-being (Smaldone et al., 2007). A greater understanding of the nature and development of sleep problems and their relationship to children's mental health may provide critical information for researchers and clinicians in the early screening, prevention, and treatment of sleep problems in childhood and adolescence.

Developmental Course of Sleep Problems

Although much has been learned about the prevalence rates of sleep disorders at different stages of childhood and adolescence (Ohayon et al., 2000; Ipsiroglu et al., 2002; Spruyt et al., 2005; Roberts et al., 2011; Schlarb et al., 2015), our knowledge concerning the individual development of sleep problems is still rather limited. According to a recent review of the latest science in sleep problems (Gregory and Sadeh, 2016), there is a critical need to clarify the nature and impact of such problems on child development.

To date, longitudinal studies on sleep problems during childhood and adolescence are dominated by designs with short time frames, typically using just a few years (Gregory and O'Connor, 2002). For example, Laberge et al. (2001) analyzed data on sleep problems from a randomly stratified, proportional sample of 1146 children (48.7% girls), with a particular focus on mothers' annual report of children's sleep patterns, sleep habits and sleep disturbances over a course of 4 years. They detected that the proportion of children with difficulties in initiating sleep declined significantly from ages 10 to 13 years. However, such studies focused on the percentage of participants with sleep problems can provide only limited information on the developmental time-course of sleep problems.

To our knowledge, very few studies have examined the development of sleep problems during childhood and adolescence in terms of a longitudinal course covering a longer time period. Gregory and O'Connor (2002) investigated the sleep problems among 490 children (46.3% girls) from ages 4 to 15 years. A decrease in the average level of sleep problems (50% decline) was found from preschool to mid-adolescence, with modest stability ($r = 0.29$). Developmental changes in sleep problems were assessed using repeated measures analyses, whilst inter-participant stability across this particular time period was assessed with bivariate correlations. Such correlational approaches tell us little about the developmental course of sleep problems; developmental trajectory analyses are required. Friedman et al. (2009) modeled the longitudinal trajectories of seven specific sleep problems frequently observed in childhood (i.e., nightmares, talks or walks, wets bed, sleeps less, sleeps more, trouble sleeping, and overtired) among 916 twins (50.8% girls) from age 4 to 16. Using latent growth curve analyses, they detected that most reported sleep problems declined over time. These studies presented the first attempt to document the average course of sleep problems (general or specific) in a community sample. However, the variable-centered approach applied in these studies precluded the possibility of examining heterogeneity in the development of sleep problems, which can provide critical information for the screening of high-risked individuals, as well as for the design of pertinent treatment approaches. Hence, person-centered trajectory analyses are required to better clarify the development of sleep problems.

Using such person-centered approaches, several studies have detected distinct subgroups of sleep problem development amongst normative child and adolescent samples. Touchette et al. (2007) investigated sleep duration among 1492 children in early childhood (2.5–6 years). Four developmental sleep duration patterns were identified: short persistent (<10h/night; 6.0%), short increasing (4.8%), 10-h persistent (50.3%), and 11-h persistent (38.9%). Similarly, Magee et al. (2014) found four distinct subgroups using growth mixture modeling (GMM): typical sleepers (40.6%), initially short sleepers (45.2%), poor sleepers (2.5%), and persistent short sleepers (11.6%) when examining the sleep duration patterns from age 0 to 1 years to age 6–7 years among 2926 children (42.7% girls). Seegers et al. (2011) examined the time spent in bed from age 10 to 13 among 1916 preadolescents (47.2%) girls and identified three distinct developmental course of time-in-bed: short sleepers (14.5%), 10.5-h sleepers (68.2%), and 11-h sleepers (17.3%). These studies identified distinct developmental courses of several normative aspects of sleep (e.g., sleep duration, time in bed) – in general about 10–15% of children were characterized as having a short sleep duration. However, to our knowledge, no studies have investigated longitudinal trajectories of general sleep problems.

Specifically, there is a need for research that examines developmental trajectories spanning childhood through adolescence. Puberty brings maturational changes to neural architecture involved in sleep as well as (in many cultures) new norms and expectations regarding sleep patterns (Dahl and Lewin, 2002; Soffer-Dudek et al., 2011). These changes (related to neural system's reorganization) have been posited to results in increased fatigue in adolescence (Soffer-Dudek et al., 2011). Thus, sleep trajectories beginning in early childhood and spanning late adolescence are worth investigating.

Predictors and Predictive Value of Sleep Problems

Sleep problems have been linked to both emotional (e.g., anxiety and depression) and behavioral (e.g., attention and conduct) difficulties in childhood and adolescence (Gregory and O'Connor, 2002). Improved understanding of the co-occurrence and longitudinal associations between these difficulties could potentially facilitate the development evidence-based prevention and intervention programs (Gregory and Sadeh, 2016).

The relationship between sleep and emotional problems has been examined in studies that have separated symptoms of anxiety and depression and in studies that have combined anxiety and depression into a single construct (Gregory and Sadeh, 2012). For instance, one study showed that troubled sleeping was associated with parent-reported anxiety/depression measures in children at ages 6 and 11 years (Johnson et al., 2000). Another study reported that sleep problems at age 4 were predictive of anxiety/depression in mid-adolescence (Gregory and O'Connor, 2002). Furthermore, robust associations between sleep problems and anxiety, as well as sleep problems and depression have been detected in children and adolescents (Ivanenko et al., 2005; Lovato and Gradisar, 2014; Peterman et al., 2015; see Willis and Gregory, 2015 for review). It is likely that the nature of any relationships between these psychopathologies are both *complex* and *bidirectional*. For example, it remains to be established whether sleep problems serve as a precursor to emotional difficulties (Alvaro et al., 2013; Lovato and Gradisar, 2014), or whether emotional difficulties may contribute to the development of sleep problems. Longitudinal studies have shown mixed results. Some studies have suggested that both disorders contribute similarly to the development of sleep problems (e.g., Kaneita et al., 2009; Meijer et al., 2010). However, others have suggested that the observed cause-effect associations were distinct (Ohayon and Roth, 2003; Johnson et al., 2006). Therefore, the etiological relationship between sleep and emotion remains unclear. A dearth of longitudinal, experimental, and more methodologically rigorous research limits our capacity to interpret the current literature (Peterman et al., 2015). Additional studies (in particular longitudinal ones) are required to further delineate the association between sleep and emotional problems in children and adolescents (Leahy and Gradisar, 2012).

Although most research has focused on sleep problems in association with emotional difficulties, there is emerging evidence that sleep problems may also be linked to subsequent behavioral difficulties (Gregory et al., 2008). The links between sleep and attention deficit hyperactivity disorder (ADHD) have been extensively studied (see Sadeh et al., 2006; Owens, 2008; Cortese et al., 2009; Tsai et al., 2016 for review). In this context, the topic of ADHD and related symptoms and behaviors has received considerable scientific and clinical attention (Gregory and Sadeh, 2012). In non-clinical samples, sleep disorders may affect children, and may potentially have an effect on daytime functioning of the child, including the regulation of attention (O'Callaghan et al., 2010). Longitudinal studies have suggested that sleep and attention problems are positively related. Sleep problems in early childhood are an indicator of subsequent attention problems that may persist into adolescence and adulthood (Gregory and O'Connor, 2002; Gregory et al., 2008; O'Callaghan et al., 2010; Simola et al., 2014).

Other behavioral problems such as aggression have received less attention, although there are indications that such problems may also be linked to sleep problems (Gregory and Sadeh, 2012). Several studies have suggested that poor sleep may be a causal factor in aggression and violence (see Kamphuis et al., 2012 for a review). For example, children at high-risk for sleep disorders (e.g., breathing problems, periodic leg movements during sleep) have significantly increased parent-reported aggression (Chervin et al., 2003). Children rated as having a conduct problem by a parent or teacher showed more disordered-breathing during sleep, and sleepiness predicted their behavior problems (O'Brien et al., 2011). Persistent sleep problems also appear to confer increased risk of aggressive symptoms (Pakyurek et al., 2002; Simola et al., 2014). In addition, parent-rated sleep problems in childhood are correlated with higher scores on an aggressive behavior scale later in life (Gregory et al., 2008).

Few studies have examined longitudinal relationships between sleep and behavioral problems (Gregory and Sadeh, 2012). In one such study, Pieters et al. (2015) showed that, in the short term (i.e., within a year), sleep problems appear to predict externalizing problems in early adolescence. Longer-term evidence is rarer and in the only study to date Wong et al. (2009) have suggested that early childhood sleep problems (at ages 3–8 years) predict trajectories of externalizing problems, with such problems particularly linked to sleep problems for boys.

Finally, as most research on gender differences in sleep has been conducted in adults, the literature regarding the role of gender on sleep problems in childhood and adolescence is scarce and has shown mixed results (see Krishnan and Collop, 2006; Galland et al., 2012; Mong and Cusmano, 2016 for review). Some studies have indicated that gender has no or relatively little influence on sleep (Voderholzer et al., 2003; Chaput and Tremblay, 2007; Dollman et al., 2007). In contrast, other studies have suggested the presence of gender differences with regards to sleep patterns and insomnia prevalence, the latter showing a considerable female preponderance (Hysing et al., 2013). For example, nightmares were reported more frequently by girls (Liu et al., 2000), and an increase in a variety of sleep problems (insomnia, daytime tiredness, and insufficient sleep) has been associated with the pubertal development period in girls, but not in boys (Knutson, 2005). Therefore, specific attention should be paid to the role of gender when examining sleep problems in minors.

The Present Study

The present study aimed to investigate the overall pattern and the latent trajectory classes of general sleep problems from ages 5 to 14 years among a large community sample, using latent growth curve modeling and GMM. These analytic approaches allow examination of the overall course of sleep problems during childhood to adolescence, as well as examination of subgroups with distinct developmental patterns. The purported bidirectional nature of any relationships between sleep problems and emotional (anxiety and depression) and behavioral (attention problems and aggressive behavior) difficulties were examined by testing whether baseline emotional and behavioral problems could serve as predictors of sleep trajectory classes. Moreover, the predictive value of sleep trajectory classes on anxiety/depression, attention problems, and aggressive behavior later in life (i.e., at age 17) was analyzed. Based on extant research (Gregory and O'Connor, 2002), we expected a general decline in sleep problems over the 10-year period of the trajectories (from ages 5 to 14 years).

Further, we expected to find at least two subgroups with a distinct trajectory of sleep problems, i.e., one group including the majority of children and adolescents reporting none or few sleep problems, and another group of children and adolescents reporting persistent sleep problems during childhood and adolescence. As associations between sleep problems and emotional and behavioral difficulties have been well established (O'Callaghan et al., 2010; Kamphuis et al., 2012; Lovato and Gradisar, 2014), we expected that anxiety/depression, attention problems, and aggressive behaviors would predict the development of sleep problems, and vice-versa.

With respect to the role of gender, we did not have a specific hypothesis concerning the gender differences in sleep problems due to minimal prior research in this area (Galland et al., 2012), therefore an explorative approach was implemented for this particular research question. However, as girls tend to report more emotional difficulties (see Hyde et al., 2008; McLean and Anderson, 2009 for review), and boys tend to report more behavioral difficulties (see Archer, 2004; Rucklidge, 2010 for review), we also explored the potential moderating role of gender on the relationship between sleep problems and emotional and behavioral difficulties.

MATERIALS AND METHODS

Participants and Procedures

Participants were from the Western Australian Pregnancy Cohort (Raine) Study. The methodology and recruitment for this study are described in detail elsewhere (Newnham et al., 1993). In brief, 2900 women between 16 and 20 weeks gestation (mean 18 weeks) were recruited from the public antenatal clinic at King Edward Memorial Hospital (KEMH) in Perth, Western Australia and surrounding private clinics between May 1989 and November 1991. Data collection occurred in accordance with Australian National Health and Medical Research Council (NHMRC) Guidelines for Ethical Conduct and was approved by the ethics committees of KEMH, Princess Margaret Hospital for Children and the University of Western Australia. Written parental consent was obtained at recruitment and at each follow-up until the age of 18. Assent was obtained from participants at age 14–17, and written consent from participants from age 18. Eligible women were required to have sufficient English-language skills to give informed consent, an expectation to deliver at KEMH, and an intention to reside in Western Australia to enable future follow-ups of their child.

Of the 2900 women enrolled, 2804 delivered live babies. There were 64 multiple births, and as such, the initial cohort consisted of 2868 children (49.3% girls). These children were assessed at birth, and were followed up at ages 1, 2, 5, 8, 10, 14, 17, 20, and 22 years of age using questionnaires and physical assessments. This study focused on the 5, 8, 10, and 14-year follow-ups, as detailed sleep problems data were collected at these assessments with adequate retention rate.

Data on sleep problems were available for 2116 participants at age 5 (73.8% retention); 2037 participants at age 8 (71.0% retention); 1994 participants at age 10 (69.5% retention); and 1774 participants at age 14 (61.9% retention). In order to better capture the developmental patterns, we focused on participants who had data on sleep problems for at least three out of the four measurement points. The effective sample size was 1993 (48.6% girls; 69.5% retention).

Measures

Sleep Problems

Six items from the parent-report of Child Behavior Checklist (CBCL, Achenbach, 1991a) comprised of a 'sleep problem scale' and were used to measure child and adolescent sleep problems.

Although not a standardized CBCL scale, the CBCL sleep composite has been shown to be strongly correlated with the validated Children's Sleep Habits Questionnaire (CSHQ, Owens et al., 2000c) and also with clinical diagnoses of sleep disorders. The sleep composite shows similar external correlations with youths' social problems and psychopathology symptoms as the CSHQ score (Becker et al., 2015). It has been widely used in previous research as a measure of overall sleep functioning (Stoléru et al., 1997; Gregory and O'Connor, 2002; Alfano et al., 2006; Beebe et al., 2007; Gregory et al., 2008; Storch et al., 2009; Troxel et al., 2013). The specific sleep-content items are "trouble sleeping," "nightmares," "overtired without good reason," "sleeps less than most kids," "talks or walks in sleep," and "sleeps more than most kids during day and/or night." Each item is rated on a 3-point scale (0 = not true, 1 = somewhat or sometimes true, 2 = very true or often true). A sum score of the 6-items scale was used to represent the level of children and adolescents' sleep problems (range 0–12), with higher scores indicating higher levels of sleep problems. Cronbach's alpha of the four measurement points ranged between 0.55 and 0.61

Emotional and Behavioral Problems at Baseline (Age 5)

The Anxious/Depressed, Attention Problems, and Aggressive Behavior scales were examined using the parent-report of CBCL (Achenbach, 1991a). None of these scales included sleep problems. The Anxious/Depressed scale consists of 14 items, sample items of the subscale included "feels or complains that no one loves him/her" and "too fearful or anxious." The Attention Problems scale consists of 11 items, sample items of the subscale included "daydreams or gets lost in his/her thoughts" and "can't sit still, restless, or hyperactive." The Aggressive Behavior scale consists of 20 items, sample items of the subscale included "cruelty, bullying, or meanness to others" and "destroys things belonging to his/her family or others." Responses were rated on a 3-point scale (0 = not true, 1 = somewhat or sometimes true, 2 = very true or often true). A sum score of all the items of the subscale was used to represent the level of children and adolescents' emotional and behavioral problems (range 0–28, 22, 40 for the Anxious/Depressed, Attention Problems, and Aggressive Behavior scale, respectively), with higher scores indicating higher levels of emotional or behavioral problems. Cronbach's alpha was 0.97, 0.96, and 0.98 for the Anxious/Depressed, Attention Problems, and Aggressive Behavior scale, respectively.

Emotional and Behavioral Problems at Age 17

The Anxious/Depressed, Attention Problems, and Aggressive Behavior scales were obtained using the Youth Self-Report (YSR, Achenbach, 1991b). Items are scored in the same way as for the parent-report CBCL. Responses were rated on a 3-point scale (0 = not true, 1 = somewhat or sometimes true, 2 = very true or often true). The sum score of all the items of the subscale was used to represent the level of children and adolescents' emotional and behavioral problems (range 0–28, 22, 40 for the Anxious/Depressed, Attention Problems, and Aggressive Behavior scale, respectively), with higher scores indicating higher levels of emotional or behavioral problems. Cronbach's alpha was 0.90, 0.85, and 0.92 for the Anxious/Depressed, Attention Problems, and Aggressive Behavior scale, respectively.

Statistical Analyses

After presenting children and adolescents' sleep problems and emotional/behavioral difficulties in a descriptive manner, the data analysis proceeded in five consecutive steps. In step 1, we applied latent growth curve modeling (LGM) to examine the overall pattern of sleep problems. Four measurements of sleep problem data assessed from childhood (age 5 years) to adolescence (age 14 years) were used as outcome variables to estimate latent growth factors that represent the average initial level (i.e., intercept) and the average growth (i.e., slopes) of sleep problems. Individual differences were modeled using random effects around these latent growth factors. A series of unconditional LGMs including different growth factors (e.g., intercept-only, linear slope, quadratic slope) were estimated to identify the model that best fit the average sleep problems longitudinal course. Because the χ^2 is sensitive to sample size, we assessed fit primarily with the comparative fit index (CFI), root-mean-square error of approximation (RMSEA), and standardized root-mean-square residual (SRMR) using criteria of CFI $\geq$ 0.95, RMSEA $\leq$ 0.06, and SRMR $\leq$ 0.08 as indicators of good fit (Hu and Bentler, 1999).

In step 2, baseline emotional and behavioral predictors (i.e., anxiety/depression, attention problems, and aggressive behavior) were added to the best fitting model identified at step 1 to get a conditional LGM, which simultaneously examined the effects of baseline emotional and behavioral predictors on the course of sleep problems. The latent growth factors (e.g., intercept and slope) were regressed on the baseline predictors. The interaction effects between baseline predictors and gender on sleep problems latent growth factors were also explored.

In step 3, we used GMM to estimate latent trajectory classes in sleep problems. GMM captures the heterogeneity in unobserved subpopulations by allowing for the differences in growth parameters, and identifies a finite number of subgroups of individuals following different developmental courses (Jung and Wickrama, 2008). GMM results in separate growth model for each latent class, which differs in terms of intercept (initial level), slope (average growth), and with their unique estimates of variances and covariate influences.

A series of models were fitted, beginning with a one trajectory model and moving to a five trajectory model. Each model was fitted using at least 1000 random perturbations of starting values to ensure replication of the best likelihood and to avoid local maxima. Evaluation of the best fitting models took into account several criteria (Nylund et al., 2007). Firstly, Bayesian Information Criterion (BIC) and adjusted BIC (aBIC) were examined with lower (i.e., closer to 0) value indicating better balance between model fit and parsimony. Secondly, Lo–Mendell–Rubin likelihood ratio test (LMR-LRT) and bootstrap likelihood ratio test (BLRT) were used to compare the k and the k−1 trajectory models. A significant *p*-value (<0.05) in LMR-LRT and BLRT indicated a statistically significant improvement in model fit with the inclusion of one more trajectory. Thirdly, we examined the entropy index that ranges from 0 to 1 while entropy closer to one indicates better classification.

In step 4, participants were assigned to their most likely trajectory latent class based on their highest posterior probability. Gender-specific group membership was compared. We conducted multinomial logistic regression with baseline emotional and behavioral predictors (i.e., anxiety/depression, attention problems, and aggressive behavior) as independent variables to examine their usefulness in predicting sleep problems trajectory group membership. The interaction between gender and each predictor variable was also examined. Odds ratios with 95% confidence intervals were estimated and reported.

In step 5, to test the predictive value of sleep problems trajectory classes on emotional and behavioral problems later in adolescence, we examined level of later anxiety/depression, attention problems, and aggressive behavior conditional on the latent trajectory class membership. Mean scores of anxiety/depression, attention problems, and aggressive behavior at age 17 years were compared between sleep problem trajectory classes using independent sample *t*-test.

Latent growth curve modelings and growth mixture modelings were performed using Mplus version 7.3 (Muthén and Muthén, 1998-2015). Other analyses were carried out using SPSS version 23. Missing data on the outcome variables were handled through full information maximum likelihood (FIML) estimation in Mplus as a standard procedure under the assumption of missing at random (Muthén and Muthén, 1998-2015). Individuals with missing values on predictors were excluded from multinomial logistic regression and comparison of means.

RESULTS

Descriptive Statistics

Table 1 presents descriptive statistics and bivariate correlations for all study variables. Results from Little's MCAR test showed that missing data on all variables were missing completely at random (p = 0.317). Means of children and adolescents' sleep problems experienced a significant decrease over time (t = 11.855, df = 1576, $p < 0.001$). Almost all study variables were significantly inter-correlated (except for anxiety/depression at age 5 and attention problems at age 17). Correlations between sleep problems measured in the four waves showed that the magnitude of associations between adjacent assessments (rs = 0.50–0.53, $p < 0.01$) was greater than that between non-adjacent ones (rs = 0.38–0.43, $p < 0.01$). Cross-sectional relationships between sleep problems and baseline emotional/behavioral predictors (rs = 0.41–0.46, $p < 0.01$) were also higher than their relationships over time (rs = 0.23–0.34, $p < 0.01$). The longitudinal relationships between sleep problems (at age 5, 8. 10, and 14) and later emotional/behavioral (at age 17) was trivial (rs = 0.09–0.16, $p < 0.01$).

Longitudinal Course of Sleep Problems from Age 5 to 14

Unconditional Latent Growth Curve Models

A model including a linear slope (CFI = 0.85, RMSEA = 0.13, and SRMR = 0.08) fit the data better than an intercept-only model (CFI = 0.98, RMSEA = 0.07, and SRMR = 0.03). The addition of a quadratic slope also improved the model fit (CFI = 0.99, RMSEA = 0.06, and SRMR = 0.01). Thus, a model including both linear and quadratic slopes was selected for the subsequent analyses. A significant negative linear slope (s = -0.56, $p < 0.01$) and a non-significant quadratic slope (q = 0.04, p = 0.76) indicated a stable decreasing trend over time (**Figure 1A**). Significant variances were observed around the intercept and both slope factors, suggesting inter-individual differences in sleep problems at initial level as well as in the development of sleep problems. This significant variance suggested that GMM might provide insight into the heterogeneity in the development of sleep problems.

Baseline Predictors of Longitudinal Course of Sleep Problems

Results from the conditional LGM are presented in **Table 2**. Significant effects were observed on the intercept factor for all baseline emotional and behavioral predictors. Children and adolescents with higher levels of anxiety/depression, attention problems, and aggressive behavior at baseline were concurrently reported with higher levels of sleep problems. Gender was not significantly related to the initial level of sleep problems.

Only emotional difficulties at age 5 were predictive of the linear and quadratic slope factors. Anxious and depressed children showed a faster decreasing pattern of sleep problems over time, characterized by a steeper and a subsequent more marked decline. Conversely, gender and baseline differences in behavioral vulnerabilities (i.e., attention problems and aggressive behavior) did not predict the longitudinal course of sleep problems from age 5 to 14.

With respect to the moderating role of gender, no significant interaction effect between gender and anxiety/depression, attention problems, or aggressive behavior was found (effect not presented). Associations between emotional and behavioral predictors and the development of sleep problems were similarly affecting boys and girls.

Latent Trajectory Classes of Sleep Problems from Age 5 to 14

Unconditional Growth Mixture Models

Unconditional GMMs with 1–5 trajectory classes were estimated including both linear and quadratic slopes. **Table 3** shows the model selection criteria used to decide on the best class solution for sleep problems trajectories. The BIC and aBIC both consistently declined for 1- through 5-class solution, although with a decelerated decreasing rate with the addition of classes. However, the model complexity also increased with the number of latent classes. Both the LMR-LRT and BLRT suggested that the 2-class solution significantly improved the model fit as compared to the 1-class solution, whereas the 3-class solution did not fit

TABLE 1 | Descriptive statistics and bivariate correlations between all study variables.

	N	*M*	*SD*	1	2	3	4	5	6	7	8	9	10
(1) Sleep problems at 5	1857	1.30	1.49	1									
(2) Sleep problems at 8	1861	1.21	1.55	0.52**	1								
(3) Sleep problems at 10	1902	1.01	1.40	0.42**	0.53**	1							
(4) Sleep problems at 14	1705	0.85	1.34	0.38**	0.43**	0.50**	1						
(5) Anxiety/depression at 5	1873	2.78	2.93	0.46**	0.30**	0.25**	0.24**	1					
(6) Attention problems at 5	1860	2.88	2.79	0.41**	0.30**	0.27**	0.23**	0.49**	1				
(7) Aggressive behavior at 5	1789	8.08	6.21	0.43**	0.34**	0.30**	0.29**	0.53**	0.58**	1			
(8) Anxiety/depression at 17	1182	5.04	5.20	0.11**	0.10**	0.09**	0.14**	0.11**	0.06*	0.10	1		
(9) Attention problems at 17	1182	5.00	3.13	0.11**	0.10**	0.11**	0.16**	0.05	0.13**	0.13**	0.60**	1	
(10) Aggressive behavior at 17	1182	7.91	5.11	0.13**	0.15**	0.12**	0.12**	0.10**	0.11**	0.23**	0.46**	0.60**	1

*The total sample size was 1993. *p < 0.05, **p < 0.01.*

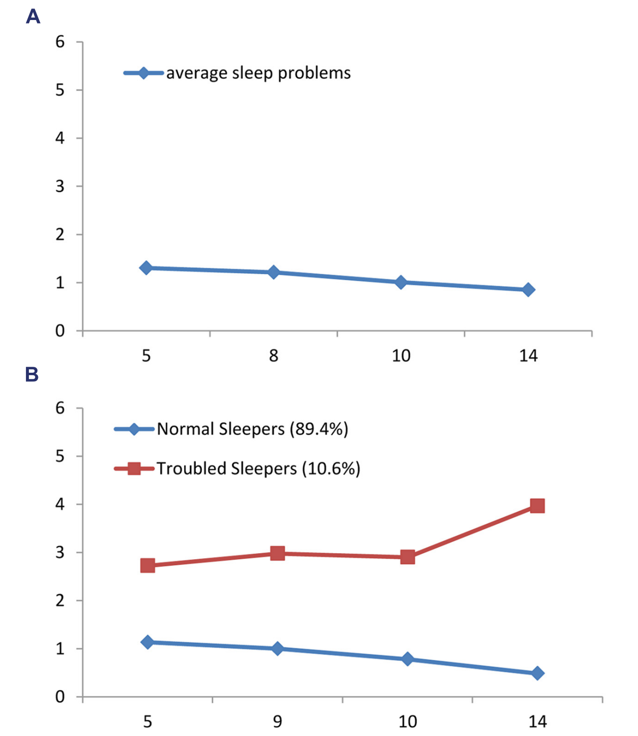

FIGURE 1 | (A) General course of sleep problems from age 5 to 14. **(B)** Latent trajectory classes of sleep problems from age 5 to 14.

the data better than the 2-class solution. Moreover, the 3-class solution yielded two classes showing a highly similar trend. In addition, the 2-class solution achieved a slightly higher entropy (0.92) than the 3-class solution (0.91), although they both showed adequate classification accuracy. Therefore, the 2-class solution was chosen.

The quadratic slope emerged to be significant only for one trajectory class. After fixing the non-significant quadratic slope, the new 2-class solution achieved a better model fit (BIC = 23740.00; aBIC = 23689.16), therefore this more parsimonious model is presented. Latent trajectory classes of sleep problems are shown in **Figure 1B**.

TABLE 2 | Unstandardized parameter estimates for predictors of sleep problems latent growth factors.

Predictors	Intercept	Linear slope	Quadratic slope
	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)
Gender	0.10 (010)	0.12 (0.45)	−0.16 (0.46)
Anxiety/depression at 5	0.15 (0.02)**	−0.35 (0.10)**	0.23 (0.09)**
Attention problems at 5	0.10 (0.02)**	−0.14 (0.10)	0.10 (0.10)
Aggressive behavior at 5	0.04 (0.01)**	0.04 (0.05)	−0.04 (0.05)

Gender was dummy-coded as boys = 0 and girls = 1.
***p < 0.01.*

The trajectory with the majority of adolescents (89.4%) was labeled *Normal Sleepers* ($n = 1782$). This class included adolescents with a lower initial level of sleep problems ($i = 1.16$, $p < 0.01$), which tended to decrease over time, as indicated by the significant negative linear slope ($s = -0.75$, $p < 0.01$). The second class was the *Troubled Sleepers* ($n = 211$), which consisted of adolescents who followed a persistent higher sleep problems trajectory (10.6 %). This class was described by a higher initial level of sleep problems ($i = 2.73$, $p < 0.01$), and a curvilinear trend as indicated by a non-significant negative linear slope ($s = -0.48$, $p = 0.59$) and a significant positive quadratic slope ($q = 2.08$, $p = 0.02$).

A contingency analysis was performed to determine whether boys and girls were similarly distributed in the sleep problems latent trajectory classes. Results of chi-square test showed a random gender distribution between *Normal Sleepers* and *Troubled Sleepers* ($\chi^2 = 0.92$, $p = 0.34$).

Baseline Predictors of Sleep Problems Latent Trajectory Classes

Results from multivariate binomial logistic regression showing the effects of baseline emotional and behavioral predictors as well as their interaction with gender on sleep problems trajectory classes are presented in **Table 4**. Only baseline behavioral predictors were able to differentiate the sleep problems between the two trajectory classes. Specifically, children and adolescents with attention problems and aggressive behavior at age 5 years were more likely to follow the *Troubled Sleepers* trajectory class

TABLE 3 | Model selection criteria to determine trajectory classes of sleep problems.

Model	Log likelihood	BIC	aBIC	LMR-LRT	BLRT	Entropy
1-class	−12188.88	24476.32	24435.02	–	–	
2-class	−11808.13	23745.41	23691.40	<0.001	<0.001	0.92
3-class	−11589.41	23338.36	23271.64	0.06	1.00	0.91
4-class	−11466.47	23122.68	23043.25	0.07	0.08	0.94
5-class	−11348.76	22917.65	22825.52	0.24	1.00	0.93

BIC, Bayesian Information Criterion; aBIC, Sample size adjusted BIC; LMR, Lo–Mendell–Rubin test; BLRT, Bootstrap likelihood ratio test.

TABLE 4 | Multivariate binomial logistic regression of baseline predictors on sleep problems trajectory classes.

Predictors	***Normal Sleepers* vs. *Troubled Sleepers***			
	OR	**Lower 95% CI**	**Upper 95% CI**	**Sig.**
Gender	2.76	1.72	6.62	0.97
Anxiety/depression at 5	2.72	2.53	2.95	0.96
Attention problems at 5	3.00	2.75	3.30	0.03
Aggressive behavior at 5	2.94	2.82	3.07	0.00
Gender*Anxiety/depression at 5	3.24	2.85	3.74	0.01
Gender*Attention problems at 5	2.50	2.23	2.84	0.19
Gender*Aggressive behavior at 5	2.65	2.50	2.82	0.43

Gender was dummy-coded as boys = 0 and girls = 1.

as compared to those without behavioral difficulties. Moreover, the interaction between gender and anxiety/depression was significantly predictive of sleep problems class membership, suggesting girls with emotional problems were at elevated risk of being *Troubled Sleepers.*

Sleep Problems Latent Trajectory Classes and Later Emotional/Behavioral Problems

We examined the level of emotional and behavioral difficulties later in life among sleep problem trajectory classes. A reduced sample ($n = 1182$) was used in this step due to missing data on emotional and behavioral problems at age 17. Means of anxiety/depression, attention problems, and aggressive behavior at age 17 in the reduced sample were compared. Results from independent sample t-test showed that there were significant differences at the level of attention problems ($M_{\text{Normal}} = 4.93$, $M_{\text{Troubled}} = 5.73$, $p < 0.05$) and aggressive behavior ($M_{\text{Normal}} = 7.79$, $M_{\text{Troubled}} = 9.04$, $p < 0.05$) between *Normal Sleepers* and *Troubled Sleepers* at age 17. No significant differences were observed for later anxiety and depression ($M_{\text{Normal}} = 4.96$, $M_{\text{Troubled}} = 5.81$, $p = 0.14$) between the trajectory groups. Missingness analyses indicated that the participants ($n = 811$) who dropped out reported significantly higher sleep problems at age 13 ($p < 0.05$) and attention problems at age 5 ($p < 0.05$) compared with the reduced sample.

DISCUSSION

Viewed as a whole, sleep problems decreased stably across the childhood and adolescence period. This finding is consistent with the work of Gregory and O'Connor (2002) in a similar aged community sample (5–14 years vs. 4–15 years) of 400 Americans, despite the current study being developed and designed in a different cultural background (Australian) and using a different statistical method (LGM vs. repeated measures analyses). Both of the studies suggest that sleep problems show a gradual declining trend during childhood and adolescence in the general population. However, this group trend does not elucidate the implicit heterogeneity of these data. Indeed, this normative picture is complicated by our finding of heterogeneity in the development of sleep problems, which showed that one in 10 young people experience chronic sleep problems into adolescence.

Hence, our second major finding from GMM identified two distinct trajectory classes of sleep problems from childhood to adolescence. The majority of children and adolescents (89.4%) reported few sleep problems, which is modeled by the latent growth curve analyses and also is reflected by the overall trajectory. However, this general course obscured the small group of children and adolescents (10.6%) who were troubled with higher levels of sleep problems over the 10-year period. Notably, this group of troubled sleepers was characterized with high, but stable sleep problems from age 5 to 10 and a sudden statistically significant rise in sleep problems from age 10 to 14 years probably due to the pubertal developmental phase. In consideration of the high prevalence of sleep disturbance in the adult population (10–40% of insomnia, e.g., Ohayon, 2002; Morphy et al., 2007) and corresponding predictive value of adolescence sleep (e.g., Dregan and Armstrong, 2010), such reported sleep problems might continue into adulthood and thus reflect a persistent disturbance. However, given the lack of later-time-point data, such an assumption should remain speculative, but should be a focus of examination in future studies.

In summary, these findings provide empirical support for the existence of two distinct subgroups of children and adolescents with different levels of sleep problems over time. The presence of *Troubled Sleepers* echoes previous literature on the continuation/persistence of sleep problems (e.g., Fricke-Oerkermann et al., 2007; Luo et al., 2013).

These results may help to reconcile a paradox within the sleep literature. On the one hand, studies on the longitudinal course of general sleep problems (Gregory and O'Connor, 2002; Umlauf et al., 2011) suggest that sleep problems decrease from early childhood through adolescence. On the other hand, sleep problems amongst adolescents are considered to be especially prevalent (e.g., Pieters et al., 2015) and receive special attention (e.g., Gradisar et al., 2011). Although our mixture modeling could visualize a subgroup with declining trajectory to reflect the cessation/remission of sleep problems (the 5-class solution), we did not report it due to insufficient statistical support. As was already proved by previous studies using sleep electroencephalography and actigraphy (Hatzinger et al., 2013, 2014; Perkinson-Gloor et al., 2015), the present findings reveal that during childhood and adolescence, the long term development of sleep problems is dominated by its stability. Heterogeneous trajectory classes of sleep problems mainly differed in the level (quantity-wise), rather than the shape of developmental course (quality-wise). If the stable nature of the trajectory class of the persistent troubled sleepers can be replicated and predictors are found, we might be able to identify this group of children and adolescents from early assessments on and find ways of prevention or early intervention of sleep problems.

In this study, early *emotional and behavioral problems* were used as predictors of the general course and distinct trajectory subgroups of sleep problems. When the average course of sleep problems in the general population was considered, anxiety/depression, attention problems, and aggressive behavior (together also known as the Dysregulation Profile, see Deutz et al., 2016) at baseline all predicted higher initial levels of sleep. Furthermore, children with early attention problems or aggressive behavior, and girls with early anxiety and depression were more likely to be *Troubled Sleepers* compared to their counterparts.

These results suggest that both emotional and behavioral problems should be considered as potent risk factors of sleep problems. Also, these findings suggest that behavioral problems share a close link with the initial level, rather than the change of sleep problems over time. This suggests that accounts of the relationship of these emotional and behavioral problems and sleep should focus on the earlier years of life, prior to the fifth year. The interaction between emotional problems and gender, being predictive of group membership in *Troubled Sleepers*, may stem from girls' greater vulnerabilities for anxiety and depression (see Hyde et al., 2008; McLean and Anderson, 2009 for review) and calls for further investigation into this complex relationship.

Trajectory group membership of *sleep problems* were used as predictors of later emotional and behavioral problems. Results showed that *Troubled Sleepers* reported significantly higher levels of attention problems and aggressive behavior at age 17 years when compared to *Normal Sleepers*, while they had similar levels of anxiety and depression. These results are partly consistent with findings from previous research (e.g., Gregory and O'Connor, 2002; Umlauf et al., 2011; Pieters et al., 2015) that sleep problems are predictive of later behavioral/emotional problems. Our findings extend these findings in important ways. For example, Gregory and O'Connor (2002) used sleep problems as single measurement at age 4 years while we used sleep problems as group membership of trajectory classes from ages 5 to 14 years. Pieters et al. (2015) examined change in relative levels via panel analyses over a single year, whereas we were able to examine over a decade of data. However, we still know little about how sleep problems are implicated in different modes of aggression. Our data, in conjunction with research indicating the impact of fatigue on impulsivity amongst adolescents (e.g., Abe et al., 2010), would suggest that future research focuses on the role of sleep disturbance in impulsively enacted aggression and violence, including cyber-aggression (Runions, 2013).

Our findings are indicative of the *bidirectional relationship between sleep problems and behavioral problems*. In contrast, only a one-way relationship was found between sleep and emotional problems, that early anxiety and depression were predictive of higher initial level of general course of sleep problems. According to the recent findings from Mulraney et al. (2016), sleep problems and emotional problems were predictors of one another in a 6-month interval but not in a 12-month interval, such a relationship might weaken or vanish in long term development.

With respect to the role of gender in sleep problems, our findings suggest that there is no or little gender difference, either in the prevalence, initial level, general course or distinct trajectory classes of sleep problems. These findings support previous studies (Voderholzer et al., 2003; Chaput and Tremblay, 2007; Dollman et al., 2007) and extend our knowledge to individual-level. The only exception was the finding that girls with emotional problems were more likely to be *Troubled Sleepers*. The underlying mechanism of such an interaction effect is unclear, however, may be an important direction for future research.

Findings from this study have *implications for the screening and treatment of sleep problems*. The stable nature of sleep problems suggests that children with sleep problems at early time point have a great chance/risk to maintain or aggravate the symptoms throughout childhood and adolescence. Thus, early screening (i.e., in kindergarten) could present a particularly important time for early intervention to improve future sleep behaviors. Such early intervention might be particularly important given the bidirectional relationship between sleep and behavioral problems. Indeed, the presence of attention problems and aggressive behavior may be suggestive of increased later sleep problems and vice-versa. It would be useful for clinicians therefore to not only assess sleep problems but also behavioral problems and vice-versa to evaluate the integrated risk. In addition, the data from our study suggests that special attention should to be paid to girls with emotional problems since they tend to show more sleep problems in childhood and adolescence.

It is important to consider *strengths and limitations of this study*. The adoption of a large sample size and longitudinal design enabled us to model the general pattern of sleep problems during childhood and adolescence and replicate the work of Gregory and O'Connor (2002). Furthermore, the utilization of GMM, a person-centered approach, allowed us to identify distinct trajectory classes in sleep problems, which is hidden in general population analyses. To our knowledge, this is the first study to empirically investigate subgroups with a different course of general sleep problems and thus find subgroup-specific predictors for better assessment and treatment.

Despite these strengths, some limitations must be considered. First, sleep problems were measured using six items derived from CBCL to assess the general sleep problems (composed of different kinds of sleep problems) and thus might not generalize to specific categorical and isolated disorders of sleep, like insomnia, hypersomnia, and parasomnia. These disorders have certainly different pathological backgrounds, implications, and trajectories. However, even when adding an exploratory factor analysis, we could not derive valid factors related to these three categories. Therefore, we suggest future study to apply more specific (or even objective) sleep assessments in longitudinal designs, to investigate the unique feature of these disorders. Second, data regarding sleep problems and early emotional/behavioral problems were based exclusively on parent-reports and there is potential for rater bias (Owens et al., 2000a; Gregory et al., 2006), although the consistency of prediction to self-reported emotional and behavioral problems at age 17 may mitigate this concern. Furthermore, since parents typically have less knowledge of internalizing problems in their adolescents, self-reports may be more appropriate than parent-reports in assessing older children. Third, although the CBCL sleep composite is a valid and reliable parameter, formal diagnoses of sleep disorder or mental health status (e.g., diagnoses of anxiety/depression disorder or other psychiatric abnormalities) would have strengthened our evaluation. Fourth, given the focus on emotional and behavioral problems, we did not examine other predictors that might influence the development of sleep problems, such as family/parental factors (Adam et al., 2007; Cousins et al., 2007; Brand et al., 2009; Kalak et al., 2012; Bajoghli et al., 2013). It would be of particular value if future research could additionally examine the predictive value of other risk factors. Finally, despite the longitudinal methodology, this is an observational study, which at best can only show associations, not causation, between trajectories and risk factors and outcomes.

CONCLUSION

In summary, this study revealed a lessening overall pattern of sleep problems from childhood to adolescence. Within this general decline, two distinct trajectory classes of sleep problems were identified: *Normal Sleepers* with the great majority of children and adolescents reporting lower level sleep problems over time, and *Troubled Sleepers*, a small group of children and adolescents reporting persistently higher level of sleep problems throughout the period investigated. Children and adolescents with attention problems, aggressive behavior, and girls with anxiety/depression at age 5 years were more likely to be *Troubled Sleepers* compared with *Normal Sleepers*. Those subjects in the *Troubled Sleepers* trajectory group had higher levels of attention problems and aggressive behavior at age 17 years. This study provided evidence for the stable nature of sleep problems during childhood and adolescence and partly supported the bidirectional model between sleep and emotional/behavioral problems.

AUTHOR CONTRIBUTIONS

BW and AR conceived and designed the study; FZ was responsible for data acquisition; BW performed the statistical analysis, interpreted the data, drafted and revised the manuscript; CI, AB, and AR contributed to interpretation of the data, drafting and revising the paper; JW, PE, R-CH, KR, RS, TM, LB, and FZ helped to drafted and revised the manuscript. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work specifically to responding to questions related to the accuracy or integrity of any part of the work. FZ and AR are joint senior author. FZ is responsible for the group's correspondence with Raine Study.

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Sleep Changes in Adolescents Following Procedural Task Training

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Recent research has suggested that some of the inter-individual variation in sleep spindle activity is due to innate learning ability. Sleep spindles have also been observed to vary following learning in both young and older adults. We examined the effect of procedural task acquisition on sleep stages and on sleep spindles in an adolescent sample. Participants were 32 adolescents (17 females) between the ages of 12 and 19 years. Spindle activity was examined in three different frequency ranges: 11.00–13.50 Hz (slow), 13.51–16.00 Hz (fast), and 16.01–18.50 Hz (superfast). No changes in spindle density were observed after successful learning of the pursuit rotor task. This result was in contrast to a number of studies reporting spindle density increases following successful learning. In the present study, participants who successfully learned the task showed no changes in their sleep stage proportions, but participants who were not successful showed a decrease in the proportion of stage 2 and increases in both SWS and REM sleep. We suggest that these changes in the sleep stages are consistent with the two stage model of sleep and memory proposed by Smith et al. (2004a).

Keywords: stage 2, rem, SWS, spindles, adolescents, learning

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INTRODUCTION

Sleep spindles are a hallmark of stage 2 sleep, often used as the defining characteristic of stage 2 onset. They are commonly considered to have a frequency range of 11–16 Hz; this range is often further divided into two types of sleep spindles, with slow spindles having a frequency range of approximately 11–13.5 Hz and fast spindles having a frequency range of 13.5–16 Hz (Zeitlhofer et al., 1997; DeGennaro and Ferrara, 2003; Fogel and Smith, 2011; Nader and Smith, 2015). We have previously identified what we believe to be a third spindle type in the frequency range of 16–18.5 Hz (Nader and Smith, 2015).

Along with the traditional slow and fast spindles, these ‘superfast' spindles (16–18.5 Hz) were observed to appear in all sleep stages in a sample of healthy adolescent males and females (Nader and Smith, 2015). The superfast spindle was observed in all of our adolescent subjects, albeit with a lower occurrence than either the slow or fast spindles. All three types of spindles were observed in all sleep stages, despite the common acceptance that sleep spindles are primarily a stage 2 phenomenon (Rechtschaffen and Kales, 1968; Steriade and McCarley, 2005). Using automated spindle counters allowed us to filter out electroencephalography (EEG) frequencies that were not of interest to us, and to focus on specific frequency ranges (Ray et al., 2009). This has resulted in better detection of the various types of spindles, as well as increased detection in sleep stages other than stage 2 including REM sleep (Gaillard and Blois, 1981; Zeitlhofer et al., 1997; Nader and Smith, 2015).

Sleep spindles, while being very consistent within an individual, have large inter-individual differences (Gaillard and Blois, 1981; DeGennaro et al., 2005; Fogel and Smith, 2011). Recent research has suggested that the sleep spindle is linked with cognitive ability both in children (Hoedlmoser et al., 2014) and adults (Nader and Smith, 2001; Bódizs et al., 2005; Schabus et al., 2006). Higher levels of spindle activity have been observed to be positively related to a number of tasks that measure various aspects of cognitive ability. Schabus et al. (2006) observed more slow and fast spindle activity (amplitude × duration) in individuals who scored highly on the Raven's Progressive Matrices (a measure of cognitive ability) and in individuals who scored highly on the Wechsler Memory Scale (a measure of memory performance). Bódizs et al. (2005) observed a similar effect using the Raven's Progressive Matrices, but they found that only the fast spindles were positively correlated with performance; the density of the fast spindles were found to explain nearly 70% of the variance in performance on the cognitive test. Other studies have provided evidence supporting the hypothesis that baseline spindle activity is positively linked to cognitive abilities or learning potential (Nader and Smith, 2001, 2003, 2015; Fogel et al., 2007b; Hoedlmoser et al., 2014).

Many researchers have also explored whether spindle activity is affected by learning. To this end, researchers have employed a number of tasks to try and induce learning-dependent changes in spindle activity. Fogel and Smith (2006) found that young adults exhibited a 42% increase in the number of sleep spindles, and a 24% increase in spindle density after learning four different motor tasks. Peters et al. (2008) observed a significant increase in spindle density in stage 2 sleep after participants learned the pursuit rotor task – this increase was present in younger adults (17–24 years), but not in the older adults (62–79 years). These researchers suggest, however, that it was performance that was important, not age *per se*; the participants who learned, exhibited an increase in spindle density, but those who did not learn did not show an increase in spindle activity (Peters et al., 2008). It may also be that increases in spindle activity after learning may be dependent on intelligence, with the effect being seen primarily in those individuals with higher IQs (Fogel et al., 2007a; Schabus et al., 2008).

Other studies have suggested that children may be different than young adults with respect to the sleep spindle changes observed following learning. Hoedlmoser et al. (2014) used a declarative task in a group of pre-pubertal children rather than a procedural task, but they did not observe any relationship between memory consolidation and increased spindle activity. Similar to adults, general cognitive abilities did seem to be related to spindle activity, but learning itself did not induce any changes in spindle activity. This may have a number of implications: for example, it may be that in terms of sleep states, the declarative task does not depend on spindle activity for consolidation, the task may have been too difficult for the children (as suggested by the authors) or it may be that children respond differently than adults to learning.

Smith et al. (2004a) have previously proposed a two stage model of motor learning. In this model, the sleep stages involved in memory acquisition depend upon the level of task mastery. In this model, when a task is novel to an individual, successful post-acquisition changes in REM sleep are observed; however, when a task is familiar to the individual and he/she is simply refining a skill, then successful post- acquisition changes in stage 2 sleep are more likely. Thus, it is possible that any sleep changes observed in our adolescent sample may be dependent on their familiarity with the task/skill set.

The present study was focused on investigating the link between spindle activity and motor learning in adolescents. We recorded the sleep of adolescents both before and after acquisition of a simple motor task (the pursuit rotor). We were interested in the link between baseline sleep measures and learning; we anticipated that learning would be positively related to an increase in spindle activity from baseline to post-learning (PL) sleep. Based on the findings of Ujma et al. (2014), we were also interested in whether there were gender differences in the relationships between sleep and learning.

MATERIALS AND METHODS

Participants

The participants were 32 adolescents (17 females) between the ages of 12 and 19 years ($M = 15.36$ years) recruited from the Peterborough community. Participants were all considered to be healthy and medication free, as assessed by their parents, with no indication of sleep disorders. As well, all participants attended regular school class programs. All subjects were assessed for pubertal development, using the Tanner Scale, in order to statistically control for hormonal effects on spindle activity if necessary. This study was approved by the Trent University Research Ethics Board.

Measures

Electroencephalography in-home recordings were made using Suzanne^{TM} (Tyco-Healthcare Group LP, Mansfield, MA, USA) portable polysomnographic systems. The sampling rate was 120 Hz and data were stored on PC flash memory cards, and then downloaded off-line onto a PC computer for further analysis. We recorded EEG, electrooculogram (EOG) (horizontal eye movements only), and EMG using silver-plated electrodes. The EEG (C3, C4, FZ, and PZ) and the EOG (right and left eyes) were monopolar recordings and referenced to contralateral electrodes at A1 and A2. The EMG channel was bipolar. For the EEG and EOG channels, the low-and high-pass software filters were set at 0.03 and 30 Hz. For the EMG channel, only frequencies above 10 Hz were recorded.

Three consecutive nights of in-home sleep recording were carried out. The data from recording night 1 were considered to reflect acclimatization to the apparatus and were discarded. Night 2 recordings were used as Baseline sleep data and night 3 recordings were used as PL sleep data. Participants were asked to adhere to their normal bedtime routines as much as possible, including keeping their usual bedtime and wake time.

Sleep stages were generally scored according to standard criteria (Rechtschaffen and Kales, 1968). However, we sometimes deviated slightly from traditional protocol when scoring the REM sleep stage. The appearance of spindles during REM sleep in the raw EEG was rare, and they only became more visible in the filtered channel. However, according to standard criteria, the observation of a spindle would normally signal an ending to the REM period and the beginning of a period of stage 2 with the appearance of other stage 2 indicators. It would also be expected that there would be some increased activity in the EMG channel. If there was absolutely no change in the EMG, no other sign of a stage 2 intrusion (such as a K- complex) and further REM bursts, the epoch was counted as REM sleep despite the appearance of a spindle. Sleep spindles were counted using the automated spindle counter PRANA® (PhiTools, Strasbourg, France). For each spindle type, an expert technologist identified and recorded the peak amplitudes of 15 spindles in each of the first and second halves of the night for stage 2 (30 spindles in total for each spindle type). Values were then used to calculate the mean and standard deviation of peak amplitude for each subject. The minimal amplitude criterion for the automated spindle counter was determined by subtracting 1.96 SD units from each mean. This procedure was repeated for each subject. Spindle activity was examined in each of the 11.00–13.50, 13.51–16.00, and 16.01–18.50 Hz range. Included in the study were spindle-like waves in the 16.01–18.50 Hz range. These waves share many characteristics of conventional spindle appearance and activity. We have previously described the properties of these waves and consider them to be a special spindle subset called 'superfast' spindles (Nader and Smith, 2015). This EEG activity appears to varying degrees in all individuals.

Intelligence was assessed using the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV) Canadian Edition. Tests were administered individually by a registered psychometrist. Five participants were assessed by the same psychometrist using the Wechsler Adult Intelligence Scale—Third Edition (WAIS-III) as they were above the age for the WISC-IV.

Prior to the third night of sleep, participants were administered the Pursuit Rotor task approximately two hours prior to normal bedtime, using an online program and a laptop computer (Fogel et al., 2007b). The pursuit rotor task requires participants to use the mouse to keep the cursor on a light as it travels around a path on the computer screen. Participants completed twenty 30-s trials prior to sleep on the third night. All subjects were able to perform the pursuit rotor task with no physical difficulty. The sleep recorded the night after acquisition of the task, was considered a post-training night which allowed us to determine whether there were any sleep-related changes due to acquisition of the learning task. They were retested exactly one week later, with another 20 trials (see **Figure 1**).

RESULTS

Learning Task

The measure used to assess degree of learning was the number of seconds that the subject was able to keep the cursor on a lighted dot as it moved around the path.

When all of our participants were used, a t-test revealed that there was a significant improvement in scores from the last 12 training trials ($M = 4.76$ s, $SD = 2.19$) to the first 12 re-test trials ($M = 5.79$ s, $SD = 2.58$), $t(32) = -3.66$, $p = 0.0009$, $d = -0.66$. Results indicate that the participants did successfully learn the pursuit rotor task.

A closer examination of the learning scores suggested that some individuals did not learn the task. Participants were then split into good performers vs. poor performers, using a median split on the assessed degree of improvement. A subsequent t-test showed that there was a significant difference in performance between the two groups, $t(31) = -7.37$, $p < 0.00001$, $d = -2.60$, with the good performers demonstrating significantly more improvement ($M = 2.28$ s, $SD = 1.11$) than the poor performers ($M = -0.28$ s, $SD = 0.86$).

Pubertal Development

Participants were assessed for the level of pubertal development using the Tanner Stages. To determine whether pubertal development was playing a role in performance on the pursuit rotor task, the score on the Tanner scale was correlated with our performance measure. There was no significant relationship between pubertal development and PR performance, $r(29) = -0.20$, $p = 0.29$. We also assessed whether the pubertal development was related to baseline sleep. There were no significant correlations between scores on the Tanner scale and percentage of stage 2, $r(29) = 0.29$, $p = 0.11$, percentage of SWS, $r(29) = -0.18$, $p = 0.35$, or percentage of REM, $r(29) = -0.16$, $p = 0.39$. Participants were separated by gender to ensure that there were no relationships between pubertal development and sleep and there were none found for females or males between Tanner scale and percentage of stage 2 [$r(15) = 0.20$, $p > 0.05$; $r(12) = 0.38$, $p > 0.05$, respectively], percentage of SWS [$r(15) = -0.11$, $p > 0.05$; $r(12) = -0.26$, $p > 0.05$, respectively] or percentage of REM [$r(15) = -0.06$, $p > 0.05$; $r(12) = -0.26$, $p > 0.05$, respectively].

Sleep Measures

The proportion of the night spent in each sleep stage was assessed prior to learning and after task acquisition (**Table 1**). SWS is

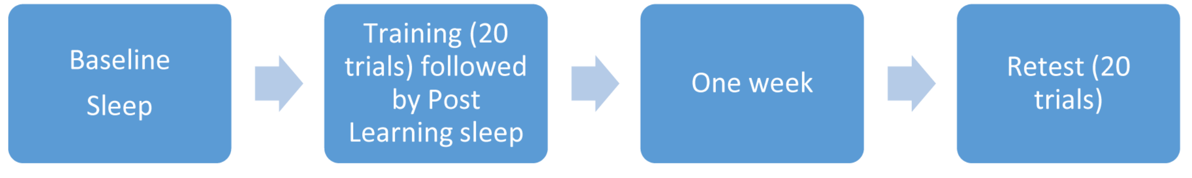

FIGURE 1 | Visual description of study design.

TABLE 1 | Mean and standard deviation of the percentage of time spent in sleep stages before and after learning (all participants).

	Stage 2%	SWS%	REM%
Baseline night	50.47 (6.87)	25.35 (6.56)	23.03 (5.48)
Post-learning night	47.67 (5.86)	26.13 (6.01)	25.02 (3.65)

composed of stages 3 and 4 combined as defined by Rechtschaffen and Kales (1968).

Learning and Sleep Measures

To test whether the level of learning was related to sleep, we examined the correlations between learning and sleep stage proportions. To begin, we examined the correlations between baseline sleep and how well-participants learned the pursuit rotor task. There were no correlations between stage 2% [$r(31) = -0.12$, $p = 0.50$], SWS% [$r(31) = 0.13$, $p = 0.47$] or REM% [$r(31) = -0.01$, $p = 0.94$], and performance on the learning task. Baseline sleep did not predict future learning.

The correlations were repeated separately for females and males. While neither gender showed significant relationships between percentage of the sleep stages and performance on the learning task, they did seem to show different patterns of relationships. Neither females nor males showed a significant correlation between baseline percentage of stage 2 and performance on the pursuit rotor [$r(15) = 0.24$, $p > 0.05$; $r(13) = -0.36$, $p > 0.05$, respectively], or percentage of SWS and pursuit rotor performance [$r(15) = 0.08$, $p > 0.05$; $r(13) = 0.15$, $p > 0.05$, respectively], or percentage of REM and pursuit rotor performance [$r(15) = -0.33$, $p > 0.05$; $r(13) = 0.29$, $p > 0.05$, respectively]. While none of these are significant, the differences between the males and females in the relationships between REM and stage 2 with pursuit rotor performance should be further investigated with more participants.

After task acquisition on night 3 (PL night), we observed a significant positive relationship between the proportion of stage 2 sleep and how well-participants learned the pursuit rotor, $r(30) = 0.37$, $p = 0.039$ (see **Figure 2**). There was also a significant negative correlation between the percentage of REM sleep and how well-participants learned, $r(30) = -0.44$, $p = 0.011$ (see **Figure 3**). There was no significant correlation between proportion of SWS on PL Night and how well-participants learned, $r(31) = -0.08$, $p = 0.68$. These relationships suggest while there was no relationship with baseline sleep and future learning, better performance on the pursuit rotor was associated with higher levels of stage 2 sleep and lower levels of REM sleep after learning.

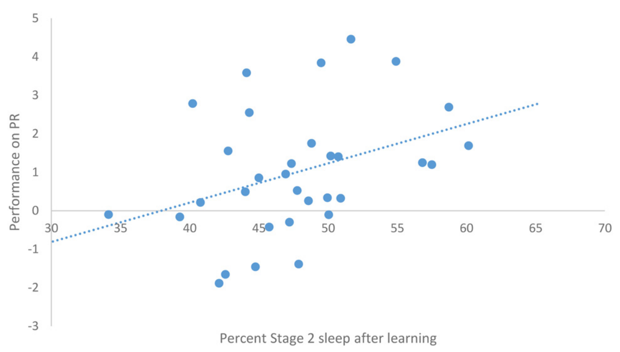

FIGURE 2 | Correlation between proportion of stage 2 sleep on PL night and performance on pursuit rotor (measured as improvement between training and testing).

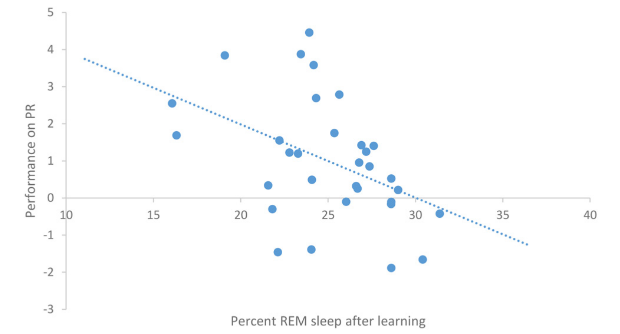

FIGURE 3 | Correlation between proportion of REM sleep on PL night and performance on pursuit rotor (measured as improvement between training and testing).

Again, the correlations were repeated for the females and males separately, to ensure that there were no gender differences. Both genders showed a similar pattern of relationships; both females and males showed a positive relationship (albeit not significant) between proportion of stage 2 sleep after learning and how well-participants learned the pursuit rotor task [$r(15) = -0.33$, $p > 0.05$; $r(13) = 0.41$, $p > 0.05$, respectively]. Both females and males showed no relationship between proportion of SWS on PL Night and how well they learned [$r(15) = -0.06$, $p > 0.05$; $r(13) = -0.08$, $p > 0.05$, respectively]. Females showed a significant negative relationship between the proportion of REM sleep on the PL Night [$r(15) = -0.55$, $p = 0.02$], but the relationship for males was not significant [$r(13) = -0.41$, $p > 0.05$].

Examination of the sleep stage proportions (minutes of particular sleep stage/total sleep) for all participants, showed no significant differences between Baseline and PL night in either percentage of SWS (25.35 and 26.13%, respectively), $t(31) = -1.03$, $p = 0.31$, $d = -0.18$, or percentage of REM sleep (23.03 and 25.02%, respectively), $t(31) = -1.97$, $p = 0.06$, $d = -0.36$. However, the change in percentage of REM sleep showed a strong trend toward an increase in REM sleep after learning. When examined separately, neither females nor males showed a significant change in percentage of SWS from Baseline to PL night [$t(16) = -0.79$, $p > 0.05$; $t(14) = -0.65$, $p > 0.05$, respectively]. The increase in REM from Baseline to PL night was not significant in either females or males [$t(16) = -1.32$, $p > 0.05$; $t(14) = -1.43$, $p > 0.05$, respectively]. There was a significant decrease in the proportion of stage 2 from Baseline (50.47%) to PL night (47.67%), $t(31) = 2.22$, $p = 0.03$, $d = 0.40$. Females and males both showed similar decreases in the proportion of stage 2 from Baseline to PL night, although neither reached significance [$t(16) = 1.47, p > 0.05$; $t(14) = 1.61, p > 0.05$, respectively].

To explore this further we looked at sleep stage proportions based on degree of learning of the pursuit rotor task, using the median split on performance scores. Good performers had a mean of 2.28 ($SD = 1.11$) and poor performers had a mean of −0.28 ($SD = 0.86$). We ran an ANOVA testing whether there was an interaction between sleep stage percent changes from Baseline to PL night and whether or not participants learned. There was a significant main effect of stage, $F(2,60) = 4.24, p = 0.019$, and a significant interaction between stage and whether or not learning occurred, $F(2,60) = 3.71, p = 0.03$. *Post hoc* Tukey tests revealed that participants who did not perform well on the pursuit rotor task showed a greater decline in the proportion of stage 2 sleep than those who showed better performance on the task (these last mentioned participants actually showed no change in proportion of stage 2). *Post hoc* tests also showed that poor performing participants also showed a larger increase in the proportion of SWS than participants who learned (good performers again, remained very consistent in the proportion of SWS from Baseline to PL night. Tukey tests also showed that participants who did not perform as well-increased the proportion of REM sleep significantly in comparison to those participants who showed better mastery on the PR. Good performers again, remained steady in the proportion of this sleep stage. **Figure 4** demonstrates the changes in sleep stage proportions.

IQ and Sleep Measures

To begin, we correlated full scale IQ (FSIQ; $M = 98.55$, $SD = 8.56$) with the performance on the pursuit rotor task (measured as the difference between training and testing). FSIQ was not significantly related to performance, $r(31) = 0.20$, $p = 0.28$.

Using a median split of FSIQ, we examined the changes in sleep stage proportions from Baseline to PL night. Lower IQ individuals had a mean IQ of 91.81 ($SD = 4.98$) and the higher IQ individuals had a mean of 104.88 ($SD = 5.94$). The results were very similar to those observed using performance scores. An ANOVA was run testing whether there was an interaction between sleep stage percent changes from Baseline to PL night and IQ. There was a significant main effect of stage, $F(2,60) = 4.20, p = 0.02$, but no significant effect of FSIQ, $F(1,30) = 0.23, p = 0.64$ and no significant interaction between stage and FSIQ, $F(2,60) = 1.26, p = 0.29$. A *post hoc* Tukey test revealed that there was a significant difference between the change in the proportion of stage 2 and the change in the proportion of REM sleep. The proportion of stage 2 sleep declined by 2.8% and the proportion of REM sleep increased by 1.99%.

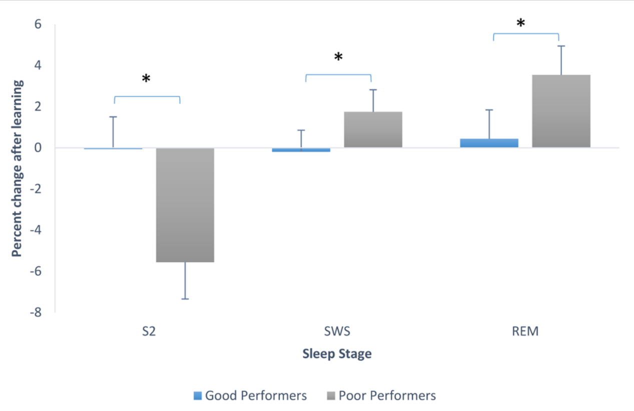

FIGURE 4 | Sleep stage percent changes from Baseline to PL night (after learning), separated by good performers and poor performers (bars indicate SE). SWS refers to combined S3 + S4.*$p < 0.001$.

Spindle Densities

To examine the hypothesis that learning would be related to spindle activity, we examined the correlations between spindle densities on PL night and learning but observed no significant relationships. Spindle density was chosen as the best way to assess spindle activity, because it allows us to easily compare across individuals, as it takes the time spent in stage 2 into account; it is the only measure which can truly assess an increase in the output of any spindle generator. Number of spindles alone may simply mean that there was an increase in stage 2 sleep. To confirm that there were no changes in spindle activity related to learning, we examined the spindle density differences from Baseline to PL night using three ANOVAs. The slow spindle density differences (11–13.5 Hz) were examined first in a 2 (poor performers vs. better performers) × 4 (electrode location) ANOVA, there was no main effect of learning, $F(1,25) = 0.64$, $p = 0.43$, and no main effect of electrode location, $F(3,75) = 0.10$, $p = 0.96$, and no interaction, $F(3,75) = 2.57, p = 0.06$. The fast spindle density differences (13.51–16 Hz) were also examined in a 2 (poor performers vs. better performers) × 4 (electrode location) ANOVA, similar to slow spindles, there was no main effect of learning, $F(1,25) = 0.74, p = 0.40$, and no main effect of electrode location, $F(3,75) = 1.54, p = 0.21$, and no interaction, $F(3,75) = 0.60, p = 0.62$. The superfast spindle differences (16.01–18.5 Hz) were also examined in a 2 (good performers vs. poor performers) × 4 (electrode location) ANOVA, similar to slow and fast spindles, there was no main effect of learning, $F(1,25) = 0.15$, $p = 0.70$, and no main effect of electrode location, $F(3,75) = 0.47$, $p = 0.70$, and no interaction, $F(3,75) = 0.45, p = 0.72$.

DISCUSSION

The pursuit rotor task is a well-used task for procedural learning (Smith and MacNeill, 1994; Smith et al., 2004b; Fogel and Smith, 2006; Peters et al., 2007). Researchers using the pursuit rotor have demonstrated good learning with the task (e.g., Peters et al., 2007), our participants did show significantly improved performance at re-test time, but they did not seem to show exceptionally high scores. Participants may not have demonstrated optimal performance due to the nature of the task. It was not a particularly engaging task for adolescents who were likely used to much more action-oriented video games with elaborate color graphics. It is suggested for future research that a more engaging procedural task be used with adolescent participants to ensure maximum attention and engagement with the task.

Our findings of no relationship between spindle density changes and learning, while not what we predicted, are similar to the findings of Peters et al. (2008) who found that spindle density changes were dependent upon learning after task acquisition. Our participants did learn, but the increase in performance was not very large and this may explain why we did not observe a significant relationship between spindle activity and performance on the pursuit rotor. In order to induce larger changes in spindle density a more intensive task may be required, or simply one that is more engaging for the adolescent population.

Our baseline measures of sleep suggest that the adolescents in our group had normal sleep stage proportions prior to learning the task (Coble et al., 1984). We ran correlations to examine the link between baseline sleep measures and learning potential (measured as performance on the pursuit rotor). Baseline sleep measures were unable to predict later performance on the pursuit rotor task, suggesting that ability to perform this simple procedural task cannot be inferred from an individual's normal sleep patterns. These findings of no relationship between the baseline number of spindles and performance on the pursuit rotor, is in agreement with the findings of Peters et al. (2008) who also found that there was no correlation between baseline spindle density and motor performance. On the other hand, they are at variance with the results reported by Fogel et al. (2007b) and Fogel and Smith (2011). It is possible that with a more intensive learning paradigm, we may have seen some effects.

We did not observe any significant correlations between baseline sleep measures and motor performance when we separated our group by gender. However, males and females appeared to show opposite tendencies in the relationship between baseline REM and future motor performance and in the relationship between baseline stage 2 and future performance. Males showed a tendency toward a negative relationship between the proportion of baseline stage 2 and motor learning, whereas females showed a tendency toward a positive relationship between the variables. In contrast, males showed a tendency toward a positive relationship between the proportion of baseline REM sleep and motor performance, whereas females showed a tendency toward a negative relationship. These seemingly opposite tendencies may be due to a number of things. Ujma et al. (2014) suggest that there is a sexual dimorphism in the relationship between sleep spindle parameters and intelligence and our findings may similarly show that there are differences between the genders in the mechanisms responsible for learning. However, it would be inappropriate to speculate further on these non-significant results.

The positive correlation between percentage of stage 2 after learning and performance on the pursuit rotor, suggests that better learning is associated with higher levels of stage 2. However, these results need some qualification. We observed that participants who did not learn the task showed a decrease in the proportion of stage 2 sleep, whereas individuals who did learn the task simply maintained the percentage of stage 2 sleep that they had before learning the task. This suggests that while better learning is associated with higher levels of stage 2, it is actually because those who did not learn spent less time in that stage.

While the expected increases in spindle activity with learning did not occur in these adolescents, there was an interesting set of sleep changes that were clearly consistent with the two stage model of Smith et al. (2004a). In this model, participants exposed to a motor learning task with which they generally had had some previous experience show PL increases in stage 2 and density of stage 2 sleep spindles but no changes in REM sleep. These individuals appear to be refining a motor program that is already in place. However, participants that find the task to be new and novel show PL increases in REM sleep, but no changes in stage 2. These last individuals appear to need a new conceptual approach to learn the task, and this is reflected in an increase in REM sleep.

Examining all participants, we observed a decrease in the proportion of stage 2 sleep and a trend toward an increase in the proportion of REM sleep. By splitting the participants into those that performed better on the task and those who had poor performance in comparison, the changes in sleep become more obvious. While the participants in the present study that performed better on the pursuit rotor task showed no stage 2 or REM sleep changes, the poor performers did show these kinds of changes. As might be expected of participants that found the task extremely difficult and required a new cognitive approach, the non-learners showed an increase in REM sleep relative to the learners. As well, they also showed a drop in stage 2 (and by consequence number of spindles) that was not present in the learning group. The results might be interpreted as being parallel to the results in studies where the two groups did learn these tasks (Peters et al., 2008; Fogel and Smith, 2011). When the individual finds the task to be novel and has had no previous similar experience, the preferred sleep state was REM at the expense of stage 2. More difficult to understand was the significant increase in SWS. This stage has been considered to be important for declarative memory as opposed to procedural memory tasks (Gais and Born, 2004). It is possible that the adolescents in this study treated the task as declarative in part. More likely, they were showing a sleep response specific to their age group when exposed to a motor learning task. Only further studies using the same age group will clarify this.

The expected increase in spindle densities with learning, was not observed in these adolescents. This is in contrast to research which suggests that memory consolidation is linked to an increase in spindle activity (Fogel and Smith, 2011). However, as discussed, not all research points to the same conclusion. Peters et al. (2008) found that only the young adults showed this increase, whereas the older adults did not. This suggests that there are age-related differences and may be partly why our adolescents showed no significant changes in density. Peters et al. also suggested that the increase is performance dependent – only subjects who learned sufficiently, showed the expected increase in spindle activity. As discussed, our adolescents did not perform particularly well on the pursuit rotor task, and this may also help to explain the lack of relationship. Further, Fogel et al. (2007a), Schabus et al. (2008), and Fogel and Smith (2011) suggested that the changes in spindle activity are linked to intelligence, and may only be observed in individuals with higher IQ scores.

This study does contain some limitations which need to be addressed. First, we did not have a control 'wake' group, although we would argue that in this case one is not necessary. Our focus was on the effect of learning on sleep architecture, rather than examining how different sleep patterns affect learning. In future studies, it would be of interest to examine both effects, and in this case, having a wake group would contribute valuable information. Also, as mentioned earlier, a more captivating task may be required for this age group and may help to clarify the effect that learning procedural skills may have on later sleep. We were also limited in the sleep measures we could examine because of our take-home recording system, and future studies may want to examine sleep characteristics such as sleep efficiency and WASO, but these measures are more important for sleep disorder groups and the elderly. We did not employ sleep logs or actigraphy in our study, but the participants were a group of adolescents who were all on regimented schedules, these were not subjects who had variable sleep schedules.

AUTHOR CONTRIBUTIONS

Work is part of the Ph.D. thesis of RN. AM was heavily involved in the EEG scoring of the sleep data and helped in the basic design of the study. CS is the senior advisor and director of the lab, he provided basic direction for the implementation of the research study.

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