1 The role of sleep in predicting paranoia in non-affective psychosis: an experience sampling study

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29 Abstract

30 Introduction: Growing evidence suggests a relationship between sleep disturbance and paranoid
31 thinking, in both clinical and non-clinical populations. Research also suggests that this relationship is
32 mediated by negative affect. The aims of this study were to 1) examine whether sleep disturbance
33 predicted paranoia and the dimensions of paranoia, including distress, preoccupation and conviction
34 and 2) to test whether there was a time-lagged, relationship between sleepiness and paranoia, and
35 whether this was mediated by negative affect. Method: Sleep was measured subjectively via
36 questionnaires, sleep diary and this was used to test the first aim. Experience sampling methods were
37 also used and these were used to test the second aim. Momentary assessments of sleepiness, mood,
38 and paranoia were measured 8 times a day, for 8 days, at semi-random intervals. Multi-level
39 modelling was then used to assess relationships between the variables. Results: Twenty- three patients
40 with a diagnosis of non-affective psychosis took part in the study, and 20 completed the experience
41 sampling procedure. There was no relationship between sleep diary variables and paranoia, or its
42 dimensions. There was no time-lagged relationship between sleepiness and paranoia. A subset of
43 individuals in the sample were identified who did not report any variation or fluctuations in their
44 measurements. Discussion: There was no relationship between subjective sleep and paranoia. Lack of
45 power may be why no relationship was found. However sleep disturbances were common in people
46 with non-affective psychosis. Our findings support the treatment of sleep problems in this sample, but
47 not in relation to paranoia.

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Introduction

As many as 30-80% of people with a diagnosis of schizophrenia report sleep disruption [1]. Sleep disruption appears to be a persistent issue that is found in medicated, and non-medicated samples, as well as during acute and stable phases, [2, 3]. Importantly, sleep disturbances are linked to a range of outcomes including severity of symptoms, mood, and quality of life [1, 4] and patients report sleep is an important treatment target [5]. Together, this emphasises the importance of understanding the nature and correlates of sleep problems in people diagnosed with schizophrenia.

Sleep Disruption in Psychosis

Sleep disruption is a broad term and within this paper we use it to refer to any kind of sleep disruption reported in people with psychosis including subjective/objective sleep disruption, symptoms associated with sleep disorders or sleep disorders. It has been shown that a range of sleep disturbances have been reported in people with psychosis. For example, one study in a sample of 30 participants with a diagnosis of psychosis reported that over half the sample experienced moderate to severe levels of insomnia [6]. Other studies in psychosis samples have also reported elevated levels of insomnia, although the prevalence estimate varies [7, 8]. Nightmares are also prevalent. One study in a sample of 40 participants experiencing psychotic symptoms, reported that 55% reported weekly distressing nightmares [9]. As well as nightmares and insomnia, circadian disruption in the form of sleep/wake pattern irregularity and alterations in circadian rhythms of melatonin are also found [10, 11]. Symptoms of hypersomnolence such as daytime sleepiness have been reported in people with psychosis ranging from 32- 58% [12, 13]. These findings coupled with a number of extensive reviews on this topic provides strong evidence that sleep disruption is common in people diagnosed with schizophrenia [14-17]

The relationship between sleep disturbances and paranoia

Increased sleep disruption is associated with an increase in level of positive symptoms [1, 4]. In particular, strong relationships between sleep disruption and paranoia have being found in both clinical and non-clinical samples [18, 19]. In a longitudinal study, insomnia predicted the onset of paranoid thoughts in the general population [18]. Furthermore, in a sample of 29 people with a diagnosis of non-affective psychosis, insomnia predicted the persistence of paranoid symptoms [20]. Treating sleep using cognitive behavioural therapy for insomnia (CBTi) is associated with reductions in both paranoia and insomnia in people with psychosis [19]. It is to be noted however that in a larger trial, there was no such improvement in psychotic symptoms [21]. Investigating mechanisms linking sleep disruption to paranoia is the next step, with evidence being found for negative emotional states [22, 23] and levels of emotional awareness [24]. This research suggests that levels of negative emotions may be a key mediator in the relationship between sleep disruption and paranoia. Our aims are to understand and further explore these relationships, taking into account limitations of prior work.

Limitations of previous research

In studies examining paranoia and sleep, paranoia is often measured in terms of frequency. This research excludes other important dimensional aspects of paranoid beliefs. For example, paranoia has dimensions of distress, preoccupation and conviction associated with it [25, 26] and these aspects of paranoia could also be considered in relation to sleep. Indeed, research has shown that the presence of psychotic like experiences such as paranoia are normal and transitory, but it is when these experiences start becoming distressing that they can become persistent and problematic for the person [25, 27]. Understanding the role of sleep in predicting other dimensions of paranoid beliefs is therefore vital and may inform and refine models of paranoia. There is now growing evidence that sleep disruption may have a causal role in the development of paranoia [28-30]. However, most of these studies have been done in non-clinical samples. It has been shown that both sleep and psychotic symptoms show variability and are dynamic states. For example, paranoia fluctuates with changes in mood and self-esteem [31]. Some aspects of sleep disruption such as sleepiness has also been found to show daily variation [32]. Another study found that next -day mood was linked to prior night's sleep in patients

with depression suggesting a temporal relationship between sleep disruption and mood [33].
Therefore, techniques that take this variability into account may be well placed to help address
causality in clinical samples.

Experience Sampling Method (ESM)

To capture relationships at a daily level ESM requires participants to answer questions about mood,
context and symptoms, several times a day for consecutive days, usually at random moments
signalled on a smartphone [34]. ESM yields high levels of ecological validity, in comparison to
retrospective techniques, as it allows experiences to be captured as they unfold in daily life. ESM has
been used in a wide variety of psychiatric conditions including psychosis, borderline personality
disorder, depression and eating disorders, with high levels of adherence and acceptability reported
[34]. To date, there has only been one study using ESM to investigate relationships between sleep
disruption, symptoms and mood in a psychosis sample. This study found that both subjective and
objective sleep predicted next day psychotic symptoms including paranoia and delusions of control
[4]. The study also found that the relationship between sleep and next day paranoia was mediated by
negative affect, supporting studies conducted using retrospective measures. Another study, in a non-
clinical sample reported that sleep parameters such as total sleep time, predicted next day paranoia,
although these effects were small [35].

Current Study and Aims

We sought to investigate whether sleep predicts variation in frequency, distress, preoccupation and
conviction dimensions associated with paranoia. Furthermore, we sought to examine the temporal
relationship between sleepiness and paranoia. We did this by investigating whether levels of state
paranoia were predicted by levels of preceding state sleepiness, and whether this relationship was
mediated by levels of negative affect.

Hypotheses

Hypothesis 1: That subjective sleep parameters reported in sleep diaries predict levels of paranoia and its dimensions of distress, preoccupation and conviction measured at the daily level.

Hypothesis 2: Whether levels of sleepiness reported at one moment, predicts paranoia at the next moment, and whether this is mediated by levels of negative affect. We test this using a time – lagged analysis.

Method

Participants

This study was approved by the NHS ethics committee- Research Ethics Committee 3: West of Scotland Ethics service (reference 14/WS/0124) and by local research and development offices (reference number GN14CP140). To be eligible for the study participants had a diagnosis of non-affective psychosis (schizophrenia, schizoaffective disorder, delusional disorder, schizophreniform disorder, psychotic disorder not otherwise specified) in accordance with International Classification of Diseases-10 (ICD-10; World Health Organization, 1992). Participants were aged between 18-65, had been on a stable medication regime for the past month and were able to give full informed and written consent. Exclusion criteria included alcohol or drug dependence, head injury, neurological illness, night shift work or having travelled across time zones in the past month. There were two routes for recruitment for participants- they could be referred to the study by their clinical team or they could self-refer through adverts that were put up in local centres about the study. Capacity to consent was determined with a discussion with the patient's key worker who had to approve whether the patient was able to participate in the study. Thirty-four potential participants expressed interest in taking part in the study, of which 23 met inclusion criteria. Eight were excluded because they did not meet diagnostic criteria, 1 was excluded because they moved out of area during the study and 2 declined to participate after receiving study information. In regards to recruitment, 16 were recruited via clinical teams, 3 self-referred and 4 were recruited from charities or other organisations.

Baseline Questionnaire Measures:

A range of sleep questionnaires were selected in the study to capture a range of sleep and circadian disturbances. All questionnaires were administered face to face with patients by the lead researcher. This allowed any confusion about wording or questions to be dealt with directly. All questionnaires were done on paper.

Sleep measures

Wilson-Screening for Sleep Disorders [36].

This algorithm serves as a screening tool for sleep disorders including narcolepsy, sleep apnoea, parasomnias, restless legs and circadian rhythm sleep disorders. No one in our study met the criteria for any of the sleep disorders. The screening tool is published in [36].

Pittsburgh Sleep Quality Index [37]

The PSQI provides a reliable, valid, and standardized measure of sleep quality. Scores range from 0-21 with higher scores representing poorer sleep. A PSQI global score >5 indicates that a participant is having severe difficulty in at least two areas, or moderate difficulty in more than three areas of sleep quality in the past month. Internal consistency of the PSQI is high $\alpha = .83$ [37, 38].

Epworth Sleepiness Scale [39]

The ESS provides an assessment of daytime sleepiness. Respondents are asked to rate, on a 4-point scale (0-3), their usual chances of dozing off or falling asleep while engaged in eight different activities. Most people engage in those activities at least occasionally, although not necessarily every day. The ESS score (the sum of 8 item scores, 0-3) can range from 0 to 24. Higher scores, indicate higher sleepiness levels. Internal consistency in the study was $\alpha = 0.75$.

Sleep Condition Indicator [40]

The SCI is a screening measure for insomnia based on the DSM-V criteria for insomnia disorder. We used the short form which has 2 items. Internal consistency in the study was $\alpha=0.80$.

Nightmare Frequency:

This was assessed by asking participants how often they experienced nightmares, with options ranging from never to more than once a day.

Nightmare Distress Questionnaire (NDQ) [41]

Includes 13 items rated on a 5-point scale to assess the degree of self-reported distress attributed to nightmares. Internal consistency in the study was $\alpha=0.80$.

Morning Eveningness Questionnaire (MEQ) [42]

The MEQ scale is used to distinguish between chronotypes (whether one is a morning or an evening person). Scores range from 16 to 86, corresponding to extreme eveningness (lower numbers) to extreme morningness (higher numbers). Questions focus on individual preferences for sleep and wake times. Internal consistency in the study was $\alpha=0.70$.

Emotion measures

Toronto Alexithymia Scale (TAS-20) [43]

The TAS -20 includes 20 items and measures 3 factors of alexithymia. Factor 1 assesses difficulty in identifying feelings. Factor 2 assesses difficulty in describing feelings. Factor 3 assesses externally oriented thinking. Scores range from 20-100 with higher scores reflect higher alexithymia. Internal consistency in the study was $\alpha =0.85$.

Depression, Anxiety and Stress Scale (DASS-21) [44]

The DASS-21 is a self-report measure in which participants rate the frequency and severity of experiencing negative emotions over the previous week. Frequency/severity ratings are made on a

series of 4-point scales (0=did not apply to me at all, 3=applied to me very much, or most of the time). Internal consistency in the study was $\alpha=0.96$.

Paranoia

Green Paranoid Thoughts Scale Part B (GPTS) [45]

The GPTS is a 16-item measure of paranoia, assessing ideas of persecution over the past month.

Scores range from 16-80 with higher scores indicating greater levels of paranoid thinking. The questionnaire includes subscales for conviction, preoccupation, and distress. The questionnaire has been psychometrically evaluated in clinical and non-clinical populations. Internal consistency in the study was $\alpha=0.97$.

Daily measures and ESM

Consensus Sleep Diary. The Consensus Sleep Diary (CSD); [46] was completed by participants each morning to measure subjective sleep parameters. The CSD has been credited as a gold-standard sleep diary [46]. Participants filled out the sleep diary for 2 weeks. From the sleep diary, sleep onset latency (SOL), total sleep time (TST), wake after sleep onset (WASO), sleep efficiency (SE), and time in bed (TIB) were extracted. As with the questionnaires, the diaries were completed on paper.

ESM sampling

All participants completed the ESM procedure on smartphones (Galaxy Fame by Samsung) that they kept during the course of the study. Between the hours of 10am and 10pm, participants were prompted 8 times a day to complete questions on mood, sleepiness, symptoms as well as their current context (See supplementary info (S1) for full list of items). Participants received a beep notification in semi-random order within 90 min intervals, with a random beep occurring during that interval.

Once beeped, the questionnaire was available for up to 15 minutes as research shows answers within 15 minutes are valid [47]. The questions took on average 2-3 minutes to complete. The ESM questions were administered on an app called PsyMate which can be downloaded from App stores. The phones only contained this App on it and patients were not able to use the phone to receive calls or send texts.

ESM procedure

All participants attended a pre-experimental meeting, where they were shown how to use the phone, access the questionnaire when prompted with a beep and go over 2 practice questionnaires together. They then took the phone with them for 8 days and had access to the main researcher AR if they had any technical issues or problems with the phone. Following completion of the ESM period, participants were debriefed, and completed a comprehension questionnaire to ensure they understood the questions, the phone and that they followed the instructions correctly. Through the course of the study, two participants reported feeling paranoid about the phone and whether they were being recorded secretly. The researcher AR met with these patients to re-assure them that the phones were not recording them. Following this, the participants went onto complete the study. All the phones were returned and the procedure seemed acceptable to patients. Upon completion of the study, each participant was given £20 as well as personalised feedback on their sleep based on their data.

ESM items:

Paranoia

Paranoia items were taken from a previous study that used these items to study variations in paranoia [31]. The paranoia scale items included “I feel suspicious” and “I feel others may hurt me.” These two items formed the paranoia scale ($\alpha=0.72$ over the subject mean scores). Following completion of paranoia items, patients were then asked to report their levels of distress, preoccupation and conviction associated with the paranoid thoughts. Patients were asked: “How much are the thoughts

about others hurting causing you distress?” “How much are the thoughts about others hurting you pre-occupying your mind?” “How convincing are the thoughts about others hurting you?” These items measured distress, preoccupation and conviction. All the paranoia items were rated on a 6 point likert scale (1=not at all to 6=very).

Other experiences

While paranoia is the main symptom we are interested in, we also included measures of delusions of grandeur and reference, taken from a prior study [48] and taken from the comprehensive assessment of at risk mental states (CAARMS) [49]. Items for visual and auditory hallucinations were taken from [47] and the CAARMS. The reliability of these items were lower, and not included in our analyses.

Emotion items

To examine mood, 3 items were included to measure positive mood and 7 items were included to assess negative mood. A range of items to reflect negative affect were taken from prior ESM papers [4, 50, 51]. The items were rated on a 6 point likert scale (1=not at all to 6=very). The negative affect scale items included “I feel insecure” “I feel stressed”, “I feel lonely”, “I feel guilty”, “I feel irritated”, “I feel down” and “I feel anxious”. These seven items formed the negative affect scale ($\alpha=0.83$ over the subject mean scores). Positive mood was not related to study hypotheses but was included alongside negative affect. The positive affect scale items included “I feel cheerful”, “I feel relaxed” and “I feel content”. These three items formed the positive affect scale ($\alpha=0.78$ over the subject mean scores).

Sleep items

At every notification beep, participants completed questions on current levels of sleepiness. The items were rated on a 6 point likert scale (1=not at all to 6=very). Sleepiness items were taken from the Daytime Insomnia Symptom Scale [32] which has been previously validated in an insomnia

population. The 3 sleep scale items included “I feel sleepy”, “I feel fatigued” and “I feel exhausted”. These three items formed the sleepiness scale ($\alpha=0.84$ over the subject mean scores).

Additional items

Finally, a series of questions about context were asked. Whilst contextual items are not related to the current study’s hypotheses, they were included to provide additional information. See supplementary information (S1) for a full list of items.

ESM data analysis

Multilevel modelling (MLM) techniques are an alternative of the more often used unilevel linear regression analyses and are ideally suited for the analysis of ESM data, in which repeated ESM observations (beep level) are nested within- persons (subject level) [52]. As observations from the same subject are more similar than observations from different subjects, the residuals are not independent. Multilevel regression techniques take this into account. In the current data set we ran a two level model whereby observations at level 1, were nested within participants at level 2. Random effects were specified maximally, in accordance to [53]. The following R packages were used in our data management and analysis: tidyverse, psych, ICC, lme4 and lmerTest packages [54-59]. Level 1 and 2 variables were inspected for normality by inspection of histograms, which revealed skewness across most of the variables. Therefore, we ran the analysis with skewed predictors both log transformed, and untransformed data. The results remained consistent across both models. There is also debate on how to centre variables within MLM. Therefore, we ran our analysis centred (level 1 at group mean and level 2 at grand mean) as well as uncentred. Our results remained unchanged; therefore for ease of interpretation z scored and centred models are presented. The data and code for this study can be found here, and this analysis includes centred and uncentred models: <https://osf.io/4e86c/>. Furthermore, due to missing data, analysis such as testing whether sleep the night before, predicts next day paranoia could not be conducted.

Results

Characteristics of the sample

The mean age of patients was 46 ($SD= 9.5$) and there were 15 (65%) males and 8 (35%) females. On average, patients had 11 years of education (range 2-20). All but 2 were unemployed. All participants were in receipt of antipsychotic medication, with most on more than one type. For full list of medication and doses see supplementary information (S2). We do not have patient information on duration of illness or information about previous hospitalisations. In our sample of 23 patients, 5 (21%) were classed as good sleepers (PSQI score <5), 17 (73%) as poor sleepers (PSQI score >5) and for one person there was no PSQI score. In terms of sleepiness as measured by the ESS 6 (26%) patients could be classed as experiencing excessive daytime sleepiness based the cut off score of 10. See Table 1, for descriptive statistics of the sample.

Table 1: characteristics of the sample

	Mean(SD)	Median	Range	Possible range for questionnaire
Sleep quality	9.2(4.19)	10	1-18	0-21
Sleepiness	6.19(4.61)	6	0-17	0-24
Insomnia	2.9(2.44)	2	0-8	0-8
Chronotype	52.6(7.49)	54	37-65	16-86
Nightmare distress	25.8(13.60)	24	13-52	13- 65
Mood (DASS total score)	29.5(17.6)	26.5	4-60	0-63
Alexithymia	59.0(8.8)	59	40-77	20-100
Paranoia	40.2(22.0)	33	16-80	16-80

Retention and adherence

In accordance with previous ESM schizophrenia studies [47, 52], participants had to complete at least 33% of the experience sampling activations in order for their data to be considered valid and included

in the data analysis. Based on this, 20 participants were included in the ESM data analysis. Two participants did not respond to enough beeps and 1 participant could not complete the ESM as they had shaky hands, meaning that 87% of the sample successfully completed the ESM procedure.

Justification of using MLM

The intraclass correlation coefficient (ICC) explains the proportion of variation that is explained between subjects (level 2) and within subjects (level 1). The ICC value was 0.71 for paranoia, 0.66 for distress associated with paranoia, 0.67 for preoccupation associated with paranoia and 0.71 for conviction associated with paranoia. These values suggest that there is variance at both levels of analysis and MLM is suited for this data set.

Main analysis

Hypothesis 1: Subjective sleep measured by a sleep diary will predict levels of paranoia, as well as distress, preoccupation and conviction measured at the daily level.

Sleep diary measures were averaged over the 2 week period as there were missing data and individuals did not always write the date within their sleep diary. Therefore, sleep diary measures were treated as a level 2 variable and used to predict paranoia measured at the daily level (level 1). Descriptive values for the variables are presented in Table 2.

The relationship between sleep diary variables and paranoia.

A random intercepts model was run with SOL, TST, WASO, TIB and SE as predictors and paranoia as the dependent variable. None of our sleep diary variables predicted paranoia. See Table 3 for results for this model.

Table 2 Values for sleep diary measures (*n*=20)

Predictor	Mean (minutes)	SD	Range
SOL	47.0	27.5	4-104
TST	444.3	216.5	40-1105
SE	73.2	16.5	43-97
WASO	36.1	35.0	0-140
TIB	551.7	146.5	85- 752

SOL: sleep onset latency, TST: total sleep time, SE: sleep efficiency, WASO: wake after sleep onset,

TIB: time in bed

Table 3 Fixed effects for the model predicting paranoia from sleep diary variables

	Estimate(SE)	t(df)	p
Intercept	1.98 (0.29)	6.78(13)	.280
SOL	-0.27 (0.31)	-0.88(13)	.394
TST	-0.10 (0.49)	-0.20(13)	.840
SE	-0.03 (0.42)	-0.07(13)	.945
WASO	0.25 (0.42)	0.59(13)	.560
TIB	0.25 (0.54)	0.46(13)	.649

SOL: sleep onset latency, TST: total sleep time, SE: sleep efficiency, WASO: wake after sleep onset,

TIB: time in bed

The relationship between sleep diary variables and distress associated with paranoia.

None of our sleep diary variables predicted distress associated with paranoia. See Table 4 for the results from this model.

Table 4: Fixed effects for the model predicting distress associated with paranoia from sleep diary variables

	Estimate (SE)	t(df)	p
Intercept	1.92 (0.28)	6.65(13)	.555
SOL	-0.13 (0.30)	-0.44(13)	.665
TST	0.07 (0.48)	0.15(13)	.878
SE	0.02 (0.42)	0.05(13)	.960
WASO	0.34 (0.41)	0.83(13)	.419
TIB	0.08 (0.53)	0.15(13)	.880

SOL: sleep onset latency, TST: total sleep time, SE: sleep efficiency, WASO: wake after sleep onset, TIB: time in bed

The relationship between sleep diary variables and preoccupation associated with paranoia.

None of our sleep diary variables predicted preoccupation associated with paranoia. See Table 5 for results of this model.

Table 5: Fixed effects for the model predicting preoccupation associated with paranoia

	Estimate (SE)	t(df)	p
Intercept	1.92 (0.29)	6.56(13)	.799
SOL	-0.16 (0.31)	-0.52(13)	.610
TST	0.06 (0.49)	0.13(13)	.896
SE	0.05 (0.43)	0.13(13)	.899
WASO	0.35 (0.42)	0.83(13)	.422
TIB	0.07 (0.54)	0.13(13)	.896

SOL: sleep onset latency, TST: total sleep time, SE: sleep efficiency, WASO: wake after sleep onset, TIB: time in bed

The relationship between sleep diary variables and conviction associated with paranoia.

None of our sleep diary variables predicted conviction associated with paranoia. See Table 6 for results of this model.

Table 6: Fixed effects for the model predicting conviction associated with paranoia

	Estimate (SE)	t(df)	p
Intercept	1.99 (0.31)		
SOL	-0.20 (0.33)	-0.59(13)	.563
TST	0.07 (0.53)	0.14(13)	.887
SE	0.01 (0.46)	0.02(13)	.979
WASO	0.34 (0.45)	0.75(13)	.698
TIB	0.09 (0.58)	0.17(13)	.868

SOL: sleep onset latency, TST: total sleep time, SE: sleep efficiency, WASO: wake after sleep onset, TIB: time in bed

Time- lagged analysis

Hypothesis 2: Levels of sleepiness at one moment, will predict paranoia at the next moment, and this will be mediated by levels of negative affect (time- lagged analysis).

To take advantage of the ESM design, we tested whether paranoia measured at one timepoint (t) was predicted by sleepiness measured at the preceding timepoint ($t - 1$). Paranoia observations at the start of the day were excluded from analysis (as these observations had no preceding daily time point). This model excluded one participant who showed no variation in their sleepiness and paranoia scores (all their responses were scored as 1). This model included sleepiness at t and $t-1$ as a Level-1

predictors, thereby controlling for sleepiness at t . Sleepiness at $t-1$ did not predict paranoia at t , $B = -0.01$ ($SE = 0.02$), $p = 0.687$. Full time- lagged results are presented in Table 7.

Table 7: Time- lagged analysis of sleepiness and paranoia measured at the daily level.

Predictor	Estimate (SE)	t (df)	p
Sleepiness at current time	0.05(0.04)	1.40(50)	0.15
Sleepiness at T- 1	-0.01 (0.02)	-0.40(79)	0.68

Summary of results

Our results did not support our hypotheses, sleep diary variables were not related to paranoia, or distress, preoccupation and conviction associated with paranoia. Furthermore, there was no temporal or time- lagged relationship between sleepiness and paranoia or any of the paranoia dimensions. We also ran additional analysis to test whether there was a relationship between sleep diary variables and negative affect. This was non-significant. We also tested from the daily level 1 data, the relationship between negative affect and paranoia. This was a significant estimate = 0.44, $p = <0.001$.

Inspection of individual plots of paranoia and sleep suggested that there may be there may be some patients, where there is a positive relationship between sleep and paranoia, some for whom it is negative, while others in our sample showed little or no variation. See figure 2.

Figure 1: Individual relationships of paranoia and sleepiness measured at the daily level

In this figure, each line represents an individual person, and the relationship between sleep and paranoia measured at the daily level (level 1). From the graph, it seems there are a sample of patients who have a positive relationship between sleep and paranoia and some who have a negative. Furthermore, there also appears to be a cluster of patients (bottom left of image) who showed very little variance during the ESM procedure. The solid blue line shows the overall regression line for all patients. The scale for both variables range from 1-6, where 1= not at all and 6 = very.

Post-hoc analyses

Sensitivity Analysis:

As a check, we ran our analysis without patients who showed little or no variance. We defined lack of variance as having less than a one-point difference between the patient's maximum and minimum score across all observations. This excluded 10 patients from the sample, leaving 10 in the analysis. Excluding these individuals did not change the pattern of results between sleep diary variables and paranoia, distress, preoccupation or conviction. However, excluding these 10 participants from the sample also decreases power, which could also explain why there was no change in the pattern of results.

Moderation analysis:

Our next approach was to examine whether the within- person association between sleepiness and paranoia (level 1) varied as a function of level 2 questionnaires (moderation analysis). For example, this would allow us to examine whether the relationship between sleepiness and paranoia varies as a function of PSQI score (level 2 variable), such that those with poorer sleep quality (higher PSQI) having a positive relationship between sleepiness and paranoia. This analysis may help us tease out whether there are some patients who do exhibit a relationship between sleepiness and paranoia. We conducted this analysis by including an interaction term between sleepiness (level 1) with sleep questionnaires measured at level 2. If the interaction term is significant, it suggests moderation exists, and results will be explored further. We ran a separate model for each of our questionnaires: PSQI, ESS, SCI, nightmare distress and MEQ. There was no significant moderation for PSQI, ESS, MEQ, nightmare distress or SCI. However, it was interesting to note a near significant interaction effect for ESS, $B = -0.07$ ($SE = 0.03$), $p = 0.06$. This analysis is available here: <https://osf.io/4e86c/>

Comprehension of method:

Upon completion of the study, patients were asked 8 questions regarding the ESM procedure. The results of this showed that participants found the procedure acceptable and understood the questions. It is unlikely that our results are a result of not following or understanding the ESM procedure. For list of all the items and their scores see supplementary information (S3).

Discussion

The aims of our study were to test whether subjective sleep measured by a sleep diary predicts frequency, distress, preoccupation and conviction dimensions of paranoia. We also sought to test whether there was a temporal relationship between sleepiness and paranoia that was mediated by negative affect. We tested these relationships using ESM in a sample of people with non-affective psychosis.

In our study, the key finding was that there was no clear relationship between sleep and paranoia. This is in contrast to other ESM studies of sleep and paranoia [4, 35]. The study by Hennig et al [35], was conducted in an adolescent sample and found small effects between total sleep time and paranoia which was limited to the morning portion of the day. The sample is very different to our clinical group and this could be an explanation for the difference in results. Interestingly, the study by Hennig et al., also did not find any relationship between WASO or SE and paranoia. The study by Mulligan et al. [4] found that subjective sleep quality and objective sleep fragmentation predicted paranoia. Possible reasons for discrepant results is that we did not have measures of subjective sleep quality as predictors in our models, nor did we have a measure of objective sleep. Furthermore, the patient sample in Mulligan et al., were all experiencing insomnia whereas our sample were more heterogeneous in the types of sleep disturbances they experienced. In our study we conducted two types of analysis. In the first we tested whether sleep diary variables predicted paranoia and its dimensions of frequency, distress, conviction and preoccupation. None of our results were significant. However, we could not conduct more fine grained analysis such as looking at whether subjective sleep the previous night predicts next day paranoia due to missing data in participant's sleep diaries. We had to aggregate our sleep diary measures and this may have limited variance and our ability to detect relationships. In the second analysis, we tested whether there was a temporal association between sleepiness and paranoia, measured at the daily level. Again, we found no significant temporal relationship; levels of sleepiness at one time point, did not predict paranoia at the next time point. Therefore, we could not go on to test our mediation model of negative affect. One explanation for our results may be to do with our measure of sleep compared to prior studies. Our items of "sleep" measured at the daily level included sleepiness, fatigue and exhaustion. These items may tap into a different aspect of sleep that is not related to paranoia. For example, fatigue is generally associated with depleted energy and weakness [60] whereas paranoia is associated with heightened arousal and alertness [61]. We may have measured aspects of sleep associated with low arousal and deactivation that would not be related to paranoia. This could be a potential explanation for the lack of significance. However, when conducting moderation analysis, there was a near significant interaction for the ESS. In other words,

the relationship between sleepiness and paranoia measured at the daily level may be moderated by levels of sleepiness. The relationship between sleepiness and paranoia has not been explored. The findings suggest that the type of sleep disturbance related to paranoia is specific. Indeed, the majority of studies that have found a relationship between sleep disruption and paranoia have been primarily measuring insomnia [4, 18, 19, 22]. Insomnia and paranoia share a number of emotional factors that may drive the relationship, such as negative emotionality [4, 22]. For example, it has been shown that when adding affective measures such as anxiety and depression, the relationship between insomnia and paranoia are reduced [22]. In our study, patients with and without sleep disturbance were eligible and our sample is likely to be more heterogeneous and non-specific. Even though sleep disturbances were common in our sample, a wide range of sleep disturbances were reported. It is unclear how prevalent or dominant insomnia difficulties were in our sample; our measure of insomnia was based on only two items. However, it is important to note that there are some sleep disturbances that do not have such a clear link to symptoms. For example, a study found profound sleep and circadian disturbances in people with schizophrenia, which was independent to their symptoms at the time [11]. This finding has also been reported in other studies measuring circadian functioning [10, 62]. It may be also that there was a high level of circadian disturbance in our sample. Given that the majority of our sample was unemployed, they may have experienced lack of routine and this can cause body clocks to become out of sync with the environment [63]. As we did not have any objective measure of sleep in our study, this is speculative. Including actigraphy would have helped to visualise whether they were circadian disturbances in our sample. Clearly, future research is required to closely examine whether aspects of sleep and circadian functioning are linked to paranoia. Another important finding in our study was that there was a subsample of patients who reported very little or no variation in their sleep, mood or symptoms over the course of the ESM framework. Sensitivity analyses with and without these 10 patients made no difference to the results. However, it is worthwhile to speculate why these patients showed such little variation. It is unlikely to be due to not engaging or understanding the ESM procedure, as all patients completed a questionnaire which showed that they had no issues with the procedure. One potential explanation may be alexithymia.

Alexithymia is a trait whereby individuals have difficulties in understanding what they are feeling, or being able to verbalise how they feel [43]. Research has also shown that alexithymia is common in individuals with schizophrenia and found elevated in comparison to the general population [64, 65]. It is possible that these individuals may struggle with the experience sampling procedure. Based on a cut off for alexithymia (TAS scores >61) 10 patients in our sample could be classed as alexithymic, of which 4 were from the low-variance group. This suggests that alexithymia is unlikely to be an explanation for the results. Another potential reason could be that the sampling procedure was not long enough to capture the full range of experiences for some of the patients and that we sampled some patients during a “good week”. To our knowledge, a subsample with lack of variation has not been reported before in ESM studies of people with schizophrenia.

Finally, despite our lack of significant results, we note that sleep disruption was common in our sample. There was evidence of disturbance of sleep continuity, with patients taking more than 30 minutes to fall asleep, and being awake during the night. The self-reported sleep disturbance values are similar to other samples of patients who were recruited on the basis of experiencing poor sleep [4, 25]. Specific sleep disturbances were also common in our sample; only 5 of the patients in the sample could be classed as good sleepers. Furthermore, 6 of the patients reported excessive sleepiness (10 or more on ESS) and nightmares and insomnia were also reported. Previous research has found levels of insomnia; nightmares and circadian disruption to be elevated in people with a diagnosis of schizophrenia [1, 11, 18, 22] and our findings are in line with this.

Limitations

A number of limitations of our study should be considered when interpreting the results. Our study was fully subjective, and we did not have any objective measures of sleep. Both objective and subjective sleep are disrupted in people with schizophrenia and including actigraphy measures would have given deeper insight into sleep patterns. Furthermore, a recent study reported that the interaction between subjective and objective sleep was a stronger predictor of psychotic symptoms than using one method alone [66]. Our sample was medicated, with most patients being on multiple medications. Medication profiles were diverse and patients were also taking medications for health conditions.

Medication could have potentially confounded the relationship between sleep and paranoia. While we had a large number of observations from the study participants and our sample size was similar to a previous ESM study in patients [4], power may have been an issue in detecting some of the relationships. Finally, our study is observational and inferences about causality cannot be made. Although time-lagged data takes us closer to making causal inferences, the relationship could also exist in the opposite direction (e.g. paranoia predicting sleepiness). We ran this analysis as a check, and paranoia at $t-1$ did not predict levels of sleepiness at the next time point.

Conclusions

We did not replicate the relationship between sleep disturbance and paranoia in a sample of medicated outpatients with schizophrenia. However, sleep disturbance was present within our sample which supports the continued development of therapeutic interventions to improve sleep and circadian disturbances [14].

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Supporting information

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S1 File: Experience Sampling Items

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