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During day and night: Childhood psychotic experiences and objective and subjective sleep problems

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ABSTRACT

Background: Psychotic experiences comprise auditory and visual perceptive phenomena, such as hearing or seeing things that are not there, in the absence of a psychotic disorder. Psychotic experiences commonly occur in the general pediatric population. Although the majority of psychotic experiences are transient, they are predictive of future psychotic and non-psychotic disorders. They have been associated with sleep problems, but studies with objective sleep measures are lacking. This study assessed whether psychotic experiences were associated with actigraphic sleep measures, symptoms of dyssomnia, nightmares, or other parasomnias.
Methods: This cross-sectional population-based study comprises 4149 children from the Generation R Study. At age 10 years, psychotic experiences including hallucinatory phenomena were assessed by self-report; dyssomnia and parasomnia symptoms were assessed by mother- and child-report. Additionally, at age 11 years, objective sleep parameters were measured using a tri-axial wrist accelerometer in $N = 814$ children, who wore the accelerometer for five consecutive school days.
Results: Psychotic experiences were not associated with objective sleep duration, sleep efficiency, arousal, or social jetlag. However, psychotic experiences were associated with self-reported dyssomnia (B = 2.45, 95%CI: 2.13–2.77, $p < 0.001$) and mother-reported parasomnia, specifically nightmares ($OR_{adjusted} = 3.59$, 95%CI 2.66–4.83, $p < 0.001$). Similar results were found when analyses were restricted to hallucinatory phenomena.
Conclusions: Childhood psychotic experiences were not associated with objective sleep measures. In contrast, psychotic experiences were associated with nightmares, which are a known risk indicator of psychopathology in pre-adolescence. More research is needed to shed light on the potential etiologic or diagnostic role of nightmares in the development of psychotic phenomena.

1. Introduction

Psychotic experiences compromise auditory and visual perceptive phenomena, such as hearing or seeing things that are not there, or delusional thoughts, in the absence of a psychotic disorder (Kelleher et al., 2010). With a prevalence around 7%, psychotic experiences are common in the general adult population (Linscott and van Os, 2013). The prevalence is particularly high in children aged 9 to12 years with rates up to 17%, whereas in adolescence the prevalence declines to 7.5% (Kelleher et al., 2012a; Kelleher et al., 2012b). It is important to study

Abbreviations: BSI, Brief Symptom Inventory; CBCL, Child Behavior Checklist.

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childhood psychotic experiences because children, who report such symptoms in late childhood or early adolescence, have a 5 to 16 times higher risk for developing psychotic disorders in adulthood (Kelleher and Cannon, 2011; Poulton et al., 2000; Welham et al., 2009). Indeed, psychotic experiences share a genetic risk with psychotic disorders (Jeppesen et al., 2015b; Zavos et al., 2014). Further, children with psychotic experiences are at increased risk for various non-psychotic psychopathologies, such as bipolar disorder, suicidal behavior, anxiety, and depressive disorders (Kelleher et al., 2012b; McGrath et al., 2016; Wigman et al., 2011), which highlights the trans-diagnostic characteristics of psychotic experiences and supports the need to have a better understanding of their etiology and development across childhood and adolescence.

Sleep problems, such as insufficient sleep, symptoms of dyssomnia (including insomnia or excessive sleepiness), and symptoms of parasomnia (a comprehensive term for nighttime behaviors including sleep-walking, sleep-talking, and nightmares) (Fleetham and Fleming, 2014; Mason 2nd and Pack, 2007), are considered as possible triggers of psychotic experiences across age groups (Lee et al., 2012; Oshima et al., 2010; Reeve et al., 2017; Reeve et al., 2015; Taylor et al., 2015; Thompson et al., 2015). In adults, sleep problems are associated with both severity and number of psychotic experiences (Andorko et al., 2017; Reeve et al., 2015). Similarly, in high-risk adolescent populations shorter sleep duration and parasomnia have been associated with psychoses (Lunsford-Avery et al., 2015; Lunsford-Avery and Mittal, 2013; Ruhrmann et al., 2010). A few studies using self- or mother-reported measures of sleep problems have been conducted in pediatric populations (Jeppesen et al., 2015a; Lee et al., 2012) and found that psychotic experiences co-occur with self-reported sleep problems (Jeppesen et al., 2015a). Consistent with this, others report that psychotic experiences in adolescence often are preceded by severe nightmares in childhood (Fisher et al., 2014). While there is a rising interest in the role of sleep problems in the development of psychotic experiences, so far very few clinical studies and no population-based studies used objective measures of sleep to study this association. Addressing this gap can help elucidate the developmental mechanisms behind the association between objectively assessed sleep difficulties and psychotic experiences in childhood. In this study, we investigated in a general pediatric population whether childhood psychotic experiences are associated with actigraphically measured sleep duration, sleep efficiency, and arousal. Additionally, previous literature points at the difference of week and weekend sleep in late childhood and adolescents; teenagers tend to sleep less during schooldays and make up for this during weekend days by rising later and sleeping longer (Carskadon, 2011; Crowley et al., 2018). Thus, we calculated the "social jetlag". Social jetlag is the discrepancy in sleep between school days and weekend days (Wittmann et al., 2006). Third, we investigated whether childhood psychotic experiences are associated with self- or mother-reported sleep problems such as dyssomnia and parasomnia symptoms. We examined the associations between our various sleep measures and hallucinatory phenomena specifically as these have been shown to be most predictive of clinically-confirmed psychotic symptoms (Kelleher et al., 2011). Based on previous population-based studies (Fisher et al., 2014; Jeppesen et al., 2015a; Lunsford-Avery et al., 2015), we expect that psychotic experiences in childhood are associated with objective shorter sleep duration and reported sleep dysfunction, such as symptoms of dyssomnia and parasomnia.

2. Methods

2.1. Design and study population

This cross-sectional study was embedded in Generation R Study, a prospective population-based cohort from foetal life onwards. Women who were pregnant between April 2002 and January 2006 and living in Rotterdam were eligible for participation (61% included). This sample was largely representative of the Rotterdam female population (Jaddoe et al., 2006). The Generation R Study aims to identify genetic and environmental risk factors for the growth and development of mothers and children.

All 7393 participants who consented in the age 10 assessment wave received questionnaires and were invited at the research centre for objective behavioural assessment (Kooijman et al., 2016). Children without information on psychotic experiences or sleep problems were excluded ($n = 3244$) yielding a sample size of 4149 children for the present study.

The subsample of 1153 children was selected based on the following criteria: first we selected participants who had participated within the Generation R Focus Study: This includes participants with good follow-up rates (Kooijman et al., 2016). Ethnic minorities were not included in order to address genetic and epigenetic questions. Second, we oversampled children who were born premature in this study to counter the selection effects observed for children born preterm. Indeed, our subsample showed similar rates of premature children to the total cohort. Due to logistic reasons, the accelerometer data collection was conducted nearly one year after the 10 years (questionnaire) assessment. Of the invited children, 953 participants consented to participate (response rate of 82%). Children were excluded from the analyses if data on weekday sleep was not available or when data did not pass standard quality control. Data were excluded if the actigraphy wear time was under 6 h or if sleep time was under 4 h. Sleep time under 4 h was often due to exceptional social activities and field trips in this population and did not reflect typical patterns or insomnia (Acebo et al., 1999; Meltzer et al., 2012). The final sample consisted of 814 children with information on psychotic experiences and good quality actigraphy measures on objective sleep (mean age 11.7 years, SD = 0.20). The children participating in the subsample were more often of Dutch nationality and had mothers with higher educational levels and lower levels of psychopathology (all $p < 0.001$). However there were no differences between the total sample and the actigraphy sample on mother- and self-reported exposure and outcome variables. The Medical Ethics Committee of the Erasmus Medical Center approved all study procedures, and all parents provided written informed assent.

2.2. Measures

2.2.1. Psychotic experiences

Psychotic experiences were assessed by self-report questionnaire using three items derived from the widely used Youth Self-Report (Ivanova et al., 2018): "I hear sounds or voices that according to other people are not there", "I see things that other people think are not there", "I have thoughts that other people would find strange". Responses were scored on a three-point scale, i.e. "Not at all", "A bit" or "Clearly". Responses from all three items were summed to calculate a total score which ranged from 0 to 6, with higher scores indicating more psychotic experiences; the correlation between the items was moderate to large (0.38–0.56). Scores were classified into the following categories: no symptoms (0 points), some symptoms (1–3 points), and several symptoms (4–6 points). To asses hallucinatory phenomena separately, we combined the two hallucinatory phenomena questions to a hallucinatory phenomena score categorized as: no symptoms, some symptoms (1–2 points), and several symptoms (3–4 points). These cut-offs were chosen so that the children in the upper category would have endorsed "clearly" on at least one of the items.

2.2.2. Objective sleep measures

Sleep was assessed using a tri-axial wrist accelerometer (GENEActiv; Activinsights, UK) which children wore for nine subsequent days (five school days and four weekend days) on their non-dominant wrist. The GENEActiv accelerometers record raw accelerometer data; for the current study accelerometers were set at a frequency of 50 Hz, which allowed us to use the accelerometers for 14 subsequent days without

recharging and in line with another study (Ronnlund et al., 2016; Sahlberg et al., 2018). The GENEActiv PC software version 2.2 was used to download the raw data as binary files. The binary files were processed using the R-package GGIR (van Hees et al., 2014).The processing included auto calibration with gravity as reference, detection of atypical values and non-wear. The algorithm is using an accelerometer-derived arm angle averaged over 5-s epochs to detect sleep. If there is no arm-movement larger 5° for at least 5 min this will be classified as a period of sustained inactivity or sleep. This procedure generated the following sleep measures: sleep duration, sleep efficiency, and sleep arousal (van Hees et al., 2015). Sleep duration is the total time classified as sleep during the night, indicating the time between falling asleep and waking minus the time lying awake. Sleep efficiency is the total sleep duration divided by bed time and waking time. Arousal is the number of sleep periods during the night, the higher the number awakenings, the higher the arousal. We calculated social jetlag by taking the average midpoint sleep during the weekend subtracted by the average midpoint sleep during week (Wittmann et al., 2006). For the measures of sleep duration, sleep efficiency, and sleep arousal only school days were included in the analyses, representing the typically pattern of weekday sleep to minimize the influence of atypical weekend events.

2.2.3. Multi-rated sleep problems

2.2.3.1. Self-reported dyssomnia. At age 10 years, dyssomnia symptoms were assessed by self-report questionnaire asking six questions about their perceived sleep i.e. “Do you find it difficult to go to bed?”; “Do you find it difficult to fall asleep?”; “Do you think you get enough sleep?”; “If you wake up at night, do you find it difficult to fall asleep again?”; “Do you feel rested when you wake in the morning?”; “When you come out of your bed in the morning, do you feel rested?”. These questions were derived from the widely used Sleep Disturbance Scale for Children (SDSC) (Bruni et al., 1996) and slightly rephrased for our pediatric population. Similar questions can be found in other sleep scales for children such as the Sleep Self Report (Owens et al., 2000), and School Sleep Habits Survey (Wolfson and Carskadon, 1998). There were three possible responses for each item: “No”, “Sometimes” or “Yes”, which were scored on a Likert scale. Responses from all six items were summed to calculate a total score with an internal consistency of $\alpha = 0.64$, higher scores indicate more dyssomnia problems.

2.2.3.2. Mother-reported child sleep problems. At age 10 years, children's sleep problems were quantified using the Child Behavior Checklist 6–18 (CBCL), a reliable and valid measure for behavioural problems (Achenbach and Ruffle, 2000; Verhulst and van der Ende, 2013). The CBCL was completed by the primary caregiver, in the majority of cases the mother, who rated various sleep problems of the child in the previous two months on a three-point Likert scale (0 = not true, 1 = somewhat true, 2 = very true).

In line with a previous study (Verhoeff et al., 2018), we selected 5 items from the CBCL/6–18 questionnaire a priori because there is no established subscale for measuring sleep problems from the CBCL/6–18. We ran a confirmatory factor analysis in order to construct a sleep problems scale at 10 years and to examine which questions loaded together. This resulted in a two-factor solution (combined internal consistency of $\alpha = 0.52$). The first factor compromised 3 questions representing dyssomnia symptoms: “Trouble with sleeping”; “Sleeps less than most kids”; “Overtired with no good reason” (internal consistency of $\alpha = 0.55$), the second factor compromised 2 questions representing parasomnia symptoms: “Nightmares” and “Talks or walks in sleep” (internal consistency of $\alpha = 0.33$).

2.2.4. Mother-reported child emotional and behavioural problems

The CBCL/6–18 was also used to assess child emotional and behavioural problems at age 10 years, (Achenbach and Rescorla, 2001). The CBCL/6–18 consists of 8 syndrome scales: anxious/depressed, withdrawn/depressed, somatic complaints, social problems, thought problems, attention problems, rule-breaking behaviour, and aggressive behaviour measured on a continuous severity scale. Items were scored by mothers on a three-point scale (0 = not true; 1 = somewhat true; 2 = very true), based on behaviour in the past six months. We computed a total problem scale including all items of the CBCL and excluding the items measuring sleep problems.

2.3. Confounders

Based on previous literature we considered the following confounders (Kelleher and Cannon, 2011; Morgan et al., 2009). Sleep problems and psychotic experiences are both associated with age, ethnicity, and sex of the child (Kelleher and Cannon, 2011; Sadeh et al., 2000; Spauwen et al., 2003). Likewise, both sleep problems and psychotic experiences are related to maternal educational level and psychopathology, such as depressive symptoms (Kelleher and Cannon, 2011; Sadeh et al., 2000). Gestational age was added as a confounder because we specifically added children born prematurely to this study. Sex and age of the children were obtained from the medical records completed by community midwives and obstetricians. Child ethnicity was considered as Dutch when both parents were born in the Netherlands, while children were classified as non-Dutch if at least one of the parents was born outside the Netherlands (further specified as ‘Other Western’ or ‘Other Non-Western’). Information on maternal educational level was obtained by questionnaires during pregnancy. Maternal education was defined by the highest attained educational level and classified into three categories (low, middle, and high education). Finally, maternal depressive symptoms were assessed using the Brief Symptom Inventory (BSI) (De Beurs, 2004) when child was at mean age 10 years.

2.4. Statistical analysis

Self-reported dyssomnia was square root transformed in order to approach normality as on inspection of the data self-reported dyssomnia was not normally distributed. Because of the low prevalence of sleep problems, we categorized the scores for mother-reported dyssomnia into two categories, “no or one symptom” and “two or more symptoms” and mother-reported parasomnia into two categories, “no symptoms” and “one or more symptoms”. First, we tested the association of psychotic experiences with objective sleep-duration, sleep efficiency, arousal, and social jetlag in those with accelerometer data using linear regression models. Second, we analysed the association of psychotic experiences with self-reported continuous dyssomnia symptoms using linear regression. Next, to test the association of psychotic experiences with mother-reported symptoms of dyssomnia, parasomnia, and more specifically nightmares, sleep walking and sleep talking, we conducted logistic regression analyses for these binary outcome variables. All analyses were repeated separately for hallucinatory phenomena, considered the most typical positive symptom of the psychosis continuum (Kelleher and Cannon, 2011). Analyses were adjusted for the confounders, described above. To reduce bias due to missingness, missing data on the confounders were ten times imputed. All analyses were conducted in SPSS version 24 (IBM Corporation).

2.5. Sensitivity analyses

For sensitivity analysis, models concerning objective sleep measures were rerun using combined weekend plus weekday sleep as it has been suggested that weekend sleep may better represent children's natural sleep (Snell et al., 2007). In an additional step we adjusted for concurrent child psychopathology assessed with mother-reported CBCL, in order to derive specific insight into the association between psychotic experiences and sleep problems. Further, in order to obtain the estimates for the sleep duration of all weekday nights and psychotic

Table 1
Characteristics of the study population.

	N	Total sample $N = 4149$	N	Accelerometer sample $N = 814$
Child characteristics				
Sex (% girls)	2111	50.9	814	52.6
Ethnicity	4149		814	
Dutch %	2814	67.8	691	84.9
Other western %	348	8.4	45	5.5
Nonwestern %	987	23.8	78	9.6
Psychotic experiences	4149		814	
No symptoms %	2261	54.5	404	49.6
Some symptoms %	1641	39.6	352	43.2
Several symptoms %	247	6.0	58	7.1
Hallucinatory phenomena	4149		810	
No symptoms %	2865	69.1	546	67.1
Some symptoms %	1076	25.9	221	27.3
Several symptoms %	208	5.0	43	5.3
Dyssomnia (child-reported)	4074	10.9(2.5)	802	11.0(2.5)
Dyssomnia (mother-reported)	4118		814	
Sometimes %	489	11.8	88	10.8
Not at all %	3629	87.5	694	685.3
Parasomnia	4121		814	
Sometimes %	1141	27.5	216	26.5
No or one symptom%	2980	71.8	566	69.5
Nightmares	4121		814	
Sometimes %	711	17.1	126	14.6
Not at all %	3422	82.5	668	77.2
Sleep (weekday)				
Duration (hours: minutes)	–	–	814	8:00(0:36)
Efficiency %	–	–	814	82.3(5.2)
Arousal (number awakenings)	–	–	814	24.3(3.3)
Social jetlag (hours:minutes)	–	–	813	0:45(1:01)
Maternal characteristics				
Age at inclusion (years)	4149	31.6 (4.6)	814	32.2 (3.9)
Educational level	4149		814	
No education/primary school %	200	4.8	14	1.8
High school/lower vocational training %	1605	38.7	254	32.1
Higher vocational or academic training %	2344	56.5	523	66.1
Depressive symptoms	4149	0.2(0.4)	814	0.2(0.3)

Data represent means (SDs) unless specified otherwise.

experiences, sensitivity analyses were conducted including nights with <4 h sleep duration. Finally, post-hoc Bonferroni adjustments were carried out for our 8 hypotheses, yielding more conservative alphas ($\alpha = 0.05/8 = 0.00625$).

3. Results

Characteristics of the study population are presented in Table 1. High scores ('several symptoms') of psychotic experiences were reported by 6.0% of the children.

3.1. The association of psychotic experiences with objective weekday-sleep

Psychotic experiences were not associated with objective sleep duration (B = −0.04,95%CI: −0.17–0.09), sleep efficiency (B = 0.33,95%CI:−0.82–1.48), arousal (B = −0.29,95%CI: −1.06–0.48), or social jetlag (B = −0.20,95%CI:–0.52–0.12) (Table 3). Similarly, hallucinatory phenomena were not associated with sleep duration (B = 0.07,95% CI:−0.11–0.26), sleep efficiency (B = 1.11,95% CI: −0.68–2.90), arousal (B = −0.62,95% CI:−1.66–0.43), and social jetlag (B = −0.26,95%CI:−0.71–0.18) (Table 2).

3.2. The association of psychotic experiences with sleep problems

3.2.1. Self-reported sleep problems

Psychotic experiences were associated with higher levels of self-reported dyssomnia (B = 2.45, 95%CI: 2.13–2.77,). Likewise, when examined separately, hallucinatory phenomena were associated with higher levels of dyssomnia (B = 2.02, 95%CI: 1. 69–2.40) (Table 3).

3.2.2. Mother-reported sleep problems

Psychotic experiences were also associated with mother-reported dyssomnia ($OR_{adjusted} = 3.48$, 95%CI: 2.48–4.89). Similarly hallucinatory phenomena by itself were associated with mother-reported and dyssomnia ($OR_{adjusted} = 2.31$, 95%CI: 1.59–3.35). We observed a dose-response relationship of psychotic experiences with mother-reported dyssomnia and also of hallucinatory phenomena with mother-reported dyssomnia. For parasomnia, results indicated that more psychotic experiences were related to higher levels of mother-reported parasomnia, and specifically, more nightmares. The association between psychotic experiences of the child was not present for sleep walking or sleep talking (data not shown), indicating that the association for parasomnia was driven mainly by nightmares ($OR_{adjusted} = 3.59$,95% CI: 2.66–4.83). When analyzing hallucinatory phenomena specifically, the same dose-response relationship was observed; children with hallucinatory phenomena were more likely to have more mother-reported nightmares ($OR_{adjusted} = 2.74$,95% CI: 1.99–3.78) (Table 3).

3.3. Sensitivity analyses

The results were essentially unchanged when we analysed objective sleep measures including weekend sleep (Table S1). When we additionally adjusted for co-occurring child emotional and behavioural problems the null findings for objective sleep measures remained. The observed association of psychotic experiences and self-reported dyssomnia symptoms also remained but was slightly attenuated (B = 2.16, 95%CI: 1.84–2.48, $p < 0.001$). Likewise, when tested hallucinatory phenomena separately, hallucinatory phenomena were associated with higher levels of dyssomnia (B = 1.75,95% CI: 1.40–2.10, $p < 0.001$). Also, the association psychotic experiences and mother-reported dyssomnia symptoms remained but was attenuated ($OR_{adjusted}$

Table 2
The association of psychotic experiences and hallucinatory phenomena with weekday-sleep in preadolescence.

	Sleep duration, hours: minutes N = 814			Sleep efficiency, % N = 814			Arousal, no N = 814			Social jetlag $N = 813$		
	B	95% CI	p	B	95% CI	p	B	95% CI	p	B	95% CI	p
Psychotic experiences												
No symptoms	0	(ref.)		0	(ref.)		0	(ref.)		0	(ref.)	
Some symptom, yes	0.00	−0.08–0.10	0.960	−0.05	−0.83–0.74	0.903	0.17	−0.33–0.67	0.511	−0.03	−0.24–0.19	0.820
Several symptoms, yes	−0.04	−0.17–0.09	0.551	0.33	−0.82–1.48	0.588	−0.29	−1.06–0.48	0.452	−0.20	−0.52–0.12	0.240
Hallucinatory phenomena												
No symptoms	0	(ref.)		0	(ref.)		0	(ref.)		0	(ref.)	
Some symptom, yes	−0.03	−0.10–0.08	0.534	0.21	−0.22–0.64	0.621	0.28	−0.24–0.81	0.293	−0.09	−0.31–0.14	0.454
Several symptoms, yes	0.07	−0.11–0.26	0.452	1.11	−0.68–2.90	0.192	−0.62	−1.66–0.43	0.255	−0.26	−0.71–0.18	0.261

The associations were adjusted for sex, child's ethnicity, age at sleep assessment, gestational age, maternal education, and maternal psychopathology.

Table 3
The association of psychotic experiences and hallucinatory phenomena with multi-rated sleep problems at age 10 years in the total sample.

	Child-reported			Mother-reported								
	Dyssomnia N = 4074			Dyssomnia N = 4118			Parasomnia N = 4121			Nightmares N = 4121		
	B	95% CI	p	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
Psychotic experiences												
No symptoms	0	(ref.)		0	(ref.)		0	(ref.)		0	(ref.)	
Some symptom, yes	1.22	1.06–1.37	<0.001	1.93	1.57–2.38	<0.001	1.48	1.28–1.71	<0.001	1.83	1.54–2.19	<0.001
Several symptoms, yes	2.45	2.13–2.77	<0.001	3.48	2.48–4.89	<0.001	2.56	1.94–3.36	<0.001	3.59	2.66–4.83	<0.001
p for trend		<0.001			<0.001			<0.001			<0.001	
Hallucinatory phenomena												
No symptoms	0	(ref.)		0	(ref.)		0	(ref.)		0	(ref.)	
Some symptom, yes	1.11	0.96–1.31	<0.001	1.67	1.35–2.06	<0.001	1.55	1.33–1.81	<0.001	1.93	1.61–2.31	<0.001
Several symptoms, yes	2.02	1.69–2.40	<0.001	2.31	1.59–3.35	<0.001	2.12	1.57–2.84	<0.001	2.74	1.99–3.78	<0.001
p for trend		<0.001			<0.001			<0.001			<0.001	

The associations were adjusted for sex, child's ethnicity, age at sleep assessment, gestational age, maternal education, and maternal psychopathology.

= 2.12,95% CI: 1.47–3.05, $p < 0.001$) if adjusted for child emotional and behavioural problems. Importantly, when analyses were restricted to hallucinatory phenomena the association between psychotic experiences and mother-reported dyssomnia disappeared. The association for psychotic experiences and mother-reported nightmares remained if adjusted for child emotional and behavioural problems, but with a smaller OR, ($OR_{adjusted}$ = 2.50,95% CI: 1.83–3.43, $p < 0.001$); similarly the association specifically for hallucinatory phenomena with nightmares was attenuated ($OR_{adjusted}$ = 2.00, 95% CI: 1.42–2.81, $p < 0.001$) (Table S2) by this adjustment. Results did not change when we reran a sensitivity analysis including the nights with a sleep duration shorter than 4 h (B = −0.04, 95% CI: −0.17 to 0.10, $p = 0.61$; B = 0.08, 95% CI: −0.11 to 0.26, $p = 0.41$) for psychotic experiences and hallucinatory phenomena, respectively. All statistically significant results survived the multiple testing corrections.

4. Discussion

In this population-based study we extended previous findings (Fisher et al., 2014; Jeppesen et al., 2015a) by examining how psychotic experiences and hallucinatory phenomena were associated with objective measures of sleep duration. To the best of our knowledge, this study is the first to examine the association of objective and subjective sleep parameters with psychotic experiences in youth. We found no association of psychotic experiences or hallucinatory phenomena with objective sleep duration, sleep efficiency, arousal, or social jet lag. We found that psychotic experiences were consistently associated with subjective sleep problems across raters. Consistent with this, we observed a dose-response association, whereby more child-reported psychotic experiences were associated with higher levels of mother-reported dyssomnia and parasomnia. Taken together, our findings suggest that in the general pediatric population psychotic experiences co-occur with multi-rated sleep problems and most strongly with nightmares.

Our finding that psychotic experiences were not associated with observed sleep problems is at odds with prior studies. Previous studies using actigraphic measures of sleep in young people at high risk for psychosis, reported shorter sleep duration, and more fragmented sleep during the prodromal phase prior to the onset of psychosis (Lunsford-Avery et al., 2015; Lunsford-Avery and Mittal, 2013). The literature about circadian rhythm may help to clarify the seemingly conflicting results. Adolescents at high risk for psychosis often display alterations in circadian rhythm, indicating that more desynchronized day-night rhythms might result in recurrence of psychotic episodes (Lunsford-Avery et al., 2017). Important clues for the construction of the circadian rhythm are Zeitgebers. Zeitgebers are events such as exposure to light, timing of food intake, but also occupational or educational obligations (Golombek and Rosenstein, 2010). Potentially, these Zeitgebers, in particular the fixed school schedule, of the relatively young children in our sample may have been protective against developing desynchronized day-night rhythms, and subsequently prevented sleep problems occurring.

We found that child self-reported psychotic experiences are associated with mother-reported parasomnia symptoms, and especially nightmares. As the phenotypical resemblance between nightmares and psychotic experiences, child self-reported psychotic experiences might be particularly susceptible to information bias and thereby over-reporting by the child (van der Steen et al., 2018). Of note, a previous study demonstrated that screening questions for psychotic experiences in the general pediatric population have a high level of accuracy for psychotic symptoms confirmed by clinical interview (Kelleher et al., 2011). The endorsement of child self-reported psychotic experiences was similar to that observed in previous work using clinical interview assessments (Kelleher et al., 2012a; Polanczyk et al., 2010). Additionally, our findings cannot be explained by shared method, i.e. reporter, bias because our observations were based on different reporters and instruments. Our finding that psychotic experiences and hallucinatory phenomena are associated with nightmares is in line with previous work (Fisher et al., 2014; Jeppesen et al., 2015a; Lee et al., 2012; Thompson et al., 2015). Both psychotic experiences during the day and nightmares indicate subjective experiences produced by spontaneous neural activity (Feinberg, 2011). Although, some studies report fluid passages between sleeping and waking state may result in hallucinatory phenomena (Arnulf et al., 2000; Manni and Mazzarello, 2001) suggesting some sort of continuity between nightmares and hallucinatory phenomena, there is no reason to consider them part of the same phenomenon. Several other studies point out that nightmares and hallucinatory symptoms are physiologically different (Rek et al., 2017; Waters et al., 2016). Nightmares during REM-sleep are characterized by pre-frontal area "closed-loop circuits" (Waters et al., 2016), whereas hallucinatory phenomena are characterized by abnormally modulated connections between anterior frontal areas and posterior sensory regions (Hoffman and Hampson, 2011; Jardri et al., 2011). Additionally, nightmares and psychotic experiences are different in terms of parental awareness. Parents are often not aware of psychotic experiences of their children (Kelleher et al., 2011), but know of their nightmares. Potentially, in combination with other risk indicators (Polanczyk et al., 2010), mother-reported nightmares could be considered a risk indicator for psychotic experiences.

The finding that childhood dyssomnia is associated with psychotic experiences might be the result of concurrent child psychopathology. Indeed, when controlling for concurrent psychopathology, the associations of psychotic experiences with dyssomnia symptoms attenuated, but remained significant. One possibility for the attenuation of the effect is that co-occurring psychopathology may be a common cause underlying the association between psychotic experiences and dyssomnia symptoms. Indeed, from previous studies we know that both childhood dyssomnia and psychotic experiences are known to frequently co-occur

with psychopathology (Gregory and Sadeh, 2016; Kelleher et al., 2012b; Wigman et al., 2011).This could suggest that the association was partly explained by co-occurring emotional or behavioural problems, further investigation of the direction of this association is needed.

4.1. Strengths and limitations

This study has multiple strengths. First, we made use of actigraphical measures of sleep, which is a reliable way to assess of objective sleep duration, efficiency, arousal, and social jet lag. Second, we obtained sleep measures from multiple raters, both mother and child. This enabled us to control for reporter bias and shared method variance bias as different reporters (i.e. both mother and child) and instruments (i.e. different questionnaires) were used for sleep problems. Third, because of large sample size we were able to control for various important sociodemographic confounders and co-occurring child psychopathology.

The current study also had some limitations. First, we used self-report questions to measure psychotic experiences. It would have been optimal to conduct clinical interviews to assess psychotic experiences, because self-report might inflate the prevalence of psychotic experiences (Kelleher et al., 2012a). However, self-reported psychotic experiences have been shown to be predictive of clinician-confirmed psychotic disorder (Kelleher et al., 2011), and questionnaires have been reported to increase the willingness to disclose sensitive information (Jones et al., 2008), which is particularly important for pre-adolescent children. Moreover, from previous studies we know that the genetic factors underlying psychotic experiences and clinician-confirmed psychotic disorders overlap (Jeppesen et al., 2015b; Zavos et al., 2014). Second, questionnaires on psychotic experiences were collected at age 10 years, while actigraphical measures of sleep where at age 11 years. The literature suggests that sleep is relatively stable in school-age children (6–12 years) and typically changes with the onset of puberty only (Galland et al., 2012). Although psychotic experiences in childhood are not very persistent (Bartels-Velthuis et al., 2011), this suggests that similar sleep patterns were present when the psychotic symptoms were assessed. However, future studies should employ longitudinal designs to test the extent to which persistence or desistence of psychotic experiences in children is related to sleep difficulties. Third, our measure of nightmares was based on one item, and therefore not very detailed. However, the "nightmares" item of the CBCL is associated with well-validated sleep measures, such as the parasomnia scale and the sleep anxiety scale of the Children's Sleep Habits Questionnaire, and it is associated with parasomnia sleep disorder diagnosis (Becker et al., 2015). In the future, more in-depth information on nightmares should be assessed, including nightmare severity. Polysomnographic measures would be useful in order to map the sleep activity during nightmares. Fourth, this study was cross-sectional, which precludes the possibility of examining the direction of associations and, hence, any inferences on potential causal relations. Fifth, our study did not include a full range of maternal symptoms. However, we were able to use concurrent maternal depressive symptoms as a confounder, one of the leading causes of disability ranked in the global burden of disease scale (Ferrari et al., 2013). In future research, it will be important to apply longitudinal designs as well as a clinical follow-up to trace the associations between psychotic experiences and nightmares over the developmental course, while accounting for the dynamic course of psychotic experiences and sleep.

4.2. Conclusion

Our results suggest that psychotic experiences and hallucinatory phenomena are associated with subjective sleep problems, but that the association is specifically strong for nightmares. This finding can contribute to a broader understanding of the relationship between psychotic experiences and sleep. Additionally, it stresses the role of nightmares as a potential risk-indicator of psychopathology.

Ethics approval and consent to participate

The Medical Ethical Committee of the Erasmus Medical Center Rotterdam approved the study. We obtained written informed consent and assent from all parents and children, respectively.

Contributors

Data collection was performed by the Generation R team. MKV participated in study design, collected and analysed the data, and wrote the manuscript. KB helped with data analysis, and assisted with drafting the manuscript. DK contributed to the statistical analysis, and assisted with drafting the manuscript. CC, VM, JH, and ML assisted in drafting the manuscript and reviewed data analysis. IR, LD, MH, and FV designed the study and critically reviewed the manuscript. HT participated in study design, study execution, and oversaw all aspects of manuscript development. All authors read and approved the final manuscript.

Conflict of interest

Financial disclosure

The funders had no role in the study design, data collection, analysis, interpretation of the data, or writing of the report. F.C.V. is the contributing editor of the Achenbach System of Empirically Based Assessment, from which he receives remuneration. For the other authors, no competing financial interests were reported.

Non-financial disclosure

None.

Data statement

The datasets analysed during the current study are not publicly available due to the terms and conditions participants agree to when they participate in Generation R, but are available from the corresponding author on reasonable request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.schres.2018.12.002.

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