

**Predicting Trait Anxiety Through Within-Person Means, Fluctuations, and Inertia in
Momentary Anxiety: An Experience Sampling Study**

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Date: 14.07.2025

Abstract

Traditionally, anxiety has been conceptualised and measured as a stable individual trait, yet current research suggests that it may be rooted in dynamic emotional processes experienced in daily life. Although prior research has already found a connection between general affective states and trait anxiety, less is known about the influence of anxiety-specific dynamics on trait anxiety. Thus, this study aimed to explore the association between within-person mean levels, fluctuations and inertia of state measures of anxiety and trait anxiety. This study used previously collected data with the Experience Sampling Method (ESM) from 26 non-clinical participants who were assessed four times a day for one week, measuring state anxiety. Trait anxiety was measured via the Hospital Anxiety and Depression Scale (HADS) on the eighth day. Individual metrics were computed for mean levels (person-means; PM), fluctuations (root mean square of successive differences; RMSSD), and inertia (autocorrelation function; ACF). Visualisations of scatterplots, facet time series and bar charts showed that individuals with high trait anxiety tended to show higher levels of both mean state anxiety and fluctuations. A significant effect of person-mean levels ($\beta = .53, p = .005$) and fluctuations of state anxiety ($\beta = .56, p = .005$) on trait anxiety was found in univariate analysis. In the multivariate model with the three predictors, neither person-mean levels ($\beta = .09, p = .17$) nor fluctuations ($\beta = .18, p = .116$) remained significant after being included, suggesting shared variance among these predictors ($r = .63, p < .001$). In both univariate and multivariate models, there was no significant association between inertia and trait anxiety. The present study adds to the understanding of anxiety disorders by emphasising the influence of state anxiety dynamics on trait anxiety, particularly mean levels and fluctuations. The findings highlight the need for further investigation into these dynamics among the clinical population.

Predicting Trait Anxiety Through Within-Person Means, Fluctuations, and Inertia in Momentary Anxiety: An Experience Sampling Study

Anxiety disorders are the most common mental disorder, affecting 301 million people in the world in 2019 (World Health Organisation: WHO, 2023). Currently, an estimated 4% of the global population is suffering from an anxiety disorder. An anxiety disorder may be expressed by excessive fear or worry about a specific situation (e.g., panic attack or social situation) or, in the case of a generalised anxiety disorder, about multiple situations (World Health Organisation: WHO, 2023). Most anxiety disorders onset during childhood, adolescence or early adulthood (Craske et al., 2017). While anxiety disorders seem to be chronic with increasing and decreasing symptoms, about ~40% of patients experience symptom reduction without any specific treatment. They can be a risk indicator of comorbid disease burden since they are often associated with depression and several other comorbidities (Craske et al., 2017). Fundamentally, anxiety has an adaptive function, helping individuals deal with threats and danger by preparing them for action (Willers et al., 2013). Nevertheless, excessive or dysregulated anxiety may interfere with everyday functioning and decrease quality of life (Willers et al., 2013; Wilmer et al., 2021). Considering the burden that anxiety places on both individuals and society, it is important to understand the dynamics behind anxiety to establish early diagnosis and treatment options.

One important topic to investigate is the interplay between *state* and *trait* anxiety, which involves a differentiation between those two constructs, as this may offer insights into the emotional processes underlying trait anxiety. *State anxiety* can be defined as a temporary reaction resulting from unfavourable events. In contrast, *trait anxiety* describes a more stable personality construct that manifests in responses to various situations characterised by concerns, troubles, and worries (Saviola et al., 2020). Several studies have defined trait anxiety as the frequency of anxiousness and state anxiety as the state linked to the experience

of anxiety (Takagi et al., 2018). Previous research has indeed shown a link between trait anxiety and state anxiety, with individuals scoring high on trait anxiety often experiencing increased state anxiety across various contexts. (Leal et al., 2017; Horikawa & Yagi, 2012). This suggests that the average intensity of momentary anxiety states over time represents a fundamental aspect of anxiety dynamics, meaning how it fluctuates, stabilises or persists over time.

However, while mean levels of state anxiety can be predictive of trait anxiety, there are additional dynamics related to state anxiety that may be associated with trait anxiety. These additional dynamics manifest themselves in two distinct emotional dynamics, namely *fluctuations* and *inertia* (Koval & Kuppens, 2012). Fluctuations in anxiety refer to the variability in anxiety levels over time. Excessive fluctuations in negative and positive feelings may indicate emotional instability, which is a characteristic of many psychological disorders such as depression, anxiety and borderline personality disorders (Myin-Germeys & Kuppens, 2022; Chen, 2023; Houben et al., 2015). For individuals with high trait anxiety, fluctuations may imply difficulty regulating anxiety in response to stressors. Inertia, on the other hand, refers to the persistence of emotional states over time (Myin-Germeys & Kuppens, 2022), or in this case, how slowly individuals return to baseline after experiencing anxiety. High inertia may indicate an inability to regulate emotional states effectively, a feature commonly observed in individuals with trait anxiety (Cécillon et al., 2023). Therefore, individuals with high trait anxiety might experience emotional inertia and fluctuations, in addition to high average anxiety levels.

To accurately explore the dynamics underlying state anxiety, it is necessary to observe individuals' emotional states over time with intensity. While both cross-sectional and traditional longitudinal survey study designs may be limited in this regard, the Experience Sampling Method (ESM) is useful in overcoming this barrier. ESM is a comprehensive

longitudinal data collection technique that can document people's daily activities and psychological states (Myin-Germeys & Kuppens, 2022). This intensive longitudinal data is collected by assessing participants many times a day for weeks or even months (Bringmann et al., 2020). According to research by Thapa et al. (2021), earlier experience sampling and daily diary studies have indeed found that excessive affect fluctuations and high levels of inertia can both be detrimental to psychological health and wellbeing. Thus, ESM can be beneficial for assessing symptoms and other variables of anxiety disorders in the natural environment by generating insight into emotional states and enabling the measurement of within-person mean levels along with emotional dynamics such as fluctuations and inertia (Walz et al., 2014; Jahng et al., 2008; Koval & Kuppens, 2012).

Time-series data collected via ESM can be used to compute metrics that meaningfully express these dynamic aspects of state anxiety. A baseline measure of overall state anxiety is provided by person-mean (PM) levels, which are calculated by averaging momentary anxiety scores over time within each person (Lafit, 2022). Fluctuations can be measured using metrics such as the root mean square of successive differences (RMSSD), which measures the average amount of variation between consecutive anxiety reports and has been previously used to assess emotional instability (e.g., Lenferink et al., 2024; Jahng et al., 2008). Inertia, or the persistence of affective states over time, is usually captured using the first-order autocorrelation function (ACF), which shows how accurately anxiety at one point in time predicts anxiety at the next (Kuppens et al., 2010). Using these techniques, anxiety dynamics can be investigated in more detail in everyday life and may provide insight into how anxiety persists or fluctuates over time.

Although such metrics have been widely applied in studies of mood and general affect (e.g., Schoevers et al., 2020; Lenferink et al., 2024), their use in anxiety-specific research is limited, leaving significant gaps in knowledge on whether and how daily state dynamics of

anxiety are predictive of trait anxiety. To date, much of the research on momentary mood dynamics has focused on general affective constructs such as positive and negative affect and their effect on psychopathology, rather than anxiety-specific features (Schoevers et al., 2020; Gilbert, 2012). Anxiety, as an emotional state, may differ from general affect in that it focuses more on hypervigilance, physiological arousal, and anticipatory worry, rather than on positive or negative affect (Saviola et al., 2020; Schoevers et al., 2020). Additionally, while affective inertia has been studied in the context of depression, its role in anxiety-specific processes remains underexplored. Some studies have suggested that state anxiety can promote stronger emotional inertia, indicating prolonged emotional responses (Pichon et al., 2014). Accordingly, findings from studies of affective variability and inertia may not fully apply to anxiety-specific processes since, compared to general affective states, anxiety is typically more threat-sensitive, situational and manifests in quick shifts of arousal and attention rather than slower, persistent patterns (Koval & Kuppens, 2012; Koval et al., 2013). Although mean levels of state anxiety might serve as an important baseline, they offer limited insight into the temporal dynamics of anxiety, such as how it fluctuates or persists over time, and it is yet unclear how fluctuations and inertia affect the prediction of trait anxiety. Hence, clarifying these relationships could enhance our understanding of how mean levels and dynamics of momentary anxiety contribute to the development and maintenance of trait anxiety.

The present study aims to address these gaps by investigating if and how different dynamics of state anxiety predict trait anxiety by answering the following research questions:

RQ1: To what extent can person-mean levels of state anxiety be predictive of trait anxiety?

RQ2: To what extent can fluctuations of state anxiety be predictive of trait anxiety?

RQ3: To what extent can inertia of state anxiety be predictive of trait anxiety?

By explicitly focusing on anxiety dynamics, this study seeks to provide a more comprehensive understanding of the relationship between momentary experiences of anxiety and more permanent anxiety traits. The findings are expected to contribute to the enhancement of theoretical models of anxiety. They may add to existing literature on the development of interventions for individuals with increased trait anxiety.

Methods

Design and Procedure

This study is a secondary analysis of the data collected by Hassanabadi (2019) and Hoppe (2019). This quantitative study employed an intensive longitudinal experience sampling method (ESM) design to measure self-rated state anxiety four times per day for one week. The corresponding trait variables and demographics were collected retrospectively via a questionnaire survey design once after the ESM period. The Incredible Intervention Machine (TiIM) smartphone application, developed by the BMS Lab at the University of Twente (Van't Klooster et al., 2024), was used for data collection. With this application, participants can partake in interventions on their smartphones and receive random reminders to complete the questionnaires. Therefore, participants were required to own a smartphone with iOS or Android operating systems.

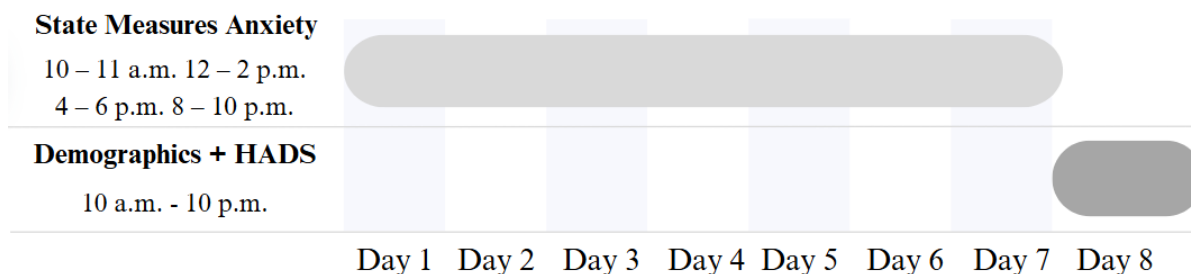
The ESM part of the study lasted a total of seven days, which aligns with recommendations from Hektner et al. (2007), suggesting that at least one week is necessary to acquire representative data on individuals' feelings. Signal-contingent, semi-random sampling was applied, which ensured collecting measures of momentary anxiety levels at relatively unpredictable times during the day. This increases ecological validity as it prevents participants from structuring their days according to the measurement schedule (Dawood et al., 2019). Participant data were measured four times daily, as more measurements were

considered too demanding for the participants (Hektner et al., 2007). It is essential to consider a balance between gathering sufficient information and not overburdening the participant with too many questions (Myin-Germeys & Kuppens, 2022).

The goal was to gather information on the participants' feelings at time points that were as representative of the distinct sections of the day as possible. Hence, measurement notifications were scheduled randomly between 10:00 a.m. and 11:00 a.m., between 12:00 p.m. and 2:00 p.m., between 4:00 p.m. and 6:00 p.m., and between 8:00 p.m. and 10:00 p.m. (see *Figure 1*). Since most participants were students, it was decided to schedule the morning measurements for after 10 a.m. If there was no response from the participant, they received a reminder 30 minutes later. If no response was given by the end of the corresponding time window, items were no longer available, and the data were counted as missing.

Figure 1

Overview of the ESM Measurement Protocol



On the eighth day, participants were asked to complete a longer online questionnaire, which included validated trait measures of anxiety. Four participants were unable to complete the questionnaire due to technical issues with TiiM on the eighth day. Thus, they received the questionnaire via the online survey tool *Qualtrics* two days later.

A pilot study involving two participants was conducted over three days to test and refine the ESM procedure before the original study started. Before the start of data collection,

participants received information about the study's procedure and were asked to provide their informed consent through the app. Additionally, participants were provided with information about the procedure and received a handout from the researchers prior to data collection. The handout consisted of a step-by-step guide to the procedure and a description of the TiiM application. The study was approved by the BMS Ethics Committee of the University of Twente (#190452).

Participants

Hassanabadi (2019) and Hoppe (2019) collected the data from 26 participants from the general population. The recruitment was conducted using convenience sampling among their personal network and via Social Media channels, and was advertised as a measure of daily variability of affect. In the ESM review by Van Berkel et al. (2017), 19 participants was the median number of participants in previous ESM studies. Small sample sizes are common in ESM studies due to the higher participant burden and limited research-related resources (Fritz et al., 2024). In addition, ESM prioritises repeated measures from individuals, allowing for detailed insights into momentary phenomena and daily processes (Koopman & Dimotakis, 2022). By understanding individual experiences rather than making broad population conclusions, it is an exploratory design (Larson & Csikszentmihalyi, 2014).

The inclusion criteria of the study were that participants had to be 18 years or older, have access to an iOS or Android-capable smartphone, be students and/or employed and speak and understand the English language.

Materials

To measure state anxiety using ESM, a single-item measure was employed, asking, "How anxious do you feel right now?" This measure was adapted from a study by Cox et al. (2018). The participants were asked to indicate their level of momentary anxiety on a visual analogue scale with a slider from 0 ("not anxious at all") to 100 ("extremely anxious").

According to Shrout and Lane (2011), a single-item measure is appropriate when assessing non-complex constructs.

On the eighth day, the participants' demographic data were measured by asking questions about their age, gender, nationality, and occupation. Moreover, participants were asked to fill out the Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith, 1983). Only the trait anxiety subscale was used for the current study context. The HADS is a widely validated questionnaire consisting of 14 items, with seven items measuring anxiety and the other seven measuring depression (Bjelland et al., 2002). Participants had to specify their feelings from the past week by selecting one of four answers, each scored from zero to three (Zigmond & Snaith, 1983). Zigmond and Snaith (1983) established the following cutoff scores for subsequent diagnostic evaluation: scores of ≤ 7 on each subscale of the HADS for anxiety and depression are considered clinically insignificant, scores ranging from 8 to 10 are classified as mild, and scores of ≥ 11 are considered clinically significant. In the current study (Hassanabadi, 2019; Hoppe, 2019), the HADS demonstrated good internal consistency with a Lambda 2 of 0.81 for the anxiety subscale.

Data Analysis

Data analysis was performed using RStudio (Version 2024.12.0+467). The dataset was pre-processed from the previously collected study of Hassanabadi (2019) and Hoppe (2019). All participants' responses were considered; no limits were set on the required ESM response rates. Before analysing the data, it was further cleaned and processed to obtain person-level features that reflect within-person dynamics. The three key indicators of this study were computed by using the tidyverse and dplyr packages.

First, person-mean (PM) levels of state anxiety were calculated for each participant across all 28 time points to address the first research question, whether mean levels of state anxiety predict trait anxiety. Second, to examine whether fluctuations in momentary anxiety

are predictive of trait anxiety, the root mean square of successive differences (RMSSD) was calculated for each participant. RMSSD is a measure of instability that quantifies short-term fluctuations in momentary affects (Schoevers et al., 2020). It captures variability and temporal dependency to measure within- and between-day instability (Jahng et al., 2008). This means that the RMSSD score reflects the fluctuation of ESM items within a day and over multiple days. RMSSD is a more relevant indicator for measuring fluctuations than measures of variability because temporal aspects of change over time are obtained by measuring these changes from each moment, rather than over an entire period (Houben et al., 2015). Third, to analyse whether inertia in momentary anxiety predicts trait anxiety, the first-order autocorrelation function (ACF) was calculated for each participant. ACF reflects the degree to which anxiety levels at one point in time are correlated with the next. The values of ACF can range from -1 to $+1$, whereby values closer to $+1$ imply higher levels of emotional inertia and more persistence in emotion over subsequent assessment occasions (Koval et al., 2021). A high degree of ACF in reported emotional states, for instance, indicates emotional inertia and may predict psychological maladjustment and lower wellbeing (Viechtbauer, 2022).

To visually explore intraindividual differences in state anxiety among participants, faceted time series plots were created using the `ggplot2` package. Based on these plots, the individual time series of three participants were selected to explore the effect of the three predictors on trait anxiety in more detail. Next, bar charts were created for trait anxiety, PM, RMSSD, and ACF scores for all participants to compare the different values. To test whether the association between each feature of state anxiety and trait anxiety was significant, separate univariate regression models with each of the parameters (PM, RMSSD and ACF) as independent variables were computed. To illustrate these effects, scatterplots with regression lines were created to show the univariate linear associations between person-mean levels,

fluctuations, and inertia and trait anxiety. A multiple linear regression analysis was conducted to examine the total explained variance and unique predictive values of PM, RMSSD, and ACF in state anxiety scores for trait anxiety, by using the *lmtest* package. To ensure model fit and statistical validity, all models were checked for violations of the regression assumptions via the *car* package and *lmtest*. Linearity and homoscedasticity were examined through residual plots, and the normality of residuals was evaluated using Q-Q plots, which revealed a normal distribution (Appendix). Additionally, heteroscedasticity and autocorrelation of residuals were assessed using the Breusch-Pagan test ($p > .88$) and the Durbin-Watson test ($p > .39$), which ensured the absence of autocorrelation in the residuals. Multicollinearity was assessed using the Variance Inflation Factor (VIF), which revealed no violation of multicollinearity ($VIFs < 2$).

Additionally, a sensitivity analysis was conducted to examine the effect of the three predictors while controlling for age and gender. The accuracy of estimates can be enhanced via hierarchical regression by controlling for confounding variables (Richardson et al., 2015). Model fit comparisons were performed using nested F-tests. Effect sizes for the predictive ability of fluctuations, inertia and person-mean levels of state anxiety on trait anxiety were analysed via standardised regression estimates and interpreted based on Cohen's (1988) rule of thumb. According to this rule of thumb, a correlation is interpreted as weak (< 0.30), moderate (0.30 to 0.50), or strong (> 0.50).

Results

Descriptives

The study included 26 participants, aged 18 to 32. Most participants were German, and 11 men and 15 women participated in the study (see *Table 1* for more details). On average, participants responded to 22.04 (78.71%) of the 28 ESM measurements, with a minimum of 13 completed measurements and a maximum of 28.

Table 1*Demographic Variables of Participants*

Variables	<i>M (SD) or n (%)</i>
Age (<i>SD</i>)	23.62 (3.67)
Gender	
Male, <i>n (%)</i>	11 (42.31)
Female, <i>n (%)</i>	15 (57.69)
Nationality	
German, <i>n (%)</i>	23 (88.46)
Dutch, <i>n (%)</i>	2 (7.69)
British, <i>n (%)</i>	1(3.85)
Student, <i>n (%)</i>	16 (61.54)
Job, next to studies <i>n (%)</i>	11 (42.31)
Full-time occupation <i>n (%)</i>	10 (38.46)
Number of responses to state measurements (<i>SD</i>)	22.04 (4.01)
HADS	
Sum score (<i>SD</i>)	13.65 (6.77)
Anxiety score (<i>SD</i>)	8.85 (3.92)

Note. $N = 26$

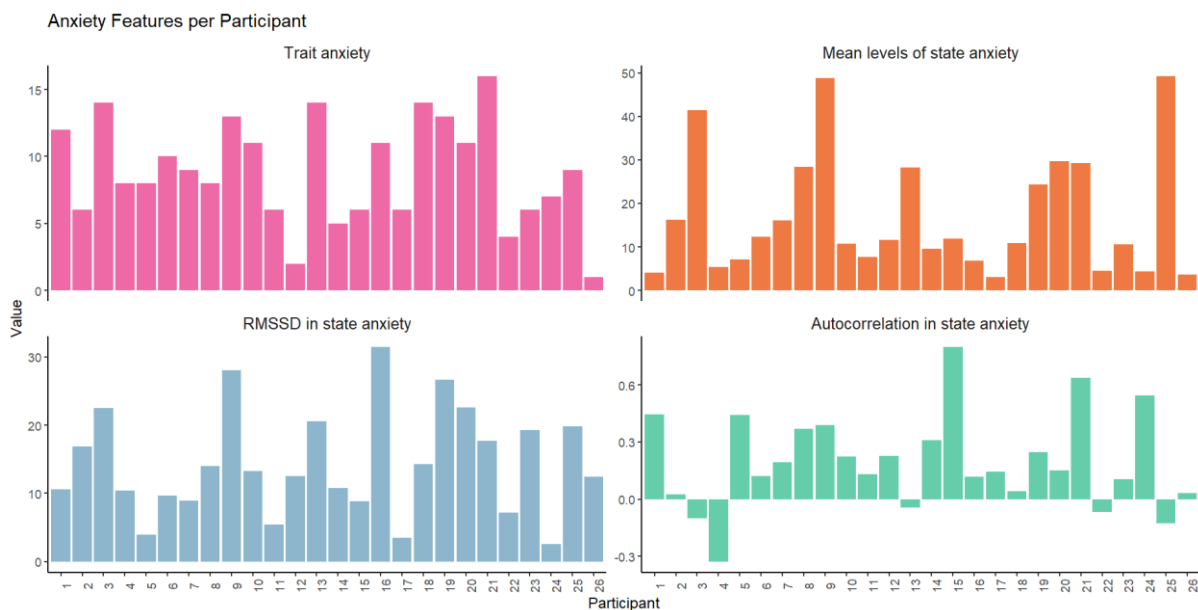
Description of Trait Anxiety, Person-Mean Levels, Fluctuations, and Inertia in State Anxiety Scores

Figure 2 displays the distribution of trait anxiety scores, person-mean (PM) levels, fluctuations (RMSSD) and inertia (ACF) of state anxiety across all participants. In general, the participants showed diverse scores across all metrics. PM levels of state anxiety varied substantially, with participants 3, 9 and 25 showing relatively high scores (above 40). High PM scores were often, but not always, consistent with high person-trait anxiety scores. For instance, while participant 21 scored high on both trait anxiety (16) and mean state anxiety

levels (29), participant 1 scored high on trait anxiety (12) and low on mean state anxiety (4). Fluctuations, measured via RMSSD, also varied between persons and were highest among participants 9, 16 and 19 (above 25). These three participants also scored relatively high on trait anxiety. ACF values ranged from -0.3 to 0.7 . For instance, participants 15 and 21 show higher inertia (above 0.6), indicating that their values are moderately influenced by the value immediately preceding them. On the contrary, participants 3, 4 and 25 showed negative values (below -0.1), indicating higher anxiety at one time point followed by lower anxiety at the next time point.

Figure 2

Distribution of Trait Anxiety, Person-Mean Levels, Root Mean Square of Successive Differences and Autocorrelation across all Participants



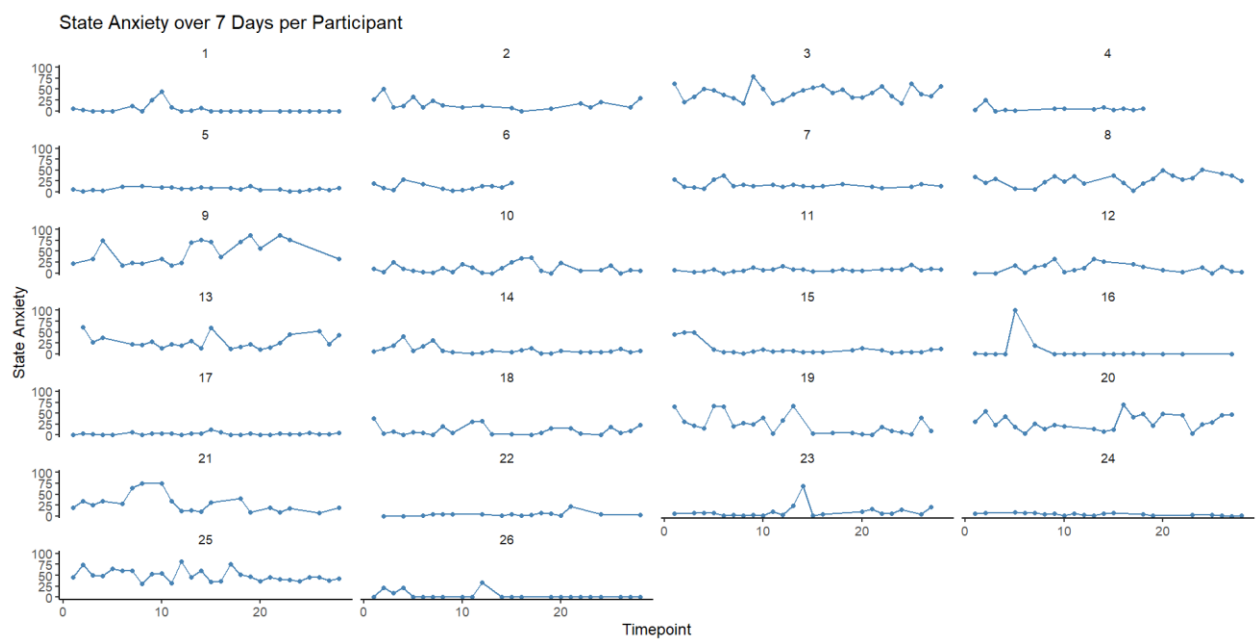
Note. RMSSD Root mean square of successive differences.

State Anxiety across Time

To visually explore individual differences in state anxiety scores over time for each participant, faceted time series of state anxiety were created across the 28 time points for all 26 participants (*Figure 3*). Markedly, different patterns in state anxiety were visible among the participants over time. Participants 17 and 24 displayed relatively low and stable levels of state anxiety across the measurement period. On the contrary, participants 3, 9, and 20 demonstrated higher average anxiety levels and fluctuated between. The time series of participants 16 and 23 reveal instances of segregated spikes or sharp shifts in anxiety levels.

Figure 3

Facet Time Series of State Anxiety across Time



Individual Case Analysis

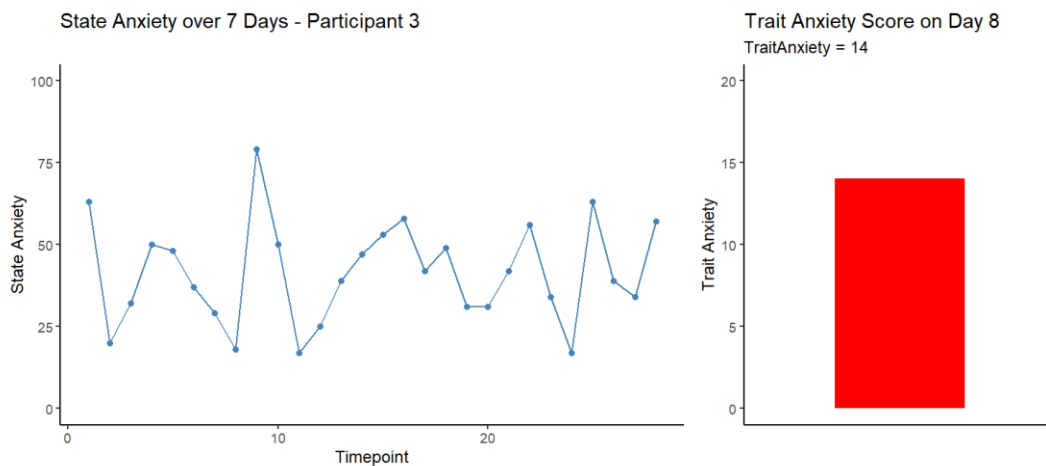
For a more detailed investigation of participants' state anxiety levels in comparison to their trait anxiety scores at an individual level, three participants were purposefully selected to be analysed further.

Participant 3

Firstly, participant 3 was selected to be explored because of their high trait anxiety score (14) and pronounced fluctuations in state scores. As can be seen in *Figure 4*, the participants' state anxiety levels were persistently increased and often exceeded 40 – 50, with alternating dips and spikes often below 25. Hence, this pattern shows high PM and moderate RMSSD scores and reflects how both high person-mean state anxiety and moderate fluctuations may indicate state anxiety dynamics predictive of increased trait anxiety.

Figure 4

Individual Time Series Plot of Participant 3



Note. The plot on the left displays the state anxiety scores of participant 3 over a seven-day period. The bar chart on the right illustrates the trait anxiety score of the same participant, measured only once on day eight.

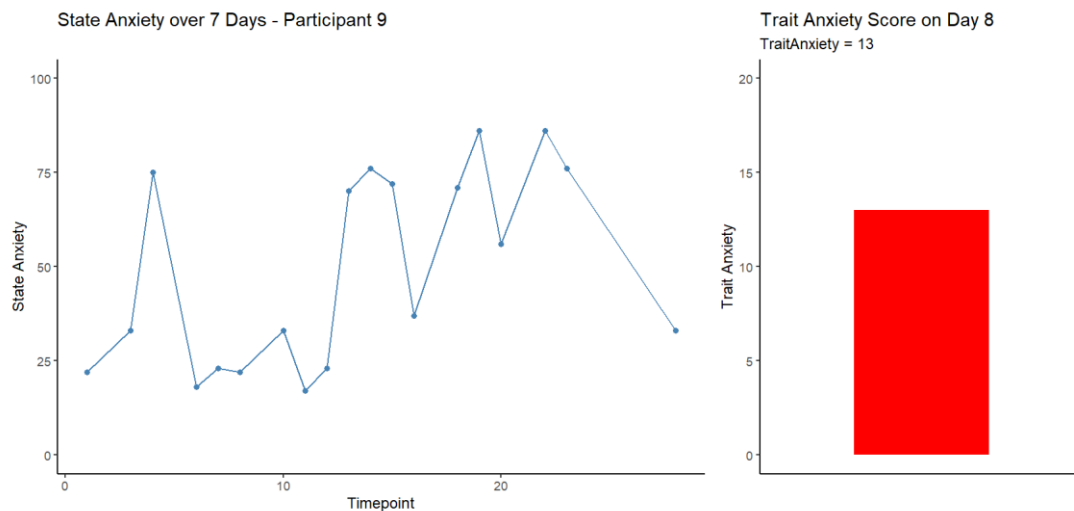
Participant 9

Likewise, the time series plot of participant 9 shows a high score in trait anxiety (13). In general, for this individual, state anxiety also seemed to fluctuate strongly, showing its lowest levels between timepoints 4 and 9. It displays a gradually increasing trend afterwards with multiple peaks reaching 90, disrupted by short decreases (see *Figure 5*). This time series

indicates moderate to high PM levels along with high RMSSD scores and confirms that greater variability in conjunction with raised mean levels is associated with higher trait anxiety.

Figure 5

Individual Time Series Plot of Participant 9



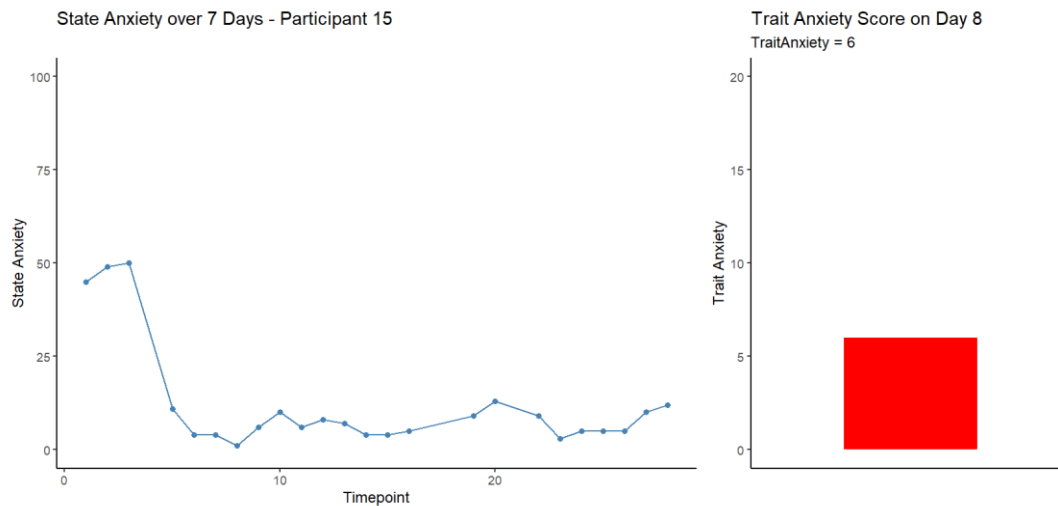
Note. The plot on the left displays the state anxiety scores of participant 9 over a seven-day period. The bar chart on the right illustrates the trait anxiety score of the same participant, measured only once on day eight.

Participant 15

In contrast, participant 15 presented a different anxiety pattern with a trait anxiety score of only 6, implying a low score. In the first three time points, the state anxiety levels were around 50, followed by a steep fall to 12 and remaining constantly low for the following time points (see *Figure 6*). This may be due to a brief stress reaction, followed by a quick emotional recovery. Accordingly, the time series supports the association between PM levels and RMSSD scores with trait anxiety, as this pattern shows that lower state anxiety levels combined with stable emotional dynamics associate with lower trait anxiety.

Figure 6

Individual Time Series Plot of Participant 15



Note. The plot on the left displays the state anxiety scores of participant 15 over a seven-day period. The bar chart on the right illustrates the trait anxiety score of the same participant, measured only once on day eight.

To conclude, these individual cases demonstrate the correspondence of different dynamics in state anxiety with trait anxiety, particularly mean levels and fluctuations. Participants 3 and 9 both showed increased and reactive state anxiety with high trait anxiety, whereas participant 15 displayed stable and lower state anxiety alongside low trait anxiety. These figures highlight the importance of person-mean (PM) levels and fluctuations (RMSSD) in understanding trait anxiety, while inertia (ACF) did not seem to affect trait anxiety in these cases.

Univariate Regression Analysis

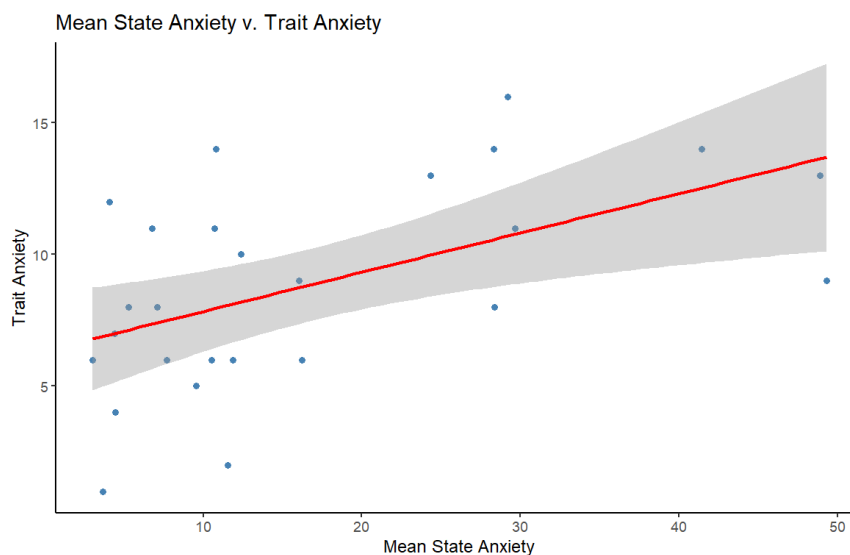
To statistically test the effect of each dynamic feature of state anxiety on trait anxiety at the group level, three individual simple linear regression models were computed. This allows for examining more interpretable, directional and predictive relationships.

Person Mean Levels and Trait Anxiety

First, it was assessed whether participants' mean levels of state anxiety across all time points predicted their trait anxiety scores. The analysis revealed a significant and strong positive association ($B = 0.15$, $SE = 0.05$, $95\% \text{ CI } [0.05, 0.25]$, $\beta = 0.53$, $t = 3.05$, $p = .005$). Individuals with higher average state anxiety levels reported higher levels of trait anxiety. In *Figure 7*, this association is displayed, showing the linear trend between mean state anxiety and trait anxiety.

Figure 7

Scatterplot of Person-Mean State Anxiety Scores v. Trait Anxiety Scores



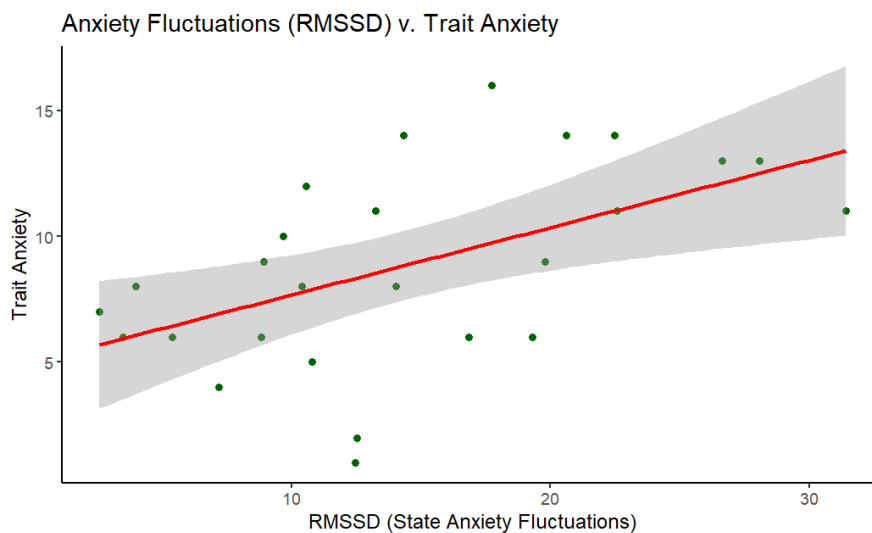
Note: The red line indicates the fitted regression line between mean levels and trait anxiety. The shaded area displays the 95% confidence interval around the regression line.

Fluctuations and Trait Anxiety

Second, to measure within-person fluctuations over time and how they predict trait anxiety scores, RMSSD scores were used as the independent variable in the second model. The results indicate that participants' fluctuations in state anxiety also significantly predicted their trait anxiety scores ($B = 0.27$, $SE = 0.09$, 95% CI [0.09, 0.44], $\beta = 0.56$, $t = 3.05$, $p = .005$). This positive linear trend is displayed in *Figure 8*.

Figure 8

Scatterplot of Fluctuations of State Anxiety Scores v. Trait Anxiety Scores



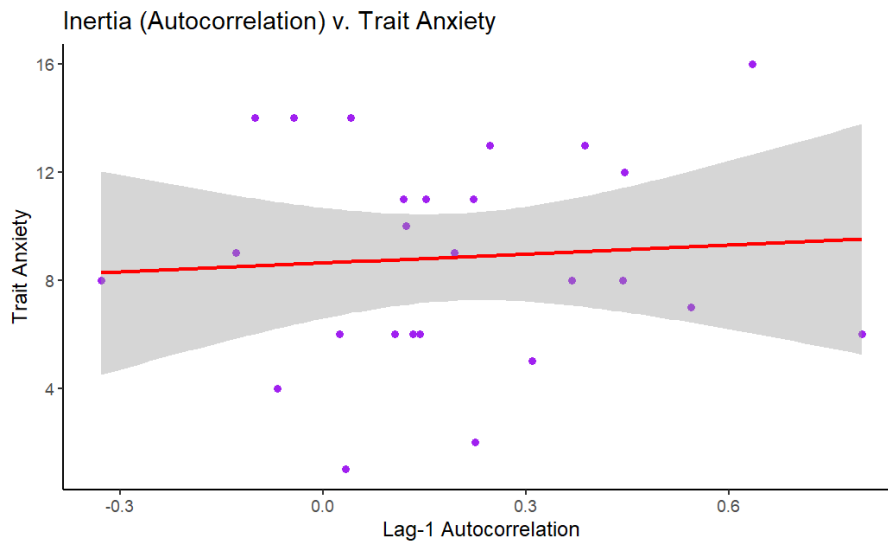
Note. The red line indicates the fitted regression line between fluctuations and trait anxiety. The shaded area displays the 95% confidence interval around the regression line.

Inertia and Trait Anxiety

Last, the third model examined whether inertia, as computed by ACF scores, predicted trait anxiety. This model revealed no significant effect of inertia on trait anxiety scores ($B = 1.11$, $SE = 3.17$, 95% CI [0.09, 0.44], $\beta = 0.07$, $t = 0.35$, $p = .729$). *Figure 9* visualises the absence of a univariate association between inertia and trait anxiety.

Figure 9

Scatterplot of Inertia of State Anxiety Scores v. Trait Anxiety Scores



Note. The red line indicates the fitted regression line between inertia and trait anxiety. The shaded area displays the 95% confidence interval around the regression line.

Multivariate Regression Analysis

A multiple linear regression analysis with person-means (PM), fluctuations (RMSSD) and inertia (ACF) in state anxiety scores was performed to examine unique predictors and the combined predictive value of all three predictors. Overall, the multivariate model (*Table 2*) was statistically significant ($F(3,22) = 4.26, p = .016$), indicating 36.7% of variance in trait anxiety ($R^2 = 0.37$, adjusted $R^2 = 0.28$) was explained by the three predictors.

Table 2

Multiple Linear Regression Analysis of Person-Mean Levels, Root Mean Square of Successive Differences and Autocorrelation

Predictor	Estimate	SE	95% CI		<i>t</i>	<i>p</i>
			<i>LL</i>	<i>UL</i>		

Intercept	4.26	1.58	0.98	7.54	2.69	.01*
PM	0.09	0.06	-0.04	0.22	1.41	.17
RMSSD	0.18	0.11	-0.05	0.42	1.64	.12
ACF	2.50	2.70	-3.08	8.09	0.93	.36

Note. *SE* = Standard error; *PM* = Person-mean levels; *RMSSD* = Root mean square of successive differences; *ACF* = Autocorrelation; *CI* = Confidence interval; *LL* = Lower limit; *UL* = Upper limit. * $p < .05$.

Nevertheless, when controlling for each other, none of the three predictors reached statistical significance, suggesting potential overlap between these dynamic indicators. Therefore, post-hoc Pearson correlations were conducted to examine potential overlap between the predictors. Person-mean (PM) levels and fluctuations (RMSSD) were strongly correlated ($r = .63, p < .001$) (Cohen, 1988), confirming shared variance among these two dynamics of state anxiety. In contrast, inertia (ACF) showed no significant correlation with either PM ($r = -.07, p = .75$) or RMSSD ($r = -.19, p = .36$).

Sensitivity Analysis Controlling for Age and Gender

Finally, a stepwise hierarchical regression analysis was conducted, controlling for the potentially confounding effects of age and gender. In *Table 3*, the change in explained variance and significant predictors at each step are summarised.

Table 3

Hierarchical Regression Analysis

Variable	β	p	R^2	ΔR^2	ΔF	p for ΔF
Step 1						
Constant	–	.00	.23			
Age	-0.43*	.04*				
Gender ^a	-1.72	.23				

Step 2						
Constant	–	.00	.43	.20	8.17**	.01*
Age	–0.32	.08				
Gender ^a	–1.82	.16				
PM	.13*	.01*				
Step 3						
Constant	–	.02	.44	.01	0.54	.47
Age	–.29	.13				
Gender ^a	–1.56	.25				
PM	.10	.10				
RMSSD	.08	.48				
Step 4						
Constant	–	.01	.50	.06	2.26	.15
Age	–.34	.08				
Gender ^a	–1.81	.18				
PM	0.10	.11				
RMSSD	0.10	.39				
ACF	3.88	.15				

Note.^a Male = 1, female = 0. *p < .05. **p < .01.

The results show that the demographic variables age and gender partly explain the variance in trait anxiety. Nevertheless, based on step 2, PM levels of state anxiety show predictive value of trait anxiety beyond demographic factors. Once demographics and mean levels are controlled for, PM, RMSSD, and ACF do not account for additional explanatory power.

Discussion

The current study examined the association between mean levels, fluctuations and inertia and trait anxiety by using previously collected ESM data in a non-clinical sample of 26 participants. It was aimed to expand existing literature, mainly focusing on positive and negative affect dynamics related to trait anxiety, by exploring how emotional states and

dynamics of anxiety experienced across a week are predictive of trait anxiety assessed via the HADS. Univariate analysis showed that person-mean levels and fluctuations of state anxiety each significantly and strongly predicted trait anxiety. In the multivariate analysis, neither remained a significant predictor due to shared variance between the two features, indicating that participants who report higher average anxiety also experience more emotional variability. Inertia did not significantly predict trait anxiety in either univariate or multivariate analysis.

The results of this research are partly consistent with expectations and reveal new insights into the association between mean levels, fluctuations and inertia of state anxiety and trait anxiety. It was anticipated that high trait anxiety levels could be dependent on high levels of inertia, fluctuations and mean levels of state anxiety. Therefore, these findings imply that while the persistence of anxiety across measurement intervals is less important, individuals who regularly experience both high and unstable levels of anxiety during their everyday lives are more likely to score high on trait anxiety. Prior research supports the connection of both person-mean levels and fluctuations in state affect with trait affect since increased emotional intensity and instability have often been shown to coexist in different psychopathological disorders (Houben et al., 2015; Leal et al., 2017; Myin-Germeys & Kuppens, 2022). This pattern may emerge because of restricted emotion regulation. Thus, individuals may experience increased sensitivity and reactivity to stressors after experiencing emotional arousal, resulting in both heightened mean levels and increased fluctuations in affect (Gross & Jazaieri, 2014; Kuppens & Verduyn, 2015). Individuals with high trait anxiety may have hyperarousal alongside difficulty modulating their emotions, which can increase rumination and worry, prolonging emotional distress and enhancing its intensity (Gross & Jazaieri, 2014; Rowa et al., 2017; McLaughlin et al., 2007). Since these strategies

are often seen in trait-anxious people, underlying regulatory deficits may be due to both high mean levels and fluctuations.

Furthermore, the current study did not confirm a predictive effect for inertia in momentary levels of anxiety. According to Houben et al. (2015), emotions that fluctuate more and show less stability are related to psychological illnesses. However, they also found that more inert, self-predictive, and lingering emotions can lead to psychological maladjustment. This suggests that emotion dynamics are a characteristic of maladjustment in which emotions experience larger changes and reach more extreme values when there are no strong homeostatic drives to return to baseline levels (Houben et al., 2015; Kuppens et al., 2010). Although it is unclear why inertia of state anxiety did not show similar significant results compared to mean levels and fluctuations, one possible explanation may be that anxiety focuses on hypervigilance, physiological arousal and anticipatory worry (Saviola et al., 2020; Schoevers et al., 2020). Hence, it is characterised rather by reactivity and more rapid shifts than prolonged affective states (Lamers et al., 2018). Perceived threats frequently cause anxiety, which can quickly decrease once the threat is no longer present (Georgiou et al., 2005). Therefore, inertia in state anxiety may be less indicative of trait anxiety than person-mean levels or fluctuation. Additionally, the sampling frequency of only four assessments per day may not have been sufficient to capture emotional inertia adequately. There was also a long gap between the last assessment in the evening and the first assessment the previous morning. Due to this night break, the first assessment of the day is often excluded by many ESM studies, as it can produce previous-day effects, meaning that the lagged association during the whole night is of a different magnitude than within a day (Kuppens et al., 2010; Viechtbauer et al., 2022). In addition, long overnight intervals can hide important emotional shifts and may have led to the non-significant result of inertia. Thus, excluding the first measurement and providing more frequent assessments (every one to two

hours) could have better captured emotional states carried on from one moment to another (Houben et al., 2015; Kuppens et al., 2010).

Implications for Future Research

The findings of this study highlight the importance of exploring dynamics of state anxiety with ESM. By analysing the dynamics of anxiety in daily life, deeper insights into the relation between momentary emotional aspects and more stable traits of psychological disorders are gained. While other studies have already focused on these features in positive and negative affect in association with trait anxiety or other psychopathological constructs (Schoevers et al., 2020; Gilbert, 2012), previous studies have not examined these dynamic processes in momentary anxiety states, which could provide a better understanding of the emotional processes that cause and sustain anxiety in daily life. In the future, it would be interesting to explore anxiety state dynamics and their role in the development of trait anxiety over a longer period and larger samples to obtain more robust evidence on the influence of these dynamics on trait anxiety (Dejonckheere & Erbas, 2022).

In this study, participants were recruited from the general population, meaning that this sample did not specifically include individuals with a clinical anxiety disorder. While the study provides insights into the emotional aspects of state anxiety and how they associate with trait anxiety in this population, it may be interesting to study these dynamics with individuals with diagnosed anxiety disorders. According to established cutoffs for the HADS (Snaith & Zigmond, 1994), some participants exhibited moderate or even severe trait anxiety. Nevertheless, people diagnosed with anxiety disorders may display even more severe levels of trait anxiety or distinct patterns in state anxiety over time. Additionally, exploring the association of state and trait anxiety in different anxiety disorders may be important since mean levels, fluctuations, and inertia may interact distinctly in individuals with generalised anxiety disorder compared to individuals with panic disorder (Walz et al., 2014).

Although inertia did not show a significant effect on trait anxiety, mean levels and fluctuations were both strongly predictive of trait anxiety levels. Thus, it may be interesting for research to further explore this connection between mean levels and fluctuations of state anxiety and investigate exactly how they contribute to trait anxiety. The coexistence of high mean levels and fluctuations in state anxiety can display underlying deficits in emotion regulation, e.g. increased awareness of physiological changes and negatively estimating these changes, which then leads to difficulties in regulating anxiety (Gross & Jazaieri, 2014). Thus, individual differences in the ability to self-soothe after experiencing negative emotions, understanding of emotions, and emotional reactivity could influence this relationship, shaping the consistency and intensity of anxiety (Berking & Wupperman, 2012). Exploring such psychological moderators could give insights into why some individuals experience both high mean levels and fluctuations in momentary anxiety levels.

Strengths and Limitations

The current study's main strengths are its focus on anxiety-specific state features, rather than positive or negative affect (Schoevers et al., 2020), and its investigation of this topic via the Experience Sampling Method (ESM), which enables the capture of emotional experiences in participants' daily lives. This approach can enhance the understanding of the relation between momentary experiences of anxiety and trait anxiety, as it has often been viewed as a rather static concept (Houben et al., 2015). Therefore, the study provides initial empirical evidence that supports the convergence of state and trait anxiety models, considering the complexity of anxiety in everyday life.

Nevertheless, several limitations must be mentioned. First, the single-item measure used by the study to assess state anxiety may have been practical in reducing participant burden. Still, a single-item measure may lack the reliability and validity of multi-item scales since it may not capture the multidimensionality of anxiety (Eisele et al., 2022; Rowa et al.,

2017). Next, the generalisability of the study's findings to larger or clinical groups is further limited by the sample's demographic homogeneity, which consisted primarily of students and working adults. Furthermore, although ESM increases ecological validity, it still relies on self-reported data, which may be influenced by participant momentary biases or fatigue (Eisele et al., 2022). Additionally, this study only focused on person-mean levels, fluctuations and inertia of state anxiety. While these parameters might add important information to understand the interplay between trait and state anxiety, this may not be the whole picture. Other analytical possibilities may offer different insights into these emotional dynamics, such as network modelling or the density of emotion networks as predictors of psychopathology (Bringmann et al., 2016; Shin et al., 2021). Lastly, although the four daily assessments provide insight into the emotional patterns of anxiety within a day, a larger sampling frequency might have enhanced the identification of processes such as emotional inertia (Dejonckheere & Erbas, 2022).

These results highlight the importance of temporal aspects of emotional experiences to gain a better understanding of psychological traits by connecting real-time emotional data with trait anxiety results. In addition, these results may inform future clinical and methodological research aimed at challenging static conceptions of trait anxiety. Further investigation into the association between momentary aspects of anxiety and trait anxiety will be necessary to develop more dynamic, individualised, and successful predictive models of anxiety, especially in clinical populations.

Conclusion

The current study explored the association between within-person mean levels, fluctuations and inertia of state anxiety and trait anxiety. By focusing on state anxiety dynamics, this study provides new perspectives on how anxiety unfolds in daily life. The results suggest that mean levels and fluctuations of state anxiety were both associated with

trait anxiety. In contrast, inertia was not found to significantly affect trait anxiety. Therefore, the results suggest that individuals who experience anxiety more intensely and unstable in their daily lives are more likely to show high trait anxiety levels. Nevertheless, since the study was conducted with a non-clinical sample, the question of generalisability remains, and the findings should be replicated in future studies.

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Appendix

Assumption testing

