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Self-Reported Sleep Disturbances Associated with Procedural Learning Impairment in Adolescents at Ultra-High Risk for Psychosis

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Abstract

Sleep disturbance contributes to impaired procedural learning in schizophrenia, yet little is known about this relationship prior to psychosis onset. Adolescents at ultra high-risk (UHR; N = 62) for psychosis completed the Pittsburgh Sleep Quality Index (PSQI) and a procedural learning task (Pursuit Rotor). Increased self-reported problems with sleep latency, efficiency, and quality were associated with impaired procedural learning rate. Further, within-sample comparisons revealed that UHR youth reporting better sleep displayed a steeper learning curve than those with poorer sleep. Sleep disturbances appear to contribute to cognitive/motor deficits in the UHR period and may play a role in psychosis etiology.

Keywords

Psychosis; schizophrenia; ultra high-risk; prodromal; sleep; procedural learning

1. Introduction

Cognitive and motor deficits are core features of schizophrenia and significant contributors to functional impairment (Bora et al., 2010; Lepage et al., 2014). Moreover, reduced

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Conflict of Interest

Dr. Mittal serves as a consultant to Takeda Pharmaceuticals. There are no other conflicts of interest to report.

Contributors

Drs. Lunsford-Avery and Mittal conceptualized the study. Dr. Lunsford-Avery conducted the analyses and drafted the initial manuscript. Dr. Mittal obtained funding and aided in the drafting of the manuscript. Mr. Dean contributed to the design of the study, helped with analyses and interpretation of results, and contributed to manuscript drafting.

cognitive and motor function occurs prior to psychosis onset, suggesting potential vulnerability markers (Bora et al., 2014; Dean et al., 2014; Sommer et al., 2016). Clarifying the nature of specific neurocognitive deficits among youth at ultra high-risk (UHR) for psychosis is essential for establishing early identification and prevention/intervention strategies (Bora et al., 2014).

Procedural learning (i.e., gradual skill acquisition through practice; Censor et al., 2012), employs cognitive and movement capabilities and has long been of interest in schizophrenia patients (Huston and Shakow, 1949), who struggle to complete daily routines (Adini et al., 2015). Recent investigations suggest a nuanced picture of procedural learning in this population. Specifically, the degree of impairment depends on individual characteristics (e.g., intelligence; Gomar et al., 2011) and task demands (Siegert et al., 2008). Consistent with broader memory deficits across the psychosis continuum (Bora et al., 2014), procedural learning deficits are also observed in non-clinical psychosis (Mittal et al., 2012) and high risk (Dean et al., 2014) samples. Procedural learning deficits may characterize at least a subset of schizophrenia and at-risk groups; however, biological mechanisms contributing to within-group heterogeneity are unclear.

Sleep is disrupted in many, but not all, individuals with schizophrenia (Cohrs, 2008) and normatively is believed to impact procedural learning (Ackermann and Rasch, 2014; Diekelmann and Born, 2010). Sleep disturbances are also observed in at-risk youth (Castro et al., 2013; Castro et al., 2015; Lunsford-Avery et al., 2015; Lunsford-Avery and Mittal, 2013; Lunsford-Avery et al., 2013; Zanini et al., 2013; Zanini et al., 2015). Normative procedural learning is linked to a distributed series of circuits involving the striatum and cerebellum (Doyon et al., 2003; Hikosaka et al., 1999). Studies indicating structural and functional frontal-striatal and frontal-cerebellar circuit abnormalities may also impact procedural learning in the psychosis spectrum (Dean et al., 2014; Kumari et al., 2002). Because these circuits include key structures that have been implicated in normative and pathological sleep (i.e., thalamus; Espana and Scammell, 2011; Lunsford-Avery et al., 2013), there may be a physiological link between sleep and learning in psychosis. Indeed, sleep abnormalities (e.g., slow-wave sleep, sleep spindles) interfere with procedural learning in schizophrenia, suggesting thalamocortical network dysfunction (Goder et al., 2006; Manoach and Stickgold, 2009; Wamsley et al., 2012).

No studies to date have examined the relationship between sleep disturbances and procedural learning in UHR youth. The current study extends our prior work, which revealed procedural learning (Dean et al., 2014) and sleep (Lunsford-Avery et al., 2013) deficits among UHR adolescents, and investigates associations between self-reported sleep disturbances and pursuit rotor (PR) task performance, a gold standard measure of procedural learning in a sample of UHR youth (Raz et al., 2000). We hypothesized that greater sleep disturbances would correlate with impaired procedural learning rate. We also examined how procedural learning trajectories differ among UHR youth reporting greater versus fewer sleep problems.

2. Method

2.1. Participants

Sixty-two UHR adolescents (aged 13–22 years) were recruited via media advertisements and community referrals. See Table 1 for demographic information. Inclusion criteria included moderate levels of attenuated positive symptoms and/or a decline in global functioning over the last year accompanied by schizotypal personality disorder and/or a family history of psychosis (Miller et al., 1999). Exclusion criteria included Axis I psychotic disorder, tic disorder, head injury/neurological disorder, intellectual disability, or substance dependence. The protocol and informed consent procedures were approved by the Institutional Review Board.

2.2. Clinical/Intellectual assessment

UHR syndromes were diagnosed using the Structured Interview for Prodromal Symptoms (SIPS; McGlashan et al., 2001; Miller et al., 2003; Rosen et al., 2002). The Structured Clinical Interview for DSM-IV (SCID; First et al., 1995) ruled out psychotic disorders. The SCID is reliable in adolescent populations (Howes et al., 2009; Martin et al., 2000). The Global Assessment of Functioning (GAF) determined current level of psychosocial functioning (Jones et al., 1995). Interrater reliability (kappa) in the current study exceeded .80.

General intelligence (IQ) was assessed using the Word Reading subtest of the Wide Range Achievement Test, 4th edition (WRAT-4), a well-validated measure of broad learning ability for adolescents (Wilkinson et al., 2006). Standard scores normed for age were calculated based on the total number of letters (max=15) and words (max=55) read accurately.

2.3 Self-Reported Sleep Disturbance

The 19-item Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989) assessed sleep latency, efficiency, quality, duration, and disturbances/continuity over the week prior to PR administration. PSQI total scores range from 0 – 21 (sub-domains range 0 – 3). Higher scores reflect greater impairment. The PSQI is a reliable, valid measure (Buysse et al., 1989) used widely with adolescents (Jones et al., 2006; Kaneita et al., 2009). In addition, specific PSQI indices, including sleep duration and efficiency, have been shown to correlate with actigraph measures assessing the same domains among UHR youth, supporting the validity of using the PSQI with this population (Lunsford-Avery et al., 2015).

2.4 Procedural learning

Procedural learning was assessed using a computerized PR task (Life Science Associates, New York, NY) previously employed with schizophrenia and young adult populations (Gomar et al., 2011; Mittal et al., 2012). Participants completed 4 blocks (3 trials each) with 45-min rest periods after each block. In each trial, participants used a computer mouse to follow a moving target around a rectangular track for 20-s (5-s intervals between trials). Initial proficiency level was calculated during practice trials using a widely-used titration strategy (Gomar et al., 2011) and target stimulus speed was adjusted to ensure each participant met a criterion of 20–25% time on target. Once proficiency was established,

target speed was kept constant across testing blocks. Procedural learning rate was calculated by subtracting the mean percent time on target for Block 1 from the mean percent time on target for Block 4.

2.5 Statistical Approach

Using SAS software (SAS Institute, Inc., Cary, NC) and two-tailed tests, Pearson correlations controlling for age, gender, and IQ examined relationships between PSQI total and subdomain scores and procedural learning rate. Age, gender, and IQ were selected as covariates given their associations with sleep and/or procedural learning (Colrain and Baker, 2011; Gomar et al., 2011; Zhang et al., 2016).

To assess within-group differences in procedural learning trajectories, the sample was divided into two groups based on the median PSQI total score of the sample: “better sleepers” (PSQI ≤ 8 , $n = 36$) and “poorer sleepers” (PSQI > 8 , $n = 23$). Three participants were dropped from group analyses due to missing data (i.e., a missed PSQI item preventing calculation of a total score). This median-split procedure is consistent with previous studies using the PSQI (e.g., Yang et al., 2003). Group differences in demographic variables were assessed using independent t-test and chi-square analyses.

Linear regressions adjusted for age and sex investigated differences in symptom severity, overall cognitive ability, and psychosocial functioning between better sleepers and poorer sleepers. Linear regressions controlling for age, gender, and IQ also examined group differences in procedural learning rate, initial mean percent time on target (Block 1), and final mean percent time on target (Block 4) among better and poorer sleepers.

3. Results

Mean procedural learning rate was positive (mean=8.29, SD=6.16) suggesting that, on average, participants displayed learning over the 4 PR blocks (~8% more time on target during Block 4 than Block 1). Covarying for age, gender, and IQ, greater PSQI total score ($r = -.48$, $p < .001$; See Figure 1); and specific difficulties with sleep latency ($r = -.35$, $p < .01$), efficiency ($r = -.42$, $p = .001$), and quality ($r = -.29$, $p = .03$) were correlated with diminished procedural learning rate. Procedural learning rate was not associated with duration or disturbances/continuity.

Within our sample, “poorer sleepers” displayed lower overall cognitive functioning compared to “better sleepers.” Groups did not differ on measures assessing symptoms or functioning (see Table 1). However, consistent with our prior work (Lunsford-Avery et al., 2013), it is notable that poorer sleepers displayed increased negative symptom severity compared to better sleepers at the trend level. As PSQI total score and negative symptom severity were significantly correlated in our full sample ($r = 0.28$, $p = .03$; adjusted for age and sex), it is likely that dichotomizing the continuous PSQI variable reduced power to detect this effect.

Regarding performance on the pursuit rotor task, poorer sleepers exhibited a significantly flatter learning trajectory across blocks compared to better sleepers controlling for age,

gender, and IQ. While mean time on target during Block 1 did not differ between poorer and better sleepers, better sleepers performed significantly better during Block 4 than poorer sleepers, suggesting a divergent procedural learning rate between the two groups (see Table 1 and Figure 2).

4. Discussion

This study is the first to document a relationship between sleep disturbances (i.e., latency, efficiency, and quality, with the largest effect for sleep efficiency) and procedural learning deficits in UHR youth. We previously proposed a developmental diathesis–stress model in which sleep disturbance reflects both an underlying vulnerability and a stressor during adolescence driving psychosis onset (Lunsford-Avery and Mittal, 2013). One hypothesized pathway by which sleep problems may amplify stress (and psychosis risk) during adolescence is through an adverse impact on cognition. This study provides preliminary support for a specific impact of sleep, particularly reduced efficiency, on procedural learning; however, longitudinal research incorporating measures of neural development (e.g., thalamocortical networks) and function is critical for clarifying the role of sleep in psychosis etiology.

Results also suggest significant variability among UHR youth, with “better sleepers” displaying a steeper learning curve than “poorer sleepers.” This heterogeneity suggests potential UHR subgroups that are more/less vulnerable to sleep-related procedural learning impairment. Further, sleep disturbance may represent a biological marker identifying youth most likely to manifest procedural learning deficits and/or benefit from sleep treatments. Finally, these results may clarify mixed findings regarding procedural learning in schizophrenia samples, which likely include individuals across the sleep health continuum.

Regarding study limitations, self-report may be less accurate than objective sleep assessments (e.g., polysomnography, actigraphy; Lockley et al., 1999; Lunsford-Avery et al., 2015) and does not capture several sleep parameters related to procedural learning in schizophrenia (i.e., sleep spindles, slow wave sleep; Goder et al., 2006; Wamsley et al., 2012). Additionally, procedural learning protocols often include two assessments (training completed prior to sleep period and testing upon waking) to evaluate the causal impact of sleep on implicit memory consolidation (e.g., Wamsley et al., 2012). Although our findings suggest that sleep problems may impair procedural learning, without a pre-sleep assessment, causation cannot be inferred. Future studies incorporating objective sleep measures and pre- and post-sleep procedural learning assessments may clarify causal relationships between sleep disturbance and procedural learning deficits among UHR youth.

In conclusion, associations between poorer sleep and procedural learning deficits in UHR youth suggest that sleep disturbances during adolescence may contribute to psychosis etiology. These findings also highlight potential avenues for prevention and intervention efforts with this population. Specifically, psychosocial treatments targeting sleep disturbances have been shown to improve sleep efficiency in adolescents (e.g., Cognitive Behavioral Therapy - Insomnia; de Bruin et al., 2015). Future studies should investigate the

utility of these approaches in improving sleep among UHR youth as well as possible downstream effects on procedural learning, clinical outcomes, and psychosocial functioning.

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Figure 1. Relationship between PSQI total score and PR learning rate in full UHR sample
Abbreviations: PR, Pursuit Rotor; PSQI, Pittsburgh Sleep Quality Index

Figure 2. Divergent procedural learning trajectories among better (PSQI = 8) and poorer (PSQI > 8) sleepers within UHR sample

Abbreviations: PR, Pursuit Rotor; PSQI, Pittsburgh Sleep Quality Index

****Note:** Error bars reflect standard errors.

Table 1

Characteristics of the full sample, better sleepers, and poorer sleepers

Variable	Full Sample (n = 62)	Better Sleepers (n = 36)	Poorer Sleepers (n = 23)	F	p
Mean (SD)					
Age, in years	18.93 (1.67)	19.08 (1.59)	18.83 (1.90)	0.31	0.58
Parent Education, in years	15.49 (3.05)	15.42 (3.42)	15.43 (2.69)	0.00	0.98
WRAT-4 Score	109.08 (14.53)	112.30 (14.03)	104.10 (14.08)	4.55	0.04
SIPS-Positive	11.72 (4.97)	12.14 (4.54)	11.61 (4.83)	0.13	0.72
SIPS-Negative	9.35 (6.92)	8.33 (6.34)	10.91 (6.88)	2.34	0.13
GAF	62.33 (13.61)	62.03 (12.55)	63.95 (13.18)	0.31	0.58
PSQI Total Score	8.12 (3.20)	6.03 (1.75)	11.39 (1.95)	102.70	<.0001
PR Learning Rate Index	8.29 (6.16)	10.90 (5.29)	4.75 (6.00)	23.99	<.0001
PR Time on Target, Block 1	30.77 (8.94)	31.06 (8.93)	30.02 (9.18)	0.01	0.91
PR Time on Target, Block 4	39.32 (9.29)	41.96 (9.62)	34.66 (6.78)	7.50	<.01
Number (%)				X²	
Gender, male	37 (60)	21 (58)	14 (61)	0.04	0.85
Anti-Psychotic Use	7 (11)	5 (14)	1 (4)	1.40	0.24

Abbreviations: SIPS, Structured Interview for Prodromal Symptoms (total symptoms); WRAT-4, Wide Range Achievement Test, 4th Edition; GAF, Global Assessment of Functioning; PSQI, Pittsburgh Sleep Quality Index; PR, Pursuit Rotor

Note: Group differences in clinical symptoms (WRAT, SIPS, GAF) and PSQI have been adjusted for age and sex. Group differences in PR (Learning Rate, Time on Target) have been adjusted for age, sex, and WRAT score as described in the text.