# Chronotype changes with age: seven-year follow-up from the Netherlands study of depression and anxiety cohort

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Short Communication

# Chronotype changes with age; seven-year follow-up from the Netherlands study of depression and anxiety cohort

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ABSTRACT

*Background:* Chronotype reflects an individual's optimal daily timing of sleep, activity, and cognitive performance. Previous, cross-sectional, studies have suggested an age effect on chronotype with later chronotypes in adolescents and earlier chronotypes in children and elderly. Additionally, later chronotypes have been associated with more depressive symptoms. Few studies have been able to study longitudinal associations between chronotype and age, while adjusting for depressive symptoms.
*Methods:* Chronotype was assessed twice with the Munich Chronotype Questionnaire 7 years apart in the Netherlands Study of Depression and Anxiety (T1: $N = 1842$, mean age (SD): 42.63 years (12.66)) and T2: $N = 1829$, mean age (SD) 50.67 (13.11)). The longitudinal association between change in age and change in chronotype was tested using a generalized estimated equation analysis adjusted for covariates (including level of depressive symptoms). Using age-bins of 5 years (age at T2), change in chronotype between T1 and T2 was analyzed with Linear Mixed Models.
*Results:* We found a change towards an earlier chronotype with higher age ($B$ (95% CI): -0.011 (-0.014–0.008), $p < 0.001$). For the age-bins, the difference in chronotype was significant for the 25–29 years age-bin.
*Limitations:* The sample did not include individuals younger than 19 years or older than 68 years.
*Conclusions:* In the whole sample chronotype changed towards becoming more morning-type over a period of 7 years, but this change was only significant for those aged 25–29 years. The study was performed in a large naturalistic cohort study with a wide age-range, including patients with a diagnosis of depressive and anxiety disorder and healthy controls.

## 1. Introduction

Chronotype is an individual's preferred timing of sleep, activity, and cognitive performance and is often referred to as a later chronotype (evening-type) or an earlier chronotype (morning-type). It has been the subject of extensive research over the years. Across the lifespan, chronotype is associated with psychological wellbeing, environmental and endogenous factors (Allebrandt et al., 2014; Roenneberg et al., 2007). From earlier cross-sectional research it appears that chronotype changes during life (Dijk et al., 2000; Fischer et al., 2017; Randler et al., 2017; Roenneberg et al., 2007). Later chronotypes are observed in adolescents with a peak around the age of 20 and earlier chronotypes are observed in young children and older persons.

The literature on the longitudinal association between increasing age and changes in chronotype is still limited. Studies that are based on large sample sizes with a wide age-ranges are still missing. Notably, changes in chronotype in a sample including patients with psychiatric diagnoses are understudied, but are relevant for the use of chronobiological interventions in psychiatry. As an example, previous studies showed that evening-type is associated with increased somatic and psychiatric

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morbidity and mortality (Antypa et al., 2016; Knutson and von Schantz, 2018; Partonen, 2015). In our previous paper about the stability of chronotype focusing on the longitudinal effect of age was beyond the scope of the study (Druiven et al., 2020). We did show that chronotype is moderately stable over a period of 7 years, apart from a minor mean level change of 10.8 min that is associated with a change in severity of depressive symptoms. We concluded that severity of depressive symptoms should be taken into account when studying chronotype.

The few available studies with a longitudinal design show evidence that chronotype indeed changes with age in adults (Broms et al., 2014; Didikoglu et al., 2019; Maukonen et al., 2019). Didikoglu et al. (2019) studied the longitudinal change of chronotype in older adults. At the first wave, 6375 participants (mean age 65.19 years, SD = 7.45) enrolled into the study of which 212 participants completed questionnaires at 5 time points across a period of approximately 35 years. Chronotype was assessed with the Personal Details Questionnaire and once with the Munich Chronotype Questionnaire (MCTQ) (Roenneberg et al., 2007). In accordance with previous cross-sectional studies, they found that from the ages of 40 to 90+ years chronotype advanced with 30 min. In a study of Broms et al. (2014) chronotype was assessed at two time points by asking a single self-rated item asking what chronotype participants considered themselves to be. They reported more morning-types in 567 male participants at the average follow-up time of 23.4 years. At baseline (mean age (SD): 47.6 (6.7)), 8.3% considered themselves evening-types, compared to 6.2% at follow-up (mean age (SD): 72.3 (6.1)). For morning-types, 34.9% considered themselves as such (mean age (SD): 49.2 (5.7)), compared to 33.7% at follow-up (mean age (SD): 72.7 (5.6)). These studies both show that longitudinal evidence supports the direction towards earlier chronotype with aging. But these results come from studies in older aged or male participants only. A less conclusive result was found in the study of Maukonen et al. (2019). Here chronotype was assessed twice with a follow-up time of 7 years, in 919 participants with an age range of 25–74 years using the shortened version of the Morningness-Eveningness Questionnaire (MEQ) (Horne and Ostberg, 1976). At baseline, participants categorized as evening-types (mean: 47.3 years, SD: 1.) were almost 10 years younger than the morning-types 2 (mean: 55.7 years, SD: 0.5, $p < 0.001$). At follow-up, chronotype changed for only a small number of participants: 4 baseline evening-types classified as morning-types and 5 baseline morning-types classified as evening-types.

The aim of the current study is to analyze the longitudinal association between a change in chronotype and a change in age over 7 years using data from the large cohort study of the Netherlands Study of Depression and Anxiety (NESDA). NESDA is a sample with a wide age-range and respondents with and without a clinical psychiatric diagnosis. To test whether the association between chronotype and age differs for different age groups, the change in chronotype will be compared for the sample separated in 5-year age-bins.

## 2. Method

### 2.1. Study sample

Data from the multi-center (Groningen, Amsterdam, Leiden) NESDA cohort study was used (Penninx et al., 2021, 2008). NESDA examines the longitudinal course of depressive and anxiety disorders. At baseline (2004–2007) 2981 participants (age 18–65 years) were included from different settings (community, general practice and secondary mental health care) of which 2329 participants had a current or past diagnosis of depressive and/or anxiety disorder. The participants were followed up after 2, 4, 6, and 9 years with a response rate of 87% ($n = 2596$), 81% ($n = 2402$), 76% ($n = 2256$), and 69% ($n = 2069$), respectively (van Eeden et al., 2019). For the current study, data from participants of the 2 (T1) and 9-year (T2) follow-up were used. The ethical committees of participating universities approved the study protocol and participants provided written informed consent.

### 2.2. Instruments

#### 2.2.1. Chronotype

The MCTQ was used to assess chronotype (Roenneberg et al., 2007). This self-report questionnaire distinguishes between sleep timing on workdays and free days. From these times the midpoint of sleep onset and offset on free days can be calculated (Midsleep on Free days: MSF). Subsequently, MSF is corrected for oversleep on the weekend due to sleep deprivation during the week because of work hours by subtracting from MSF half of the difference between sleep duration on free days and average weekly sleep duration (MSFsc) (Roenneberg et al., 2012). MSFsc is a validated measure for chronotype (Zavada et al., 2005). In NESDA, the questions of the MCTQ were slightly different between T1 and T2. However, in our previous study we concluded that this difference did not cause a significant alteration in the calculated MSFsc values (Druiven et al., 2020). The same method for calculating MSFsc was used in the current study.

#### 2.2.2. Age

Self-reported age (years) at the moment of assessment at T1 and T2 was used in this study. For the longitudinal analysis, age was used as a continuous variable. To analyze the change in chronotype between T1 and T2, age-bins of 5 years were created.

### 2.3. Covariates

#### 2.3.1. Severity of depressive symptoms

Severity of depressive symptoms was added to the analyses to control for its longitudinal association with chronotype (Druiven et al., 2020). The Inventory Depressive Symptomatology—Self Report (IDS-SR) was used at T1 and T2 to assess the severity of depressive symptoms (Trivedi et al., 2004). Consisting of 28 questions, each scored between 0 and 3, the sum-score can range between 0 and 84. Higher scores indicate a higher severity.

#### 2.3.2. Season of chronotype assessment

To control for seasonal effects on chronotype assessment, the date of assessment: daylight saving time (DST) indicating summer (long-day) time period or standard zone time (SZT) indicating winter (short-day) time period was added to the analyses (Allebrandt et al., 2014). Season was assessed at T1 and T2 and treated as a dichotomous variable (DST/SZT) in the statistical analyses.

#### 2.3.3. Sociodemographic factors

To control for possible confounding variables the following sociodemographic factors were added to the analyses: having children in the household and employment status (Bjelland et al., 2008; Díaz-Morales and Pilar Sánchez-López, 2008). Both factors are dichotomous variables (yes/no) and were assessed at T1 and T2.

### 2.4. Statistical analysis

Data were analyzed in the Statistical Package for Social Science (IBM SPSS, Chicago, IL version 23.0). *P*-values $< 0.05$ were considered statistically significant. All analyses were adjusted for possible confounders: severity of depressive symptoms, sex, children in the household, employment status, and season of chronotype assessment.

To assess the longitudinal relationship, a generalized estimated equation (GEE) analysis was used to analyze whether a change in age is associated with a change in chronotype, while adjusting for possible confounders. The GEE-analysis generates a regression coefficient that reflects the longitudinal association between the change in independent variable (age) and dependent variable (chronotype) (Twisk and Vente, 2000). For the GEE-analysis, sex was treated as time-independent variable. Age (continuous), severity of depressive symptoms, children in the household, employment status and season of chronotype assessment,

**Table 1**
Results of the generalized estimating equation (GEE) analyses: longitudinal associations between change in chronotype and change in age ($N = 2206$).

| | B | 95% CI | *p*-value |
|---|---|---|---|
| **Age** | −0.011 | −0.014–0.008 | **<0.001** |
| **Sex (female = 1)** | 0.143 | 0.060–0.227 | **0.001** |
| **Children in household (yes/no, yes = 1)** | 0.473 | 0.400–0.546 | **<0.001** |
| **Employment status (yes/no, yes = 1)** | 0.135 | 0.051–0.219 | **0.002** |
| **Severity of depressive symptoms** | 0.005 | 0.001–0.008 | **0.014** |
| **Season of assessment (SZT/DST*; SZT = 1)** | 0.016 | −0.053–0.086 | 0.648 |

* Note: SZT: Standard zone time; DST: Daylight saving time.

were treated as time-dependent variables. Participants with missing chronotype data at one of the timepoints (T1 or T2) were included in this analysis, as the GEE-analysis can adequately handle missing data.

To analyze the change in chronotype between T1 and T2, chronotype, adjusted for the already mentioned possible confounders at baseline (T1) were compared per 5-year age-bin using Linear Mixed Models.

## 3. Results

At T1, complete data on chronotype, sociodemographic factors and severity of depressive symptoms was available from 1688 participants with an age range of 19–68 years (mean (SD): 42.29 years (12.68)). At T2, complete data was available from 1752 participants with an age range of 26–75 years (mean (SD): 50.39 (13.07)). MCTQ data at T1 and T2 was available from 1237 participants.

### 3.1. Longitudinal association between chronotype and age

The results of the GEE-analysis are given in Table 1A. Controlled for covariates, a change in age is associated with an advance in chronotype (chronotype becomes earlier)($B$ (95% CI): −0.011 (−0.014–−0.008), $p < 0.001$). An increase in 1 unit of age (= 1 year) is associated with an advance of chronotype of 0.011 (= 0.66 min).

The difference in chronotype between T1 and T2 for the different age-bins is shown in Fig. 1. Adjusted for possible confounders, there was a statistically significant change in chronotype for the age-bin 25–29 ($p = 0.010$) (age at T2), with chronotype advancing over the 7 years period.

## 4. Discussion

This study shows that age is associated with a change in chronotype where chronotype advances (becomes earlier) with increasing age in a large cohort of adults (19–68) with different levels of depression and anxiety and healthy controls. The overall association between age and chronotype is consistent with earlier longitudinal research in (older) adults, and cross-sectional evidence (Dijk et al., 2000; Fischer et al., 2017; Randler et al., 2017; Roenneberg et al., 2007). Our previous study showed that a change in chronotype is associated with a change in depressive symptoms (Druiven et al., 2020). However, in this study the association between changing age and a change in chronotype was found to be independent of the level of depressive symptoms. Beside that, the effect was found to be independent of sex, having a child in the household, being employed, and the season of chronotype assessment (Allebrandt et al., 2014; Bjelland et al., 2008; Díaz-Morales and Pilar Sánchez-López, 2008; Druiven et al., 2020).

When focusing on the age-bins findings, a statistically significant advance in chronotype was only found in the age-bin of 25–29 years. Earlier, cross-sectional research showed that chronotype is at its latest at the age of 20 after which it changes to an earlier chronotype (Dijk et al., 2000; Fischer et al., 2017; Randler et al., 2017; Roenneberg et al., 2007). It is therefore expected that there is a larger change in chronotype right after the peak at age 20, here in the age-bin of 25–29, before it becomes more stable in older ages.

The results of this study should be interpreted in light of the following limitations. First, although the age-range used in this study was larger than used in previous research, especially the age-ranges in which chronotype is thought to change the most (15–20 years, (Dijk et al., 2000; Fischer et al., 2017; Randler et al., 2017; Roenneberg et al., 2007)) are underrepresented. Second, this study included two time-points. To get a definite answer to the longitudinal association between chronotype and age, participants are ideally followed up over a lifetime.

This paper demonstrates for the first time a longitudinal association between a change in age and a change in chronotype, in a sample

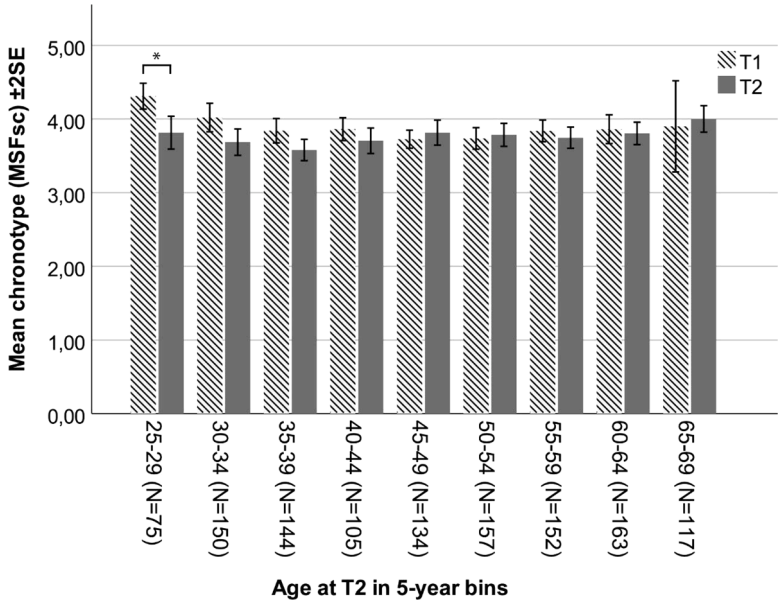


**Fig. 1.** The change in chronotype between T1 and T2 for the different age-bins (age at T2) ($N = 1237$). The analyses to test the change in chronotype per age-bin were controlled for possible confounding factors at baseline (level of depressive symptoms, sex, having a child in the household, employment status, and season of chronotype assessment).

including younger adults and participants with and without psychiatric diagnoses. Affirmation of this previously assumed association can be used in future research of the association between chronotype and other clinical factors, as well as the implementation of chronobiological interventions.

## CRediT authorship contribution statement

**S.J.M. Druiven:** Data curation, Writing – original draft, Writing – review & editing, Formal analysis. **H. Riese:** Data curation, Writing – original draft, Writing – review & editing. **J. Kamphuis:** Data curation, Writing – original draft, Writing – review & editing. **B.C.M. Haarman:** Data curation, Writing – original draft, Writing – review & editing. **N. Antypa:** Data curation, Writing – original draft, Writing – review & editing. **B.W.J.H. Penninx:** Data curation, Writing – original draft, Writing – review & editing. **R.A. Schoevers:** Data curation, Writing – original draft, Writing – review & editing. **Y. Meesters:** Data curation, Writing – original draft, Writing – review & editing.

## Declaration of Competing Interest

BP has received (unrestricted) research funding from Boehringer Ingelheim and Jansen Research. All other authors have nothing to declare.

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