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Chronotype, daily affect and social contact: An ecological momentary assessment study

L. Kivelä [a], H. Riese [b], T.G. Fakkel [a], B. Verkuil [a], B.W.J.H. Penninx [c], F. Lamers [c], W. van der Does [a,d], N. Antypa [a,*]

[a] *Department of Clinical Psychology, Institute of Psychology, Leiden University, Netherlands*
[b] *University of Groningen, University Medical Center Groningen, Department of Psychiatry, Interdisciplinary Center for Psychopathology and Emotion regulation, Groningen, Netherlands*
[c] *Amsterdam UMC, Vrije Universiteit, Department of Psychiatry, Amsterdam Public Health research institute, Amsterdam, Netherlands*
[d] *Department of Psychiatry, Leiden University Medical Center, Leiden, Netherlands*

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ABSTRACT

Eveningness is associated with lower daily positive affect (PA). The relationship between negative affect (NA) and chronotype, however, is less consistent in the literature. Eveningness may be further characterized by increased social isolation, which could explain the associations between chronotype and PA/NA. In the present longitudinal study, we used ecological momentary assessment (EMA) to investigate the associations of chronotype with daily PA, NA, and social contact in individuals with current and remitted major depressive disorder (MDD) and healthy controls. As part of the Netherlands Study of Depression and Anxiety (NESDA), 279 participants ($n = 49$ depressed, $n = 172$ remitted, $n = 58$ controls) monitored daily PA, NA, and social contact (i.e., being alone vs. with others) for two weeks, five times per day. Overall, eveningness was associated with less social contact. This effect became nonsignificant, however, after accounting for sociodemographics (gender, age, education, living situation). Chronotype was not related to PA or NA. Less social contact was associated with lower PA and higher NA independent of chronotype. In conclusion, we could not replicate the finding of lower PA among evening types, but found social contact to associate with both daily PA and NA.

1. Introduction

Depression is associated with dysregulated circadian rhythms (Antypa et al., 2016; Fabbian et al., 2016; Kitamura et al., 2010; Mendoza, 2019). Nearly all people suffering from depression have disruptions in their sleep-wake cycle (Germain and Kupfer, 2008; McClung, 2013; Nechita et al., 2015), with altered sleep patterns being one of the diagnostic criteria for mood disorders (APA, 2013; WHO, 2018). Depression is also related to *chronotype* (Muller et al., 2015). Chronotype refers to an individual's time-of-day preference for sleep and activity, and reflects one's physiological circadian rhythm which influences bodily processes such as hormone secretion and body temperature (Duffy et al., 2001; Horne and Östberg, 1976; Mongrain et al., 2006; Montaruli et al., 2021). Individuals can generally be classified as belonging to one of three chronotypes (morning type, evening type, or intermediate type; Horne and Östberg, 1977), although chronotype may also be represented on a continuum from morningness to eveningness

(Roenneberg et al., 2003).

Eveningness has been linked to affective disturbances in depression (Bauducco et al., 2020; Kivelä et al., 2018). Evening types have a higher risk of depression and tend to be more severely depressed than morning types (Hirata et al., 2007; Levandovski et al., 2011; Selvi et al., 2010). Depressed patients who report delayed sleep suffer from more severe depressive symptoms (Emens et al., 2009). Besides higher symptom severity, eveningness is also associated with higher non-remission (Chan et al., 2014) and poorer response to therapeutic interventions (Bei et al., 2015).

Though various studies suggest an association between eveningness and depression (diagnosis and symptom severity; see Kivelä et al., 2018 for a review), the underlying mechanisms remain poorly understood. Intermediary disruptions in the experience and regulation of affect may be implicated. Evening types' affect is less stable (Ottoni et al., 2012) and they have higher cognitive reactivity to sadness (Antypa et al., 2017). Evening types also experience more problems with adaptive

emotion regulation (van den Berg et al., 2018; Watts and Norbury, 2017).

Recent findings suggest that low positive affect (PA) may mediate the relationship between eveningness and depression. PA refers to the experience of positive emotions such as enthusiasm, energy and joy, whereas low PA is characterized by feelings of lethargy and fatigue (Hasler et al., 2012; Watson et al., 1988a). Like chronotype, PA follows an endogenous circadian rhythm and is modulated by both circadian phase and the homeostatic sleep drive (Miller et al., 2015; Murray et al., 2009). PA is particularly relevant when investigating the chronotype-depression link, because PA is typically blunted in depression but not necessarily in other mental disorders, such as anxiety (Watson, 2000). Accordingly, in depressed individuals, eveningness was associated with lower PA and higher depressive symptom scores (Hasler et al., 2010). Others have consistently found both low mean PA (Biss and Hasher, 2012; Carciofo, 2020; Dagys et al., 2011) and a lower PA amplitude (i.e., peak) in evening types (Hasler et al., 2012; Miller et al., 2015; Porto et al., 2006; Randler et al., 2015).

A circadian pattern has not been consistently found for negative affect (NA) (Porto et al., 2006). High NA reflects feelings of distress, anger, contempt, disgust, guilt, and nervousness, while low NA is marked by calmness and serenity (Hasler et al., 2012; Watson et al., 1988a). NA is more responsive to the environment than PA (Watson et al., 1999). Unsurprisingly, the relationship between chronotype and NA is inconsistent: while some have reported heightened NA among evening types (Carciofo, 2020; Brückmann et al., 2020), the majority of studies have failed to establish a relationship between chronotype and NA (Biss and Hasher, 2012; Cox and Olatunji, 2019; Dagys et al., 2012; Hasler et al., 2010; Porto et al., 2006; Randler and Weber, 2015). While negative affectivity is also central to depression, NA (rather than PA) specifically loads highly on anxiety (Watson et al., 1988b). Accordingly, while eveningness has been robustly linked to depression and depressive symptoms, findings on anxiety disorders remain mixed (Antypa et al., 2016; Kivelä et al., 2018; Merikanto and Partonen, 2021), which may further reflect differential associations between chronotype and PA/NA.

Lack of social contact (i.e., spending more time alone) may be another explanatory mechanism contributing to the relationship between chronotype, PA/NA, and depression. In line with the social jetlag hypothesis, evening types exhibit a greater discrepancy between their preferred sleep-wake times and conventional social schedules (Wittmann et al., 2006), and consequently may spend less time in the company of others. This discrepancy is also related to more sleep complaints among evening types (incl. daytime fatigue; Wittmann et al., 2006), which may further decrease evening types' willingness to engage with others. This reduced socialization may in turn lead to reduced PA and increased NA, and ultimately, affective disturbances such as depression (Bernstein et al., 2018; Berry and Hansen, 1996; Rivera et al., 2020). Evening types may also be intrinsically less motivated to seek out social interactions in the first place, considering findings of a lowered behavioral activation system (BAS) among evening types (Hasler et al., 2010), which is associated with decreased appetitive motivation and lowered PA (Hasler et al., 2010). Meanwhile, evening types tend to score lower on extraversion (Randler et al., 2017; Staller and Randler, 2021), which further reduces their propensity to socialize. Hence, while previously unexplored, we propose that low social contact (i.e., spending more time alone) may be a further characteristic of evening types, and contribute to the associations of chronotype with PA/NA.

In order to investigate the associations among chronotype, PA/NA, and social contact (i.e., being alone vs. with others), we used Ecological Momentary Assessment (EMA) data from the Netherlands Study of Depression and Anxiety (NESDA; Penninx et al., 2008, 2021). While previous EMA research has linked chronotype with affect rhythms in non-depressed samples (Hasler et al., 2012; Murray, 2007; Porto et al., 2006), the present study is the first to examine the associations between chronotype and momentary affect (PA/NA) in different clinical groups (current major depressive disorder (MDD), remitted MDD and controls).

We have previously shown that chronotype is associated with current but not with remitted depression in the NESDA sample (Antypa et al., 2016). Consequently, it is relevant to examine these diagnostic groups separately.

In summary, the primary aim of our study was to investigate the associations of chronotype and momentary affect (PA and NA). We expected eveningness to be associated with lower PA but did not expect NA to be associated with chronotype. We further expected the magnitude of the association between chronotype and PA to be the largest among healthy controls, followed by remitted and depressed participants, since positive affect is worse during a depressive episode (Schoevers et al., 2020) and this effect is expected in all chronotypes (i.e., depression overriding the effect of chronotype). Our secondary aim was to investigate the association between chronotype and daily social contact (i.e., being alone vs. with others). We expected eveningness to be associated with more often being alone. Further, we expected being alone (vs. with others) to be associated with lower PA and higher NA. We further expected this mediation effect to be more pronounced among depressed individuals, followed by remitted and healthy controls, due to reduced socialization associated with a (current or recent) depressive episode.

2. Methods

2.1. Participants

The data were obtained from the Netherlands Study of Depression and Anxiety (NESDA) (Penninx et al., 2008, 2021). NESDA is an ongoing longitudinal cohort study of Dutch adults aged 18 to 65 aimed at assessing the course of depression and anxiety disorders. At baseline, a total of 2981 participants were included in the study; this consisted of participants with current depression and/or anxiety ($n = 1701$), lifetime depression and/or anxiety ($n = 2329$), or no history of depression or anxiety disorders ($n = 652$). Potential participants were excluded in case of a previous diagnosis of psychosis, obsessions or compulsions, bipolarity, or severe addiction (see Penninx et al., 2008 for a more detailed description of the study procedures).

In NESDA, EMA measurement of PA, NA and social contact was performed at the 9-year follow-up. The EMA data were obtained from a subgroup of 384 participants (Schoevers et al., 2020). Of these 384 participants, 105 (27%) were unfit for our analyses because they (i) had not completed the chronotype assessment ($n = 47$), (ii) had missing diagnostic data at one of the prior follow-ups[1] or did not meet inclusion criteria (i.e., had a history of anxiety without depression) ($n = 52$), and/or (iii) filled-out less than 50% of the EMA and were excluded ($n = 8$)[2]. A total of 279 participants were included in the analyses. Those excluded ($n = 105$) did not differ from our sample in gender, age or living situation (all p's > .05), but had a lower education level ($t = -2.03$, $p = .04$). Included participants completed an average of 65 EMA entries (SD = 5, Range 45–70 i.e., a response rate of 67–100% of 70 possible entries).

2.2. Materials

2.2.1. Chronotype

Chronotype was assessed at 9-year follow-up using the Munich Chronotype Questionnaire (MCTQ; Roenneberg et al., 2003). The MCTQ

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[1] We required complete diagnostic data from all participants from baseline to 9-year follow-up in order to accurately categorize participants' diagnostic status.

[2] 17 participants did not meet inclusion criteria for chronotype data only, 50 for diagnostic data/classification only, and seven for EMA data only (i.e., response rate less than 50%); 30 did not meet criteria for both chronotype and diagnostic data/classification, and one person for both diagnostic data/classification and EMA data.

is a self-report questionnaire consisting of 29 items regarding sleep and wake times on both workdays and free days. The primary outcome parameter of the MCTQ is the midpoint in time between falling asleep and waking up on free days (MSF), corrected for the sleep-debt accumulated during the work week (MSFsc). For the MSF, sleep onset is determined by summing up participants answers to the items '*I decide to go to sleep at …'* and '*I need … minutes to fall asleep'*. Wake up time is determined based on the item '*I wake up at ….'*. The sleep-wake midpoint on free days is considered to be the best measure of one's natural chronotype, uninfluenced by work schedules (Roenneberg et al., 2007). Higher midpoint scores reflect predominant eveningness, whereas lower midpoint scores reflect morningness. However, early work schedules on weekdays disrupt the circadian rhythm of evening types more than morning types. Consequently, evening types build up a 'sleep-debt' throughout the week, for which they tend to compensate for in the weekends. The MSFsc corrects for this by subtracting half of the difference in sleep duration on free days as compared to weekdays from the average total sleep duration from the original MSF (Roenneberg et al., 2012). The MSFsc correlates moderately with the Morningness-Eveningness Questionnaire (MEQ; Horne and Östberg, 1976; Zavada et al., 2005). In our primary analyses, we used the MSFsc as a continuous measure of chronotype to maximize variance. For descriptive purposes, a categorical variable for chronotype was used based on the MSFsc quintiles in our sample. The first quintile (MSFsc $\leq$ 3.07) corresponds to the morning chronotype, the second, third and fourth quintiles to the intermediate chronotype, and the fifth quintile (MSFsc $\geq$ 4.57) to the evening chronotype (as previously done by Antypa et al., 2016, 2017).

2.2.2. Depression

The Composite International Diagnostic Interview (CIDI; version 2.1) was used to establish current and lifetime diagnoses of depressive and anxiety disorders. The CIDI is a standardized diagnostic interview, assessing the presence of DSM-IV criteria (Wittchen, 1994). The interviewer-administered CIDI has good reliability, with Cronbach alpha values of $\geq$ 0.89 (Gelaye et al., 2013; Gigantesco and Morosini, 2008). Participants were interviewed with the CIDI at baseline and at each follow-up, and were classified as either having a current depression diagnosis (i.e., MDD in the past six months at the 9-year follow-up), remitted depression (i.e., no MDD diagnosis in the past six months at the 9-year follow-up but a lifetime history of MDD), or non-clinical controls (no past or current depression or anxiety disorder diagnosis).

2.2.3. Ecological momentary assessments

Experienced momentary positive and negative affect and social contact (i.e., being alone vs. with others) were assessed through electronic EMA (smartphones) five times per day (i.e., every 3 h), for two weeks (see Schoevers et al., 2020 for more details on the EMA assessment procedure). Participants received verbal and written instructions from a trained research assistant. Timing of assessments was personalized to fit participants' natural sleep-wake rhythm during the week and weekends; the first daily assessment was aimed to be 1–2 h after waking up in the mornings.

Momentary affect: Participants were instructed to indicate their current affect ratings on 13 items pertaining to PA and NA. Six items measure PA (*'I feel… satisfied, relaxed, cheerful, energetic, enthusiastic, calm'*) and seven items NA (*'I feel… upset, irritated, listless/apathic, down, nervous, bored, anxious'*). Participants responded to the items on a Likert-scale with scores ranging from 1 (*'Not at all'*) to 7 (*'Very'*). These items were based on the UPPER study (Bennik, 2015), and have previously been shown to exhibit sufficient variability to detect moment-to-moment fluctuations in affect (Schoevers et al., 2020). For each individual, we calculated both mean momentary PA/NA (M_M i.e., mean of the PA/NA items at a given assessment time point per person) and mean person PA/NA (M_P i.e., mean of the PA/NA items throughout the whole EMA assessment period per person).

Social contact: Participants were asked to indicate whether they were currently alone or with others ('*With who are you at this moment?' (1) Alone (2) In the company of others*); participants were instructed to indicate that they were alone if there were currently no other people in the same room. For the analyses, we calculated the overall proportion of assessments when participants were with others (vs. alone) as an index of social contact per participant. In contrast to the analyses on PA/NA focusing on momentary affect, we used a global estimate of the overall proportion of time participants spent with others vs. alone over time, as we believed this to be more informative than whether a participant was with others vs. alone at any one given occasion.

2.2.4. Covariates

Sociodemographic covariates included age, gender and education (in years), and were assessed at the 9-year follow-up through questionnaires; these covariates were included as chronotype is known to vary by gender and age (Roenneberg et al., 2007), and is tied to lifestyle factors, such as education (Zerbini and Merrow, 2017). Living situation (i.e., living alone vs. with others) has also been tied to chronotype (Sládek et al., 2020), and may systematically influence whether participants were alone (or with others) at times of the EMA assessments, and was hence added as a covariate. Living situation was categorized based on the number of persons in the participant's household, measured with a self-report questionnaire at the 9-year follow-up, and was coded as 1 = household consists of one person (i.e., living alone), and 2 = household consists of $\geq$ 2 persons (i.e., living with others). Finally, affect exhibits daily fluctuations (Egloff et al., 1995); we controlled for time (of day) in our analyses, inferred from the assessment number (per day, ranging from 1 to 5).

2.3. Statistical analysis

The data were analyzed with IBM SPSS Statistics 26.0 (SPSS Inc., Chicago, Illinois).

Differences between clinical groups (current MDD, remitted MDD, controls) on sociodemographic characteristics (gender, age, education, living situation), mean person PA/NA (M_P) and social contact were assessed using either Chi-square tests (for categorical variables) and analyses of variance (ANOVAs) (for continuous variables).

Prior to fitting the models we performed data exploration to assess the distributions of the PA, NA, and social contact variables to establish their suitability for the planned (linear) statistics (incl. linearity, normality, homoscedasticity). Because we observed that the distribution of NA was non-normal with a positive skew, we repeated the analyses for NA using a gamma mixed-model; these results were in line with those obtained from the linear mixed-model. We subsequently report results from the linear mixed-model for NA for consistency between the PA and NA analyses.

First, we examined the effect of chronotype on PA and NA. The data (i.e., observations of PA $k = 18,094$, and NA $k = 18,094$) were nested within days (14 days per participant) and within participants ($n = 279$). Multilevel models (linear mixed-models) were fitted with (1) mean momentary PA (M_M) as the outcome, and (2) mean momentary NA (M_M) as the outcome. A random intercept model (Step 0) was first fitted for both PA and NA separately to determine the intraclass correlation (ICC), estimated as the ratio of between-person variance to total variance, indicating the proportion of the (total) variance in PA/NA that can be attributed to between person (vs. within person) variability (Heck et al., 2014). In Step 1, chronotype (i.e., continuous MSFsc score) was included as a fixed effect. In Step 2, gender, age, years of education, living situation and time of day (of EMA assessment) were included as fixed

effects.

Next, we examined the effect of chronotype on social contact. We ran a multiple linear regression analysis with social contact (i.e., overall proportion of time spent with others vs. alone) as the outcome[3]. Predictors were included in a stepwise manner whereby the first model contained chronotype (MSFsc) (Step 1), after which sociodemographic covariates (gender, age, education, living situations) were included (Step 2).

All models (i.e., initial random intercept model and subsequent prediction models) included a random intercept on the subject level. All prediction models specified Day and Time of Day as repeated effects, and included all predictors as fixed effects. Maximum likelihood estimation (MLE) was used for all multilevel models. All analyses were first performed for the sample as a whole, and then repeated for the three diagnostic subgroups separately (current MDD, remitted MDD, controls) (i.e., a total of four models were fitted for all analyses). In order to account for multiple testing, significance was determined at $\alpha = 0.05/3 = 0.017$ for the subgroup analyses.

Finally, in order to assess the interconnections between chronotype, social contact and PA/NA, we ran two mediation analyses with PROCESS v3.5 (Hayes et al., 2012) with PA/NA (M_P) as the outcome, social contact (proportion of time spent with others vs. alone) as the mediator, and chronotype (MSFsc) as the predictor (Figure S1). The mediation analyses were first performed for the sample as a whole, and then repeated for the three diagnostic subgroups (current MDD, remitted MDD, controls) separately (i.e., a total of four mediation models were fitted per outcome measure). The significance of the effects was determined based on the 95% bootstrapped confidence intervals with 10,000 resamples. The models were corrected for gender, age, education and living situation.

2.3.1. Power analyses

For full sample multilevel analyses, with 279 participants and maximum 70 responses per person, and with an average completion rate of 93%, we had power (1.0) to detect small effects ($d = 0.20$) (Kleiman, 2017). For the subgroup multilevel analyses, with comparable response patterns, for the MDD group with $n = 49$ we had power (0.80) to detect small effects ($d = 0.20$). For the remitted group, with $n = 175$ we had power (1.0) to detect small effects ($d = 0.20$). For the control group with $n = 58$ we had power (0.80) to detect small effects ($d = 0.20$).

For full sample regression and mediation analyses ($n = 279$), with five predictors, we had power (1.0) to detect small effects ($d = 0.20$) (Faul et al., 2007). For the subgroup analyses, for the MDD group ($n = 49$) we had power (0.80) to detect small-to-moderate effects ($d = 0.30$), for the remitted group ($n = 175$) we had power (1.0) to detect small effects ($d = 0.20$), and for the control group ($n = 58$) we had power (0.80) to detect small effects ($d = 0.25$).

3. Results

3.1. Sample description

The total sample ($N = 279$, 67% female) had a mean age of 49.1 ± 12.4, ranging from 26 to 73 years old. Differences between clinical groups are presented in Table 1.

3.2. Positive affect (PA)

The intraclass correlation (ICC) for PA was 0.43, indicating that 43% of the variance could be attributed to between-person variability, while 57% of the variance was accounted for by within-person variability.

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[3] The data met all assumption for linear regression (incl. linearity, normality, homoscedasticity). Hence a linear model was considered an appropriate fit for the data.

Table 1
Sociodemographic and clinical characteristics ($N = 279$).

	Current MDD ($n = 49$, 18%)	Clinical status Remitted MDD ($n = 172$, 62%)	Control ($n = 58$, 21%)	F test/ χ^2 test	P-value
Gender, Female (n, %)	32 (65%)	116 (67%)	39 (67%)	0.08	.961
Age, Years (m, sd)	51.2 (11.4)	47.8 (12.6)	51.1 (12.2)	2.34	.099
Education, Years (m, sd)	12.8 (2.76)	12.8 (3.16)	14.3 (2.69)	5.49	.005
Living alone (n, %)	17 (35%)	40 (23%)	16 (28%)	2.66	.265
Chronotype (n, %)				3.72	.445
Morning	9 (18%)	35 (20%)	12 (21%)		
Intermediate	27 (55%)	108 (63%)	31 (53%)		
Evening	(27%)	29 (17%)	15 (26%)		
Positive affect (m, sd)	4.01 (0.67)	4.69 (0.75)	5.47 (0.57)	57.97	< .001
Negative affect (m, sd)	2.29 (0.82)	1.62 (0.63)	1.14 (0.21)	47.22	< .001
Social contact (n, %)	39 (56%)	45 (64%)	47 (67%)	4.74	.009

Note: MDD = Major depressive disorder; Social contact reflects the number of assessments (out of a total of 70) when participants were with others (vs. alone).

Overall, chronotype was not associated with PA either before ($p = .161$) or after including the covariates ($p = .317$) (Table 2); older age ($p = .010$), higher education ($p = .016$) and living with others ($p = .023$) were associated with higher PA. There was also an effect of time of day, whereby PA increased throughout the day ($p < .001$); post-hoc comparisons indicated that the only significant difference existed between the first two time points of the day, with PA being lowest in the mornings, thereafter plateauing for the remainder of the day. This effect was also small in magnitude ($B = 0.18$) (Figure S1). Further (post-hoc) analysis of an interaction effect between time of day and chronotype was also non-significant ($p = .070$). Within the three clinical subgroups, chronotype was also not related to PA (Table S1).

3.3. Negative affect (NA)

The intraclass correlation (ICC) for NA was 0.34, indicating that 34% of the variance could be attributed to between-person variability, while 66% of the variance was accounted for by within-person variability. Overall, chronotype was not significantly related to NA either before ($p = .150$) or after including the covariates ($p = .339$) (Table 2); lower education ($p = .010$) and living alone ($p = .048$) were associated with higher NA. There was also an effect of time of day, whereby NA decreased throughout the day ($p < .001$); post-hoc comparisons indicated that all time points differed significantly from each other, with NA gradually decreasing throughout of the day. However, these effects were small in magnitude ($B = -0.03$ to -0.11). Further (post-hoc) analysis of an interaction effect between time of day and chronotype was also non-significant ($p = .117$). Within the clinical subgroups, chronotype was also not significantly related to NA (all $ps > .017$) (Table S2).

3.4. Social contact

Overall, there was a significant effect of chronotype on social contact ($B = -0.026$, $SE = 0.013$, 95% CI $[-0.050; -0.001]$, $p = .042$); a later chronotype was associated with a larger proportion of the EMA assessments spent alone. However, after including the covariates, chronotype was no longer significant ($p = .817$) (Table 2); male gender ($p = .006$) and living alone ($p < .001$) were associated with more frequently being alone. Within the clinical subgroups, chronotype was not significantly related to social contact (all $ps > 0.017$) (Table S3).

Table 2

Multilevel analyses examining chronotype associations with positive affect (PA), negative affect (NA) and social contact (*N* = 279).

	Positive affect				Negative affect				Social contact [a]			
	B	*SE*	95% CI	*P*-value	*B*	*SE*	95% CI	*P*-value	*B*	*SE*	95% CI	*P*-value
Intercept	3.506	0.468	2.585; 4.426	< .001	2.709	0.391	1.939; 3.479	< .001	0.219	0.107	0.007; 0.430	.043
Time (of day)	0.041	0.004	0.033; 0.048	< .001	–0.028	0.003	–0.033; –0.023	< .001	-	-	-	-
Gender	0.003	0.105	–0.205; 0.211	.977	–0.102	0.088	–0.276; 0.071	.247	0.066	0.024	0.019; 0.113	.006
Age	0.011	0.004	0.003; 0.019	.010	–0.007	0.004	–0.014; 0.001	.055	0.001	0.001	–0.002; 0.002	.745
Education (years)	0.039	0.016	0.007; 0.071	.016	–0.035	0.014	–0.062; –0.008	.010	–0.005	0.021	–0.013; 0.002	.146
Living situation	0.104	0.045	0.014; 0.193	.023	–0.076	0.038	–0.151; –0.001	.048	0.202	>0.027	0.150; 0.255	< .001
Chronotype (MSFsc)	–0.053	0.053	–0.158; 0.051	.317	0.043	0.044	–0.045; 0.130	.339	0.003	0.012	–0.020; 0.026	.817

Note: Social contact was estimated as the overall proportion of assessments participants spent with others vs. alone, and hence time of day of assessment is not included in the model for social contact; Gender: 1: female, 2: male; Living situation: 1: living alone, 2: with others.

[a] Based on multiple regression analysis, $R^2_{Adjusted} = 0.21$, $F(5, 278) = 15.5$ $p < .001$.

3.5. Mediation analysis of chronotype, social contact and PA/NA

Overall, chronotype was not directly associated with either PA (Path c (PA), $b = –0.065$, $SE = 0.052$, 95% CI [–0.167, 0.038]), NA (Path c (NA), $b = 0.036$, $SE = 0.043$, 95% CI [–0.049, 0.120]) or social contact (Path a (PA and NA), $b = –0.003$, $SE = 0.012$, 95% CI [–0.021, 0.026]). However, increased social contact was independently associated with both higher PA (Path b (PA), $b = 0.717$, $SE = 0.266$, 95% CI [0.193, 1.241]) and lower NA (Path b (NA), $b = –0.479$, $SE = 0.221$, 95% CI [–0.913, –0.045]), even after accounting for living situation and other covariates. When repeating the analyses in the three clinical subgroups, social contact was not related to either PA or NA (Tables S4 & S5; Figure S3).

4. Discussion

The present study investigated the associations among chronotype, momentary positive and negative affect, and social contact in individuals with current MDD, remitted MDD, and non-clinical controls. While previous EMA research has linked chronotype with affect rhythms in non-depressed samples (Hasler et al., 2012; Murray, 2007; Porto et al., 2006), our aim was to examine whether these associations may dependent on clinical status, with the expectation that chronotype effects on daily affect may be reduced during a depressive episode (i.e., depression overriding the effect of chronotype).

Firstly, irrespective of diagnostic status, we did not observe the expected lower PA scores among evening types, as previously reported in both clinical (Hasler et al., 2010) and non-clinical samples (see e.g., Hasler et al., 2012; Murray, 2007; Porto et al., 2006). A number of factors may explain the discrepancy. Previous studies have predominantly employed adolescent and young adult student samples (Biss and Hasher, 2012; Carciofo, 2020; Dagys et al., 2012; Porto et al., 2006; Randler et al., 2015), whereas our sample consisted mainly of older (middle-aged) adults. Both morningness and PA are known to increase with age (Biss and Hasher, 2012; Roenneberg et al., 2007), while affect also generally tends to get more stable with age (Scheibe and Cartensen, 2010). In the NESDA sample, it has also been previously demonstrated that depressed individuals experience higher variability in affect (Schoevers et al., 2020), whereas previous studies have mostly focused on non-depressed samples (see e.g., Hasler et al., 2012; Murray, 2007; Porto et al., 2006). We measured affect repeatedly (five times) during the day, whereas other EMA studies have typically used either once- (Biss and Hasher, 2012) or twice-daily ratings (Brückmann et al., 2020; Randler et al., 2015), typically in the mornings and/or evenings. Effects may diminish with repeated assessments, as in the present study, especially among evening types and depressed individuals whose affect is more labile. Further, other EMA studies employing repeated assessments have specifically assessed diurnal variability in PA as a function of chronotype (reporting a later and shorter-lasting acrophase (i.e., peak-period) and lower amplitude (i.e., peak) of PA among evening types) rather than total effects of chronotype on mean momentary PA

(Hasler et al., 2012; Miller et al., 2015; Porto et al., 2006). Our data were not fit for cosinor analyses because data inspection showed insufficient circadian variability; even though we observed a significant linear effect of time with PA increasing and NA decreasing throughout the day, these effects were very small with negligible inter-daily patterns. We have also previously shown evening types to specifically experience worse mood in the mornings (Antypa et al., 2016); this has also been reported by others (Diaz-Morales et al., 2015; Murray, 2007). However, our (post-hoc) moderation analyses did not indicate a significant interaction effect between time of day and chronotype on either PA or NA. Finally, differences in chronotype measures may explain the non-replication of prior associations between eveningness and PA. In the present study, we used the Munich Chronotype Questionnaire (MCTQ; Roenneberg et al., 2003) which has a stronger focus on actual sleep/wake times rather than individuals' subjective preference for and self-reported functioning at morning vs. evening hours, in comparison to the Morningness-Eveningness Questionnaire (MEQ; Horne and Östberg, 1976) and the Composite Scale of Morningness (CSM; Smith et al., 1989). Indeed, many of the previous studies have used the MEQ (Biss and Hasher, 2012; Porto et al., 2006) or the CSM (Hasler et al., 2012; Miller et al., 2016; Randler and Weber, 2015). Similarly, differences in PA measures may add to these inconsistencies, with the majority of the prior studies (Carciofo et al., 2020; Dagys et al., 2012; Hasler et al., 2010, 2012; Miller et al., 2015; Porto et al., 2006; Randler et al., 2015) using the PANAS (Watson et al., 1988a), which has a greater focus on more cognitively-oriented items (e.g., proud, inspired, determined).

Secondly, chronotype was also not associated with NA, irrespective of diagnostic status. This finding was not unexpected, as prior research has provided mixed results on the association between chronotype and NA, with most studies failing to show an association (see e.g., Biss and Hasher, 2012; Hasler et al., 2010; Porto et al., 2006); our study, therefore, adds further support for a lack of association between chronotype and NA.

Thirdly, eveningness was associated with less social contact, but this effect became nonsignificant after accounting for sociodemographics, with gender being a significant covariate: males spent more time alone. This is in line with previous research showing that men tend to have smaller social networks (Ajrouch et al., 2005) and less social interactions than women, especially in middle to late adulthood (Sander et al., 2017). Since our study was the first to investigate chronotype in relation to social contact (i.e., being alone vs. with others) during the day, it is difficult to generalize our findings since the initial significant effect of chronotype may also be confounded by gender, as men are more frequently evening types (Roenneberg et al., 2007).

Finally, although our full mediation model of social contact, chronotype and PA/NA was not supported, it provided evidence for an association of social contact with both higher PA and lower NA scores, independent of chronotype. Similar findings have been reported previously: social contact is associated with higher PA and lower NA at the end of the day (Bernstein et al., 2018; Cronce et al., 2020), and social interactions are one of the most important factors to influence (i.e.,

alleviate) depressive mood in everyday life (Pemberton and Tyszkiewicz, 2016; Steger and Kashdan, 2009). Prior diary studies have also demonstrated the effect of social interactions on mood (Rivera et al., 2020; Vittengl and Holt, 1998). However, although we observed this effect in our full sample, it was no longer apparent when examining the clinical subgroups separately. This is probably due to the fact that both social contact and ratings of PA were systematically lower (and ratings of NA systematically higher), among the current MDD group in comparison to the remitted MDD group, which also had systematically lower ratings than the control group. Hence, with decreasing sample sizes, smaller within-group differences in social contact and PA/NA would fail to reach significance within the clinical subgroups.

Certain limitations of our study should be noted. Our PA variable did not show circadian variability and the NA variable was non-normally distributed with a positive skew. Repeating the analyses for NA with a model better suited for non-normal data (a gamma mixed-model) showed similar findings, comparable to those obtained with a linear mixed-model. Finally, while we used a PROCESS mediation model to assess for the interconnections between chronotype, social contact and PA/NA, we cannot imply causality from our model as our data was essentially cross-sectional in nature. Future research should further assess these relationships in a prospective design.

Strengths of our study include the large sample incorporating both clinical (current and remitted MDD) as well as non-clinical control participants, and the use of EMA data. EMA enables the ambulatory assessment of individuals multiple times per day, in real time (Stone and Shiffman, 1994), and allows researchers to draw highly ecologically valid conclusions while circumventing recall biases inherent in traditional retrospective self-reporting (Ebner-Priemer and Trull, 2009; Fredrickson, 2000; Wenze and Miller, 2010). This may be particularly relevant when studying clinically depressed populations that are known to exhibit biased memory and cognitions (Beck, 1963): when recalling affective states, depressed patients tend to overestimate the intensity of both positive and negative emotions, as compared to real-time estimates (Ben-Zeev et al., 2009).

In conclusion, contrary to prior findings, we did not observe a relationship of chronotype with either PA or NA in an EMA study of adults with current MDD, remitted MDD, and non-clinical controls. We found that a later chronotype was associated with less social contact, although this effect was confounded by gender differences. Further, reduced social contact was associated with both lower PA and higher NA, independent of chronotype.

CRediT authorship contribution statement

L. Kivelä: Data curation, Formal analysis, Writing – original draft. **H. Riese:** Methodology, Supervision. **T.G. Fakkel:** Writing – original draft. **B. Verkuil:** Writing – review & editing. **B.W.J.H. Penninx:** Resources, Project administration, Writing – review & editing. **F. Lamers:** Writing – review & editing. **W. van der Does:** Writing – review & editing, Supervision. **N. Antypa:** Conceptualization, Resources, Writing – review & editing, Supervision.

Declaration of Competing Interest

None.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2021.114386.

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