To what extent do university students' momentary experiences of loneliness and

mood influence each other on a daily basis?

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BSc Thesis – Positive Clinical Psychology and Technology (202000384)

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June 25, 2025

Abstract

Loneliness is a widespread psychological phenomenon that particularly affects students during the transition to university life. This study investigated the bidirectional relationship between loneliness and mood among university students using the Experience Sampling Method (ESM). A total of 33 students participated for 14 consecutive days and rated their current loneliness and mood three times a day via the TIIM app. Linear mixed-effects models were used to examine the effects of loneliness on mood and vice versa, including both concurrent and lagged analyses with a one-measurement-unit delay to further assess the effect and direction of the relationship. The results showed a significant negative relationship between loneliness and mood (b = -0.981, p < .001), suggesting that increased loneliness is associated with poorer mood. On the other hand, increased positive mood was also significantly associated with lower levels of loneliness (b = -0.194, p < .001), confirming a bidirectional effect. Lagged effect further demonstrated the temporal influence of both relationships, with delayed loneliness significantly predicting reduced mood (b = -0.357, p < .001), and delayed mood weakly predicting increased loneliness (B = -0.048, p =.016). These results emphasized the dominant emotional impact of loneliness over mood and suggest that loneliness serves as a more stable and central factor in students well-being. In particular, the use of ESM made it possible to track psychological states in real time, taking fluctuations into account and emphasizing the importance of momentary assessments. The main limitation was the lack of diversity in the sample, which limited the generalization to students. Nevertheless, the study shows how important it is to address the issue of loneliness in higher education.

To what extent do university students' momentary experiences of loneliness and mood influence each other on a daily basis?

Loneliness is no longer just an individual problem, but a widespread social phenomenon. Statistics show that one in three people worldwide is seriously affected by loneliness (American Psychiatric Association (APA), 2024). Despite advances in digitalization and ubiquitous connectivity through social media, more and more people are reporting persistent feelings of social isolation. Recent studies reveal that 80% of adolescents and 40% of over-65s report feeling lonely occasionally, with prevalence decreasing in middle adulthood but increasing again after the age of 70 (Hawkley & Cacioppo, 2010). Furthermore, studies by Hawkley et al. (2022) reveal that young people under the age of thirty are especially affected, as they experience higher levels of loneliness compared to older generations. These findings are also confirmed by Twenge et al. (2019), who found that the prevalence of loneliness among young people has increased significantly since 2011 and therefore identifies students as a particularly vulnerable age group.

Generally, *loneliness* can be defined as the subjective perception that the number of social relationships does not match what the individual considers desirable, or that the level of intimacy an individual desire is not being achieved (Fokkema et al., 2012). In this context, loneliness arises when people feel that their need for connection is not being met, regardless of how many social contacts they have (Danvers et al., 2023; Ousman & Nazir, 2023). The experience of loneliness is subjective and varies between individuals. A person could engage in minimal social contact and still not feel lonely because they feel comfortable alone. Conversely, a person could be surrounded by others and still feel isolated. Consequently, loneliness is an individual difference that is not based on the number of social interactions, but on subjective perception (Danvers et al. 2023). Based on the evolutionary theory of loneliness (ETL), loneliness has an adaptive function by promoting and restoring meaningful social connections, like how physical pain protects the integrity of the body (Cacioppo &

Cacioppo, 2018). Loneliness therefore serves as a protective mechanism that motivates us to seek connection and closeness to others, as social isolation was considered dangerous in the evolutionary past.

Although loneliness is rooted in evolutionary mechanisms to promote social bonding, persistent loneliness is associated with a variety of negative psychological effects. On the one hand, prolonged loneliness has serious implications for psychological well-being, as being strongly associated with mood-related disorders, including heightened levels of depression, anxiety and emotional instability (Giacco, 2023; Kuczynski et al., 2024). Sufferers often experience increased stress, a greater fear of negative judgment, and a decline in optimism and self-esteem, which in turn increases feelings of isolation and social withdrawal (Hawkley & Cacioppo, 2010; Ellard et al., 2022). On the other hand, loneliness has also been shown to have significant physiological consequences. Research has shown that prolonged loneliness is associated with an increased risk of developing serious health problems like cardiovascular disease, stroke and type 2 diabetes (Christiansen et al., 2021). In addition, loneliness is often associated with unfavorable coping strategies, disturbed sleep patterns and lower overall life satisfaction (Ellard et al., 2022). As a result, the combination of these psychological and physiological stressors can increase vulnerability to serious mental illnesses such as depression, anxiety disorders, suicidal thoughts and self-injurious behavior (Centers for Disease control and Prevention (CDC), 2024).

While loneliness is a widespread problem in society, certain population groups, such as students, are at increased risk due to their unique circumstances. Research by Ellard et al. (2022) highlights that students are particularly vulnerable to loneliness during their time at university. As they navigate the transition to adulthood, students often leave behind familiar emotional support systems, such as family and friends, and try to build new relationships (Özdemir & Tuncay, 2008). As a result, students must adapt to an unfamiliar environment and make new social contacts, which increases their vulnerability to loneliness and social isolation

(Zahedi et al., 2022). Consequently, loneliness can result in poorer academic performance, engagement in unhealthy behaviors such as substance abuse and internet addiction, and elevated stress levels (Ousman & Nazir, 2023). The impact of loneliness, which not only affects academic performance but also impacts students' emotional well-being and daily experiences, highlights the importance of investigating this group in more detail. Therefore, students were identified as the target group for this study.

As the perception of loneliness is subjective and varies from person to person, the psychological effect of loneliness also differs from person to person. A connection has been proven between loneliness and its effects on mood (Giacco, 2023). Understanding this relationship is crucial as it demonstrates the significant impact that loneliness can have on a person's momentary mood.

Mood

Generally, *mood* can be described as a prolonged, usually low-intensity emotional state, that can either be positive or negative in nature. Furthermore, it can last for hours, days or even weeks without the person always being clear about what triggered the condition (American Psychological Association (APA), 2018). Unlike emotions, which are intense, short-term reactions to specific triggers, mood is more long-lasting and less intensive (Creswell, 2009). In addition, Beedie et al. (2005) explain that mood is more subtle and often influences a person's perception and behavior without being linked to a specific event.

Mood can influence behavior by shaping the way people process information and make decisions. In this regard, a helpful model for understanding the effect of mood on behavior is the Mood-Behavior Model (MBM). According to the MBM, mood influences behavior through two pathways, either their influence on cognitive processes, such as judgments and evaluations, or through the alignment of behavior with motives, such as the desire to seek pleasure or avoid discomfort (Gendolla, 2000). For example, a person in a

positive mood is more likely to engage in social activities, while a person in a negative mood may withdraw and avoid challenging situations.

These interactions between mood and behavior are particularly relevant when considering the bidirectional relationship between mood and loneliness. On the one hand, loneliness promotes a negative mood. In this context, Cacioppo and Patrick (2008) explain that the perception of loneliness affects a person's psychological well-being and causes negative emotional reactions such as sadness and anxiety. In addition, loneliness distorts perceptions of social interactions, causing lonely people to perceive social interactions as less supportive and friendly, which exacerbates negative mood (Cacioppo & Patrick, 2008). On the other hand, mood is also related to loneliness, as the study by Kearns & Creaven (2016) provides a basis for mood being a relevant predictor of loneliness by highlighting that individual differences in the processing and experience of feelings are related to levels of loneliness. For example, a negative mood can cause those affected to evaluate social situations pessimistically and increasingly withdraw, which in return increases the feeling of loneliness. This downward spiral of social isolation and negative emotions leads to a persistently negative mood and impairs general well-being.

Consequently, if the mood stays persistently negative, a pathological disorder could develop. Accordingly, mood disorders, for example occur when prolonged periods of excessive sadness or elevated mood are accompanied by other symptoms that meet the criteria for a disorder and significantly impair a person's ability to function (Coryell, n.d.). As a result, it can have a significant impact on sufferers and their ability to function in daily life, affecting social relationships, work performance and their general quality of life.

Experience Sampling Method

One way to gain a more detailed insight into the relationship between loneliness and mood is to use the Experience Sampling Method. In general, the Experience Sampling Method (ESM) describes a structured diary method in which subjects are asked to report their

thoughts, feelings and symptoms as well as the context of their normal daily life (Myin-Germeys et al., 2009). This involves collecting data from the participants' daily lives at least once a day over a period of weeks or months, allowing researchers to track the temporal dynamics and fluctuations in mood (Trull & Ebner-Priemer, 2014). Compared to other methods, ESM thus offers the advantage of precisely tracking psychological processes in real time through detailed temporal recording and providing insights into the development and interactions of psychological experiences in natural contexts (Fritz et al., 2024). This advantage is particularly relevant for the investigation of the relationship between loneliness and mood to obtain more precise and stabile results, but also to measure both variables, and especially long-lasting mood in an effective way.

Research Gap

In society, loneliness is often stigmatized as a problem that mainly occurs with increasing age, with loneliness being overlooked at a young age (Vasileiou et al., 2019). Consequently, research on the risk factors, consequences and external influences of loneliness has focused primarily on older adults, with less research on people at a young age (Crewdson, 2016; Holmén et al., 2013; Lee & Ishii-Kuntz, 1987). In addition to this social stigmatization, previous studies investigating the relationship between loneliness and mood often have the same methodological structure. Specifically, these studies rely on retrospective data collection methods and laboratory-based methods that can overlook the dynamic and momentary nature of participants' real life experiences (Trull & Ebner-Priemer, 2014). The use of ESM fills this gap by capturing fluctuations in loneliness and mood in real time and thus providing a more accurate and nuanced understanding of how loneliness and mood are related. At the same time, students were chosen as a target group that is particularly affected by and at risk of experiencing loneliness (Barreto et al., 2021; Özdemir & Tuncay, 2008). This study addresses that gap by using ESM, which enables the real-time assessment of loneliness and mood in a group which is shown to be particularly at risk. The use of ESM will capture these momentary

changes and provide an accurate and context-specific understanding of how loneliness and mood affect one another to explore the relationship between loneliness and mood more deeply.

The Current Study

Given the limitations of previous studies and social beliefs about loneliness, the present study aims to address this gap by using ESM to investigate the dynamic relationship between loneliness and mood in students in real time. The way in which this development influences the momentary emotional state needs to be examined in more detail. Additionally, to the examination of the concurrent relationship between loneliness and mood, the present study also investigates whether these variables predict each other over time using a lagged analysis approach, to further assess the dynamic relationship between loneliness and mood.

Therefore, the following research question guides this study: *"To what extent do university students' momentary experiences of loneliness and mood influence each other on a daily basis"*.

Based on this research question the following hypotheses have been formulated:

1. Hypothesis: Higher levels of loneliness are associated with a more negative mood on a daily basis among university students

2. Hypothesis: A more negative mood is associated with increased feelings of loneliness on a daily basis among university students

3. Hypothesis: Higher levels of loneliness at a previous time point (t-1) are associated with a more negative mood at the subsequent time point (t) among university students

4. Hypothesis: A more negative mood at a previous time point (t-1) is associated with increased feelings of loneliness at the subsequent time point (t) among university students

Methods

Design

For this study ESM was utilized, using the smartphone version of the *Twente*

Intervention and Interaction Maschine (TIIM) (Version 3.1.7). Participants had to answer

short surveys three times a day over a period of 14 consecutive days, which means 42 prompts

in total. The prompts were delivered to the participants at standardized intervals of 4 hours at

10:00 AM, 2:00 PM, and 6:00 PM. The study was given approval by the BMS Ethics

Committee of the University of Twente on March 24th, 2025 (protocol number: 250566). All

participants actively gave their informed consent to participate in the TIIM app, after being

informed about the aim of the study, the type of data collection, potential risks and their

rights. The participants' data was anonymized and stored in encrypted form.

Participants

Participants were eligible to take part on condition that they met the defined inclusion

criteria. Specifically, students had to be at least 18 years old and not diagnosed or currently

treated for a mental disorder or illness. Additionally, participants were required to have a

mobile device with an Android or iOS operating system that could be connected to the

internet to ensure use of the TIIM app during the time of data collection. Furthermore,

participants received a registration guide after indicating their willingness to participate and

were guided through app installation and consent process.

A total of 52 participants gave their informed consent and started the study. Due to an

insufficient response rate of less than 70%, 19 participants had to be excluded, resulting in a

final sample of 33 participants.

Procedure

The data collection for this study was administered by the TIIM app. Prior to the start

of the study, all necessary components within the app, including informed consent,

demographic questionnaire, ESM questionnaire, as well as timing rules were implemented

and tested over a period of 5 days. Participants were recruited in two different ways. Firstly, through social media platforms of the researcher's network, whereby mainly friends, family members and colleagues were contacted. Secondly, participants could sign up through the SONA system of the University of Twente, which is a participant recruitment system, whereby students at the University of Twente can sign up to participate in exchange for SONA points. Here, students were credited with 1.75 SONA points in exchange for participation.

In both ways, participants were informed about the study aim and procedure by a short description before they received a document on the steps of registration in the TIIM app (Appendix A). After registering in the TIIM app, participants were first offered a text with more detailed information on the study, including the right to withdraw without providing any reasons or explanations, after which a signature was required as a sign of consent. Following this, the participants were asked to answer the demographic questions on the same day of registration.

Finally, from the following day of registration, participants received 3 daily notifications to complete the main questionnaire over 14 days. In addition, participants received a reminder notification after 30 minutes if they did not answer the previous questionnaire. The participants had time to complete the current prompt until reception of the following prompt, which equaled four hours. In total, the data was collected between the 8th of April and 13th of May 2025. After the participants finished all days of participation, they were informed that the survey had ended and given the researchers, and the supervisors contact information for further questions, remarks or notification of withdrawal.

Materials

Twente Intervention and Interaction Machine (TIIM)

The ESM part of the study was administered through the TIIM application. TIIM is a software created by the BMS Lab of the University of Twente helping researchers to create

and host interventions, longitudinal studies, ESM studies and questionnaires (University of Twente, n.d.). The software allows researchers to design and schedule questionnaires and participant notifications based on predefined conditions or schedules. Practitioners manage these settings, including timing rules and questionnaire content, via an online dashboard. Additionally, TIIM enables notifications and reminders to be sent to participants and provides researchers with a comprehensive and already structured overview of the data collected.

Measurement of Loneliness

Loneliness was measured by using four questions of the DeJong Gierveld Loneliness scale (DJGLS). Due to the repeated measures used in the ESM, two questions were selected to measure the subscale social loneliness and two questions to measure the subscale emotional loneliness (De Jong Gierveld & Van Tilburg, n.d.). All four questions could be answered on a 5-point Likert scale, with the first two questions ranging from 0 = "never" to 4 = "always" and the other two questions ranging from 4 = 'never' to 0 = "always" due to the reverse coding, with a higher score indicating higher levels of loneliness. All questions were aimed at the current emotional state of the participants. Overall, the original DJGLS has an adequate reliability, characterized by a Cronbach's α of 0.89 for the social loneliness subscale, 0.77 for the emotional loneliness subscale and a value of 0.89 for the total scale, which was tested in a sample of Mexican adults (Giraldo-Rodríguez et al., 2023). Furthermore, an exploratory factor analysis of the original DJGLS was performed, showing a satisfactory validity (KMO = 0.849), with a significant Bartlett's test of sphericity (p < 0.001).

Measurement of Mood

Mood was measured by using a self-constructed single-item measure. Specifically, mood was measured by the question "How would you rate your mood right now" on a 7-point Likert scale ranging from 1 = "Very negative" to 7 = "Very positive". The question to measure mood is based on established methods from emotion research that were selected to ensure an efficient and less stressful survey of the participants' current mood at the various

points in time (Wilhelm & Schoebi, 2007). In addition, the single-item measure was used, due to the number of questionnaires the participants had to answer every day. Regarding the reliability and validity of this type of measurement, single-item measurements show a high level of consistence in measurement results compared to multiple-item measurements, which supports the use of the method (Verster et al., 2021).

Data Analysis

The data analysis of this study was performed using RStudio (Version 4.4.2). To ensure data quality, participants with a response rate lower than 70% were removed from the data set, as this response rate is regarded as sufficiently (Hektner et al., 2007). After the data cleaning, the descriptive statistics of the demographics were calculated and visually displayed. Mood and loneliness scores were then standardized. The mood scale ranged from -3 (very negative) to 3 (very positive) and the loneliness scale from 0 (no loneliness) to 4 (very lonely), with higher positive scores indicated greater loneliness and more positive mood. To aggregate associations within individuals, the data set was grouped by participant and an average mood and loneliness score was calculated for each participant across all observations, resulting in an individual mean for each participant. The person mean was then subtracted from the momentary mood and loneliness score for each observation, resulting in a person mean-centered score for both variable for each time point (Wang et al., 2020).

Afterwards, the within-person descriptive statistics were computed for all participants. Building up on this, the mean and the standard deviation were calculated from the within-person descriptive statistics of all participants. In addition, scatter plots of the participants' mean on loneliness and mood were created to explore between-person associations.

Before conducting the main analysis, exploratory analysis was performed examining general trends and variability in the data, to detect overall patterns of mood and loneliness across time points. Following the exploratory analysis, linear mixed effect models (LMEs) were set up and compared for the two hypothesis groups, H1 and H3 for measuring the effect

of loneliness on mood and H2 and H4 for measuring the effect of mood on loneliness. A model with random intercept and a model with additional random slope were set up for both hypothesis groups and tested to see which model fits better. Next, an intraclasscorrelation was performed for both models investigating the proportion of variance in the dependent variable for both models (Snijder & Bosker, 2012).

The main analysis contained two separate linear mixed-effect models, as a bidirectional relationship was investigated. The first model handled mood as DV and loneliness as IV variable, investigating the effect of loneliness on mood. The LME were chosen, due to its adequately account for within-person variability and between-person differences, while also handling missing data and unequal numbers of observations per participant in a flexible and robust manner. The second model concerned the effect of momentary mood on loneliness, containing mood as IV and loneliness as DV. Both models were checked for the necessary assumption, containing normality of residuals, homogeneity, linearity, and independence of errors. The models were then tested for the corresponding hypotheses by calculating the effect and effect strength as well as statistical significance. Lastly, a lagged analysis was conducted for both models to investigate whether previous changes in the independent variables causing following changes in the dependent variable. To do so, the predictor variable was lagged by one time point (4 hours) to test whether prior levels of mood or loneliness predicted changes in the corresponding dependent variable.

Results

Sample characteristics

Out of 33 participants, 72.73% identified themselves as female and 27.27% as male. The mean age of the participants was 21.66 years (SD = 1.90) and ranged between 18 and 26 years. The majority of participants had German citizenship (90%). Moreover, most

participants are following a bachelor's program, mainly psychology and indicated to be single (Table 1).

Table 1.

Sociodemographic Characteristics of the Participants

| Characteristics	n	%
Gender		
Male	9	27.27
Female	24	72.73
Nationality		
German	30	90.91
German & French	1	3.03
Norwegian	1	3.03
Azerbaihani	1	3.03
Level of Education		
Undergraduate	28	84.84
Graduate	3	9.1
Other	2	6.6
Study program		
Psychology	8	24.24
Medicine	2	6.6
Others	23	69.7
Marital status		
Single	32	96.97
In a domestic relationship	1	3.03

Note. N = 33

Descriptive statistics

The following statistics refer to a within-person analysis that focuses on the intraindividual variation of loneliness and mood. Loneliness had a mean of 1.15 across all participants ($M = 1.15$, $SD = 0.37$). The highest mean of a participant in terms of loneliness was 2.42, compared to the lowest mean of loneliness at 0.55.

In contrast, mood showed a mean of 1.31 ($M = 1.31$, $SD = 0.54$). The highest mean of a participant for mood was 2.12, while the lowest mean was -0.13. Figure 1 illustrates the distribution between the loneliness means and the mood means for each of the 33 participants. The data points are distributed across the plot, with no clear linear or other systematic relationship between the two variables.

Figure 1

Mood means vs Loneliness means
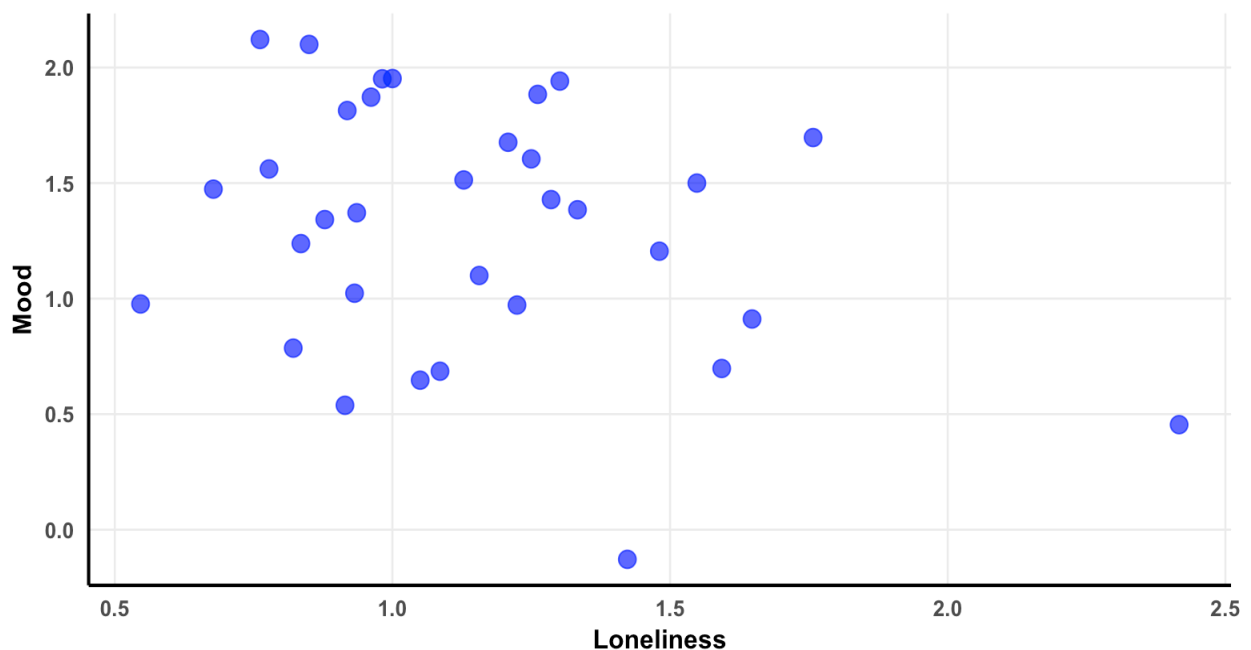
Exploratory Analysis

Figure 2 shows the visualization of the mean values of loneliness and mood of all participants across all 42 measurement points. Visual inspection shows that loneliness

remains relatively stable on average over time, while mood shows stronger fluctuations. Here, temporal patterns emerge, that could indicate possible systematic correlations or lagged correlations between the two variables, which will be investigated in the next sections. In this context, a trend can already be recognized which shows that mood and loneliness have many points of overlap. Therefore, loneliness seems to rise when mood begins to fall.

Figure 2

Standardized means of loneliness and mood across all 42 measurement points
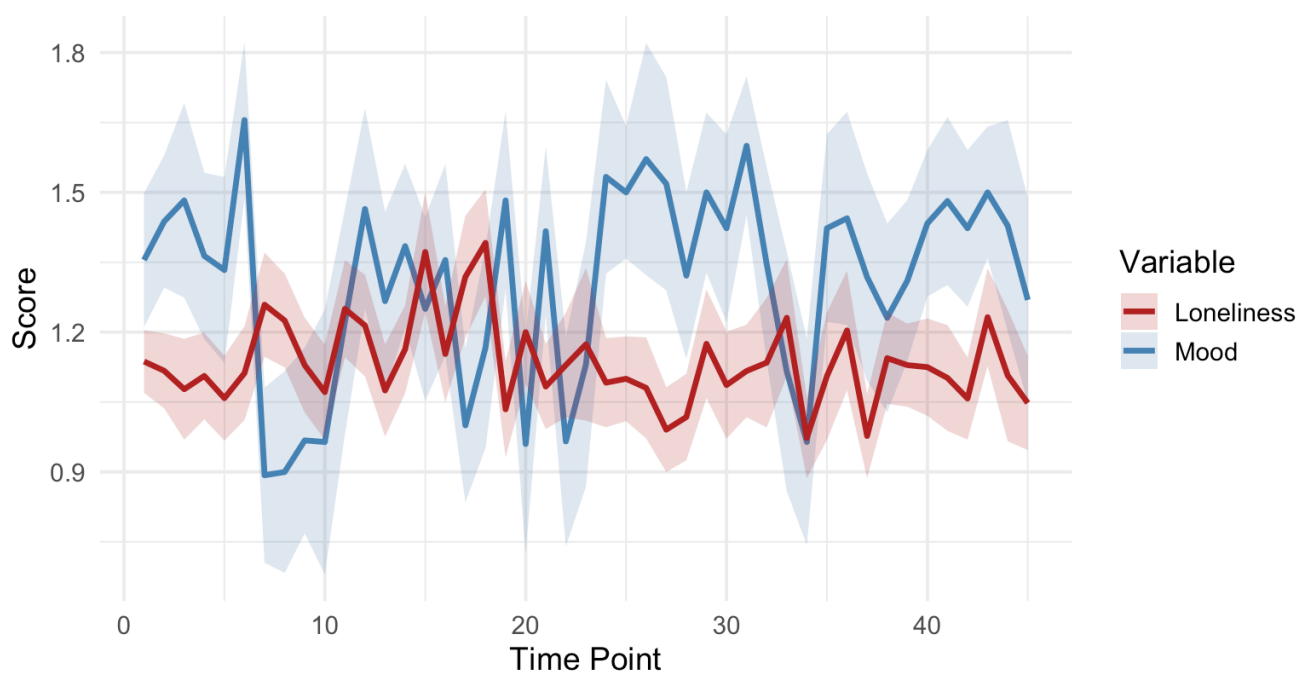
Model selection

To measure model fit, the likelihood ratio test showed that the random slopes model fitted significantly better for the effect of loneliness on mood (L.Ratio = 45.46, p < .0001) (Table 2). Therefore, Model 1 with random slopes was used to account for individual differences in the relationship between loneliness and mood. For the reasons of clarity and comprehensibility, Model 1 is used in the following, which refers to the version with random slopes.

Table 2.

Comparison of model performance between random-intercept and random-slope models for

the effect of loneliness on mood

Model	df	AIC	BIC	logLik	L.Ratio	p
Model 1 (RI)	4	3103.602	3124.164	-1547.801		
Model 1 (RS)	6	3062.143	3092.986	-1525.072	40.459	<.001*

Note. RI = Random Intercept model; RS = Random Intercept + Random Slope model. * = Significance at the level of p < 0.05

In addition, a comparison was also made between the model with random intercepts and the model with additional random slopes for hypotheses 2 and 4, investigating the effect of mood on loneliness (Table 3). Here, the likelihood ratio test also showed a better fit of the model with random slopes (L.Ratio =107.44, p < .001). For clarity, this is referred to as Model 2, which represents the version with random slopes.

Table 3.

Comparison of model performance between random-intercept and random-slope models for

the effect of mood on loneliness.

Model	df	AIC	BIC	logLik	L.Ratio	p
Model 2 (RI)	4	1206.2	1226.6	-599.11		
Model 2 (RS)	6	1102.8	1133.6	-545.39	107.44	<.001*

Note. RI = Random Intercept model; RS = Random Intercept + Random Slope model. * = Significance at the level of p < 0.05

For both models, Q-Q plots were created to check the null hypothesis that the residuals are normally distributed. In both cases, the points displayed an almost linear distribution along the reference line, which means that the normal distribution assumption can be considered fulfilled for both models (Appendix B).

Furthermore, a residual versus fitted values plot was created to test the assumption of homoscedasticity and linearity. For both models, no systematic patterns or increasing scatter could be recognized, which indicates a constant variance of the residuals. Consequently, both models fulfill the assumptions of homoscedasticity and linearity (Appendix C).

The assumption of independence of the observations was checked graphically using the residuals over the measurement time points. The residuals of both models showed no recognizable temporal trends or systematic patterns around the zero line. The assumption is therefore fulfilled, and the observations can be considered independent of each other (Appendix D).

The intraclass correlation (ICC) was calculated to determine the proportion of variance in the dependent variables' mood and loneliness. For mood, the adjusted ICC was 0.238 (0.238%), meaning that 23.8% of the total variance in mood was due to differences between participants. This suggests that between-participant differences in mood account for a negligible proportion of the total variability, confirming that the main variability in mood occurs over time within participants and justifying the use of random effects in the model.

A slightly low to moderate adjusted ICC value of 0.407 was obtained for loneliness as the dependent variable, indicating that only about 40.07% of the variability in loneliness is explained between participants. The remaining 59.3% of the variation results from within-participant differences, suggesting that individual variation within participants plays a dominant role in explaining loneliness compared to between-participant differences.

Hypotheses related results

Hypotheses 1

The results of Model 1 show that loneliness has a strong negative influence on mood (b = -0.981). For every unit of an increase in loneliness, mood decreases by 0.98 units. Thus, a higher level of loneliness is associated with a lower mood. This effect was shown to be significant ($t(1230)$ = -8.32, $p < .001$), thus confirming the first hypothesis.

Table 4.

Fixed effects of the Linear Mixed Model predicting mood from loneliness

Effect	B	SE	t	Df	p
Intercept	0.000	0.022	0.017	1230	.986
Loneliness (centered)	-0.981	0.118	-8.316	1230	< .001*

Note. * = Significance at the level of $p < 0.05$

Hypotheses 2

On the other hand, the results of model 2, used to test hypotheses 2, showed a slightly negative effect between mood and loneliness. Accordingly, loneliness increases by about 0.19 units when mood decreases by one unit, indicating that loneliness increases when mood drops. The effect was shown to be statistically significant ($p < 0.001$), causing a confirmation of the second hypothesis.

Table 5.

Fixed effects of the Linear Mixed Model predicting loneliness from mood

Predictor	B	SE	t	Df	p
Intercept	0.001	0.010	0.05	30.12	.957
Mood (centered)	-0.194	0.027	-7.16	30.12	< .001*

Note. $p < 0.05$ (*)

Hypothesis 3

In addition to the analyses of concurrent relationships, a lagged analysis was calculated for both models to investigate whether the relationship between mood and loneliness is also evident over time and to recognize the dynamics of the relationship more deeply over time. The results of the lagged analysis of Model 1 showed a significant negative effect of delayed loneliness on mood (B = -0.357, SE = 0.076, t = -4.72, p < .001), confirming the third hypothesis. This indicates that higher loneliness scores at an earlier measurement time point are associated with significantly lower mood at the following time point (4 hours later) (Table 6). Moreover, if a person's loneliness score rises by one unit at the previous measurement time, their mood falls by an average of 0.357 units at the following measurement time.

Table 6.

Linear Mixed Model for the prediction of mood through lagged loneliness

Predictor	B	SE	t	Df	p
Intercept	-0.001	0.026	-0.032	1197	.975
Loneliness (centered)	-0.357	0.076	-4.722	1197	< .00*1

Note. * = Significance at the level of p < 0.05

For the random effects, the variability of the intercepts between participants was very low (SD = 0.00007), whereas the variability of the random slopes for delayed loneliness was greater (SD = 0.21) (Table 7). This suggests that the effect of loneliness on mood varied considerably between individuals. Overall, these results suggest that, on average, loneliness measured at the previous time point significantly predicts subsequent changes in mood over time.

Table 7.

Random effects of the Lagged Analysis investigating delayed effect of loneliness on mood

Random Effects	SD
Intercept	0.00007
Loneliness	0.214
Residuals	0.904

Hypothesis 4

On the other hand, the results of the lagged analysis of Model 2 showed a significant slightly negative effect of lagged mood on loneliness (B = -0.048, SE = 0.019, t = -2.53, p = .016). If a person's mood score falls by one unit at the previous measurement time, their loneliness increases by an average of 0.048 units at the following time (Table 8). This shows that lower mood scores at an earlier measurement time are significantly associated with slightly higher loneliness at the following measurement point. The fourth hypothesis was therefore considered as confirmed.

Table 8.

Linear Mixed Model for the prediction of loneliness through lagged mood

Predictor	B	SE	t	Df	p
Intercept	0.000	0.012	0.05	1204	.963
Mood (centered)	-0.048	0.019	-2.53	33	.016*

Note. * = Significance at the level of p < 0.05

In terms of random effects, the variability of intercepts between participants was minimal (SD = 0.0005), while the slopes for delayed mood showed slightly higher variability

(SD = 0.063), suggesting slight interindividual differences in how prior mood related to subsequent loneliness (Table 9).

Table 9.

Random effects of the Lagged Analysis investigating delayed effect of loneliness on mood

Random Effects	SD
Intercept	0.0005
Slope	0.0631
Residuals	0.3316

Discussion

The aim of this study was to examine the bidirectional relationship between loneliness and mood within-person, to assess how fluctuations in loneliness and mood are related over time on a daily basis. Therefore, the study aimed to further highlight the interacting effect of mood and loneliness on students and provide an extended insight into the depth of the relationship through momentary measurements. For this purpose, a 14-day ESM study was set up, which recorded measures of loneliness and mood in students several times a day. The subsequent analyses showed the extent of the bidirectional relationship. Additionally, a lagged analysis was conducted by delaying the predictor variable by one measurement point to examine its predictive power and to further assess the interaction between loneliness and mood.

The results of the analysis showed that loneliness has a significant strong negative effect on mood, suggesting that loneliness is a strong predictor of mood. These findings were further supported by the results of the lagged analysis, which also found a significant moderate negative lagged effect of loneliness on mood. This underlines the direction of the

effect and explains that previous loneliness, albeit milder, also has a predictive effect on mood. At the same time, mood was also found to have a significant low negative effect on loneliness, suggesting that negative mood increases loneliness, but does not fully explain it due to the mild effect strength. This effect was also underpinned by the lagged analysis, which found a significant very slight negative effect of previous mood on loneliness, which further supports the direction of the effect of mood on loneliness. Since the effect of mood on loneliness was smaller than the effect of loneliness on mood, it can be concluded that mood influences loneliness but does not fully explain it. Based on the results, all hypotheses could therefore be recognized as confirmed.

Hypotheses 1 & 3

Starting with the first and third hypothesis, concerning the hypothesized effect of loneliness as predicator variable, a strong negative association between loneliness and mood was found. The main findings of this study were that momentary loneliness has the strongest effect on mood at the moment it is experienced, whereby the effect initially persists but diminishing in strength. These results are in line with other studies investigating the relationship between momentary loneliness and mood, confirming the expectation (Kuczynski et al., 2024; van Winkel et al., 2017). Nevertheless, it was found that the effect strength is significantly stronger compared to other studies (Kuczynski et al., 2021). The immediate effect strength of loneliness on mood makes clear that loneliness in momentary experience leads to a strong reduction in mood, which makes loneliness a robust predictor of mood. People therefore react particularly sensitively and strongly to their current feeling of loneliness. Furthermore, the time delay of loneliness indicates that the effect of loneliness on mood is persistent, even if this effect diminishes over time. Loneliness therefore not only immediately triggers a strong deterioration in a person's mood, but also ensures a lasting, albeit milder, reduction in mood. Particularly regarding bidirectionality, in comparison to the effect strength of mood on loneliness, it is evident that loneliness not only has a significantly

stronger direct effect, but also that the delayed effect is stronger than the immediate effect of mood on loneliness. This illustrates that loneliness is deeply rooted in the emotions and underlines its strong predictive influence. While mood can fluctuate in response to various situational factors, loneliness tends to become more firmly anchored in emotions and resist short-term improvements in the absence of meaningful social contact.

This persistent emotional impact of loneliness is consistent with theoretical perspectives that view loneliness not just as a temporary feeling, but as an adaptive signal. In this regard, the result of this study shows consistency with the Evolutionary Theory of Loneliness, which states that loneliness triggers like an alarm system that promotes negative emotions to increase motivation to seek meaningful social interactions (Cacioppo & Cacioppo, 2018). It becomes clear that moments of heightened loneliness evoke a negative mood to remind of the need for social interactions and community. As a result, the non-adherence to this alarm system of the body could be the reason for unfavorable coping mechanisms, sleep disturbances and general reduction of life satisfaction (Ellard et al., 2022).

Another aspect worth considering is the complexity of the bidirectional relationship itself. Mood can be influenced by a variety of situational and interpersonal factors, apart from loneliness such as social interactions or sleep quality, which can further contribute to a poorer mood (Barjaková et al., 2023; Yue et al., 2025). For example, academic pressure, to which students are regularly exposed, is positively associated with mood disturbances (Steare et al., 2023). Consequently, external and situational factors may play into the strength of the effect of loneliness on mood, even though loneliness plays an important role in mood. This could also explain the milder effect of the delayed analysis, as since the last measurement a person has been able to influence mood through positive experiences, social interactions or other distractions. Nonetheless, the results make clear how important it is to consider loneliness as a major influencing factor on mood, as the ESM survey in particular takes into account short-

term fluctuations and the participants' everyday life and thus partly includes the situational influence on mood.

Hypotheses 2 & 4

Regarding the second and fourth hypotheses, this study clearly established that higher mood is associated with a reduction in feelings of loneliness. Generally, this underlines that a person who experiences a higher level of mood tends to experience a lower level of loneliness on a momentary basis and this effect persists but diminishes progressively over time. The findings are consistent with the results of other studies, thus confirming the previous established expectations of this study (Department for Culture, Media and Sport, 2022; Giacco, 2023). This immediate but weakening pattern was further confirmed by the results of the lagged analysis. In this regard, it was found that previous high mood reduces the feeling of loneliness, albeit only very slightly, supporting the view that the influence of mood on loneliness is short-lived. Together, both the direct and delayed effects of mood on loneliness suggest that mood alone is only marginally sufficient to have a noticeable effect on loneliness. Moreover, this result suggests that loneliness is a relatively stable experience that cannot simply be changed by short-term emotional states. Even if positive mood favors less loneliness, the feeling of loneliness often persists as long as there is no actual, meaningful social interaction and feeling of connectedness. Delayed positive mood also underlines these results by disproving that good mood only reduces loneliness in the momentary experience, but that this effect hardly lasts over time. This becomes even more evident when compared to the effect strength of loneliness on mood, whereby the effect of mood on loneliness is significantly lower in both the direct and delayed effects. In concrete terms, this further highlights that mood is not a strong regulator of loneliness and can only make a minor contribution to reduce loneliness.

This limited emotional impact of mood on loneliness is consistent with theoretical perspectives that view mood not as a direct determinant of loneliness, but rather as a

contextual variable that influences social perception and motivation. In this regard, the results align with the assumptions of the Mood-Behavior Model (MBM), which posits that mood shapes behavior by influencing cognitive evaluations and motivational tendencies, such as rewarding experiences or the avoidance of discomfort. (Gendolla, 2000). Accordingly, an increase in mood therefore leads to a reduction in loneliness, as a person evaluates their social situation more positively and directs behavior towards pleasurable experiences such as social activities that also reduce the feeling of loneliness. The same is true in the other direction, with negative mood being associated with cognitive distortions that lead to a more pessimistic evaluation of social interactions and a greater likelihood of social withdrawal (Cacioppo & Hawkley, 2009). Thus, mood requires cognitive interpretation of the social environment to assess loneliness, which has a potential impact on the relationship between mood and loneliness. This could also be the reason for the relatively small effect size observed in this study, as the experience of loneliness is not solely determined by emotional states but is strongly influenced by individual emotion regulation strategies and cognitive appraisals (Kearns & Creaven, 2016). Consequently, mood alone does not appear to be sufficient to significantly influence feelings of loneliness unless it is supported by adaptive cognitive processes that help to reinterpret or reframe social experiences.

Therefore, the consideration of contextual and interpersonal factors is evident. The effect of mood on loneliness is marginal, which indicates that loneliness cannot be attributed to mood alone, and other influencing factors must be considered in the relationship. For example, next to emotion regulation, a variety of factors related to a person's life circumstances play a major role in the perception of loneliness like physical health factors, social support systems including friends, neighbors, colleagues, marital status or disruptive life events (National Academies of Sciences et al., 2020). Mood is therefore an important factor that has been shown to influence the feeling of loneliness, but other moderating or

mediating variables such as living conditions or the amount of social interaction should still be taken into account.

Strengths

A key strength of this study lies in the use of ESM, which made it possible to record psychological processes in their natural environment and in real time. By using ESM, the actual moment is assessed repeatedly over time increasing accuracy and sensitivity and providing a better understanding of the variability in psychological constructs (Verhagen et al., 2016). Due to the high frequency of measurements, ESM allowed individual fluctuations in mood and loneliness to be considered and thus provided more representative results than cross-sectional studies. Additionally, Napa Scollon et al. (2009) explains that ESM is less influenced by recall errors because participants report their current state of mind for each momentary measurement, which made the results more valid and more resistant to bias. In summary, ESM created the advantage for this study through the large number of measurements at the current moment that the most valid results possible are recorded, which consider both fluctuations and recall error, providing the study an overall sustainable meaningfulness.

Besides the use of ESM, the use of a within-person design to investigate the relationship between loneliness and mood was another strength of this study. In contrast to between-person analyses, which only depict differences between participants, the within-person design made it possible to precisely record intra-individual relationships between momentary loneliness and mood over time (Murayama et al., 2017). Considering that loneliness is based on subjective perception, the importance of a within-person analysis is emphasized to adequately address the individuality of loneliness (Cacioppo & Cacioppo, 2018; Danvers et al. 2023). The use of an explicit analysis within a person thus examined more specifically whether an increase in loneliness in a person is accompanied by a decline in

their current mood. In doing so, results became more valid and helped to create more precise generalizability.

Finally, the lagged analysis represented a further strength that supports the study in drawing interpretative conclusions about the bidirectional relationship between loneliness and mood. Specifically, the lagged analysis helped to test the causality between two variables in more depth and thus provides additional information about the stability and direction of the relationship (Dormann & Griffin, 2015). Consequently, the results of the main analysis and the lagged analysis together, strengthened the relationship between loneliness and mood. As both models pointed the same direction of effect, this convergence increases the interpretative clarity of the results. Therefore, the lagged analysis was an important tool of this study to better and more profoundly understand the relationship between loneliness and mood and to recognize its direction of effect. The analysis not only showed the direction in which loneliness and mood influence each other but also provides information on how this relationship develops over time.

Limitations

A possible weakness of the study therefore lies in the composition of the sample. This study concentrates on the target group of students, who are particularly affected by loneliness and its effects (Barreto et al., 2021; Özdemir & Tuncay, 2008). Although the target group was aimed at students in general, most participants were female undergraduate students with German nationality. The homogeneity of the sample limits the generalizability of the results, as other subgroups of students are underrepresented. Particularly since studies have shown that there are significant differences in loneliness between age, gender and cultural factors, the homogeneity of the sample limits its informative value (Barreto et al., 2021). Therefore, future studies should strive for more diversification in the sample to obtain results that can be generalized as far as possible.

Second, the compliance rate of participants who initially entered and successfully completed the study was relatively low to average, resulting in smaller sample sizes and making it more difficult to estimate effects accurately. Of all participants who initially entered the study, only slightly less than two-thirds of participants successfully completed the study without meeting the exclusion criteria. This also means that more than one-third of the original participants dropped out of the study because they answered less than 70% of the prompts. The loss of each individual participant reduces the size of the sample and ultimately reduces the significance of the results. Even if this only has an indirect influence on the significance of the study, the low compliance rate represents a limitation that should be considered in the future. Precisely, because interventions and adjustments in data collection can influence the compliance rate, this is a limitation that can be adapted and improved in the future to improve robustness and generalizability of the findings.

Another weakness of the present study is the lack of consideration of potential third-party variables that could influence both loneliness and mood. Thus, there is a risk that confounding variables moderate or mediate the relationship between loneliness and mood, whereby the relationship is dependent on at least one third variable. For example, studies already show that a key factor influencing mood is sleep quality, while physical activity influences feelings of loneliness (Palmer & Alfano, 2017; Musik et al., 2022). The limited consideration of potential confounding variables may affect the conclusiveness of the study, although a clear relationship between the two variables has been demonstrated and is significant. As these third-party variables were not recorded and controlled for in the ESM survey, it is possible that they may influence the observed effects to some extent, limiting the validity of the findings.

Future research

The limitations showed that future research is needed to understand the relationship between loneliness and mood more deeply. First, attention should be paid to a representative

sample size that also considers numerous different subgroups of students to ensure that the diversity of the population is covered. A slightly larger and more diverse sample size will allow more accurate conclusions to be drawn from the results, increasing the clarity of the findings. Furthermore, it is of high relevance to consider the influence of confounding variables and to include them in future studies if necessary. The advantage of this would be to investigate the relationship between loneliness and mood in more depth and to measure the reciprocal effect of the two variables under moderating circumstances, which this study does not consider. Nevertheless, the ESM remains advisable for future research, as it is one of the key strengths of this study. Particularly in the case of mood and loneliness, which can fluctuate in individual measurements depending on the situation, it is useful to use ESM to take momentary, daily fluctuations into account and thus obtain more precise results. The consideration of between-person analyses could also be relevant in future research. Loneliness is a variable based on subjective perception, which is primarily intended for within-person design. However, a comparison of within-person versus between-person can provide further insight about the relationship, which this study missed. Such a comparison could help to assess the extent of individual fluctuations and deliver further insights into the relationship of loneliness and mood.

Practical implications

This study provides important indications of a bidirectional relationship between loneliness and mood, which can be implicated above all in the areas of education and health. First, this study highlights the relevance of loneliness in students, which is an increasingly unrecognized problem in society that receives little attention and prevention efforts (U.S. Department of Health and Human Services, n.d.; Özdemir & Tuncay, 2008). The development of practical interventions by universities to promote social activities and integration helps to reduce social isolation and prevent loneliness through regular social interaction. Specifically, universities could introduce mentoring programs for new students

during the first few months of their studies to promote social integration at an early stage. Another way to combat loneliness in student life would be to introduce self-help groups for affected students, whereby those suffering can come together and work together to counteract loneliness. This type of interventions actively combats and prevents loneliness, which not only promotes the well-being of students, but also benefits the social cohesion of the university.

Additionally, the use of ESM to continuously measure loneliness and mood has been shown to be particularly effective in detecting fluctuations. These ESM-based data could be a practical tool in psychological counseling for affected students to identify individual patterns in mood and loneliness and to design person-oriented interventions. Specifically, mood and loneliness trackers could be developed through continuous ESM recording, which would send direct notifications to those affected in the event of potential symptoms. This would have a self-monitoring effect and could help to not simply neglect signs and create motivation to actively counteract signs of loneliness and bad mood. Furthermore, the relevance of individual interventions due to individual fluctuations stands out, which should be considered in the fight against loneliness to counteract it in the most success-oriented way possible. Through targeted interventions and programs by universities, such as contact offers and group activities, social isolation can be recognized at an early stage and addressed effectively to prevent loneliness.

Importantly, the results of this study show that loneliness is a much stronger predictor of mood than vice versa. This asymmetry emphasizes the central role that loneliness plays in the relationship of loneliness and mood. Consequently, preventive and therapeutic interventions should prioritize the direct reduction of loneliness rather than improvements in mood. In contrast, interventions that focus only on improving mood may not be sufficient to reduce loneliness. Therefore, loneliness should be addressed as a priority intervention point in student support programs.

Conclusion

In summary, the present study provides insights into a bidirectional relationship between loneliness and mood in students. By using the ESM, intra-individual fluctuations in loneliness and mood were recorded and the dynamic development of this relationship in everyday life was made visible. The results indicate that both higher current loneliness is associated with a worse mood and, conversely, a better mood is associated with lower loneliness. Additionally, both effects have been shown to last for several hours, but diminish over time. Overall, the effect of loneliness on mood was significantly more pronounced, while the effect of mood on loneliness was only slight. This suggests that loneliness plays a more central role in the relationship and is significantly more stable than mood. Based on the results, the study therefore emphasizes the need to intensify the promotion of mental health in the university context to primarily reduce loneliness and strengthen the mood of students. In particular, the further use of ESM-based interventions for this purpose and a stronger focus on individual and institutional solutions is a promising method for future research and interventions.

Reference list

American Psychiatric Association. (2024, January 30). *New APA poll: One in three Americans feels lonely every week*. https://www.psychiatry.org/news-room/news-releases/new-apa-poll-one-in-three-americans-feels-lonely-e

American Psychological Association. (2018). *Mood*. *APA Dictionary of Psychology*, https://dictionary.apa.org/mood

Barjaková, M., Garnero, A., d'Hombres, B. (2023). Risk factors for loneliness: A literature review. *Social Science & medicine*, 334, 116163. https://doi.org/10.1016/j.socscimed.2023.116163

Barreto, M., Victor, C., Hammond, C., Eccles, A., Richins, M. T., Qualter, P. (2021). Loneliness around the world: Age, gender, and cultural differences in loneliness. *Personality and Individual Differences*, 169, 110066. https://doi.org/10.1016/j.paid.2020.110066

Beedie, C., Terry, P., & Lane, A. (2005). Distinctions between emotion and mood. *Cognition and Emotion*, 19(6), 847–878. https://doi.org/10.1080/02699930541000057

Cacioppo, J. T., Cacioppo, S. (2018). Chapter Three - Loneliness in the modern age: An Evolutionary Theory of Loneliness (ETL). *Advances in Experimental Social Psychology*, *58*, 127- 197. https://doi.org/10.1016/bs.aesp.2018.03.003

Cacioppo, J. T., Hawkley, L. C. (2009). Perceived social isolation and cognition. *Trends in Cognitive Sciences*, 13(10), 447-454. https://doi.org/10.1016/j.tics.2009.06.005

Cacioppo, J. T., & Patrick, W. (2008). *Loneliness: Human nature and the need for social connection*. W W Norton & Co.

Centers for Disease Control and Prevention. (2024). *Health effects of social isolation and loneliness*. https://www.cdc.gov/social-connectedness/risk-factors/index.html

Crewdson, J. A. (2016). The effect of loneliness in the elderly population: A review. *Healthy Aging & Clinical Care in the Elderly*, 8, 1-8. https://doi.org/10.4137/hacce.s35890

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Sage Publications, Inc.

Christiansen, J., Lund, R., Qualter, P., Andersen, C. M., Pedersen, S. S., Lasgaard, M. (2021). Loneliness, social Isolation, and chronic disease outcomes. *Annals of Behavioral Medicine*, 55(3), 203-215. https://doi.org/10.1093/abm/kaaa044

Coryell, W. (n.d.). Overview of mood disorders. *MSD Manual*. https://www.msdmanuals.com/home/mental-health-disorders/mood-disorders/overview-of-mood-disorders

Danvers, A. F., Efinger, L. D., Mehl, M. R., Helm, P. J., Raison, C. L., Polsinelli, A. J., Moseley, S. A., Sbarra, D. A. (2023). Loneliness and time alone in everyday life: A descriptive exploratory study of subjective and objective social isolation. *Journal of Research in Personality*, 107, 104426. https://doi.org/10.1016/j.jrp.2023.104426

Department for Culture, Media and Sport. (2022). *Mental health and loneliness: the relationship across life stages*. GOV.UK. https://www.gov.uk/government/publications/mental-health-and-loneliness-the-relationship-across-life-stages/mental-health-and-loneliness-the-relationship-across-life-stages

Dormann, C., & Griffin, M. A. (2015). Optimal time lags in panel studies. *Psychological methods*, 20(4), 489–505. https://doi.org/10.1037/met0000041

Ellard, O.B., Dennison, C. and Tuomainen, H. (2022), Review: Interventions addressing loneliness amongst university students: a systematic review. *Child and Adolescent Mental Health*, 28: 512-523. https://doi-org.ezproxy2.utwente.nl/10.1111/camh.12614

Fritz, J., Piccirillo, M. L., Bringmann, L. F., Cohen, Z. D., Frumkon, M., Kitley, O., Moeller, J., Neubauer, A. B., Norris, L. A., Schuurman, N. K., Snippe, E. (2024). So you want to do ESM? 10 essential topics for implementing the experience-sampling method. *Advances in Methods and Practices in Psychological Science*, 7(3), https://doi.org/10.1177/25152459241267912

Fokkema, T., De Jong Gierveld, J., & Dykstra, P. A. (2012). Cross-national differences in older adult loneliness. *The Journal of psychology*, 146(1-2), 201–228. https://doi.org/10.1080/00223980.2011.631612

Gendolla, G. H. E. (2000). On the Impact of Mood on Behavior: An Integrative Theory and a Review. *General Psychology*, 4(4), 378-408. https://doi-org.ezproxy2.utwente.nl/10.1037/1089-2680.4.4.378

Giacco D. (2023). Loneliness and mood disorders: consequence, cause and/or unholy alliance?. *Current Opinion in Psychiatry*, 36(1), 47–53. https://doi.org/10.1097/yco.0000000000000832

Giraldo-Rodríguez, L., Álvarez-Cisneros, T., & Agudelo-Botero, M. (2023). Psychometric properties of the 11-Item De Jong Gierveld Loneliness Scale in a representative sample of mexican older adults. *Healthcare*, *11*(4), 489. https://doi.org/10.3390/healtcare11040489

Hawkley, L. C., & Cacioppo, J. T. (2010). Loneliness matters: A theoretical and empirical

    review of consequences and mechanisms. *Annals of Behavioral Medicine*, 40(2), 218–

    227. https://doi.org/10.1007/s12160-010-9210-8

Hawkley, L. C., Buecker, S., Kaiser, T., & Luhmann, M. (2022). Loneliness from young

    adulthood to old age: Explaining age differences in loneliness. *International*

    Journal of Behavioral Development, 46(1), 39–49.

    https://doi.org/10.1177/0165025420971048

Hektner, J. M., Schmidt, J. A., & Csikszentmihalyi, M. (2007). Psychometrics of ESM Data.

    In *Psychometrics of ESM data.* (pp. 104-125). SAGE Publications, Inc.,

    https://doi.org/10.4135/9781412984201.n6

Holmén, K., Ericsson, K., Winblad, B. (2013). Quality of life among the elderly.

    Scandinavian Journal of Caring Sciences, 13(2). 91-95.

    https://doi.org/10.1111/j.1471-6712.1999.tb00521.x

Kearns, S. M., Creaven, A. (2016). Individual differences in positive and negative motion

    regulation: Which strategies explain variability in loneliness?. *Personality and Mental*

    Health, 11(1), 64-74. https://doi-org.ezproxy2.utwente.nl/10.1002/pmh.1363

Kuczynski, A. M., Halvorson, M. A., Slater, L. R., Kanter, J. W. (2021). The effect of social

    interaction quantity and quality on depressed mood and loneliness: A daily dairy

    study. *Journal of Social and Personal Relationships*, 39(3), 734-756.

    https://doi-org.ezproxy2.utwente.nl/10.1177/02654075211045717

Kuczynski, A. M., Piccirillo, M. L., Dora, J., Kuehn, K. S., Halvorson, M., A., King, K. M.,

    Kanter, J. W. (2024). Characterizing the momentary association between loneliness,

    depression, and social interactions: Insights from an ecological momentary assessment

    study. *Journal of Affective Disorders*, 360, 376-386.

    https://doi.org/10.1016/j.jad.2024.05.148

Lee, G. R., Ishii-Kuntz, M. (1987). Social Interaction, loneliness, and emotional well-being among elderly. *Research on Aging*, 9(4). https://doi.org/10.1177/0164027587094001

Murayama, K., Goetz, T., Malmberg, L. E., Pekrun, R., Tanaka, A., Martin, A. J. (2017). *Within-person analysis in educational psychology: Importance and illustrations*. In D. W. Putwain & K. Smart (Hrsg.), *British Journal of Educational Psychology Monograph Series II: Psychological Aspects of Education – Current Trends: The Role of Competence and Beliefs in Teaching and Learning*. 71-87. The British Society, https://motivationsciencelab.com/wp-content/uploads/2022/02/Murayama_Goetz_et_al_2017_BPSMonograph.pdf

Myin-Germeys, I., Oorschot, M., Collip, D., Lataster, J., Delespaul, P., & van Os, J. (2009). Experience sampling research in psychopathology: opening the black box of daily life. *Psychological Medicine*, 39(9), 1533–1547. https://doi.org/10.1017/S0033291708004947

Napa Scollon, C., Prieto, C. K., Diener, E. (2009). Experience Sampling: Promises and Pitfalls, Strength and Weaknesses. *Assessing Well-Being*. Social. 39. Springer, Dordrecht. https://doi-org.ezproxy2.utwente.nl/10.1007/978-90-481-2354-4_8

National Academies of Sciences, Engineering, and Medicine, Division of Behavioral and Social Sciences and Education, Health and Medicine Division, Board on Behavioral, Cognitive, and Sensory Sciences, Board on Health Sciences Policy, & Committee on the Health and Medical Dimensions of Social Isolation and Loneliness in Older Adults. (2020). *Social isolation and loneliness in older adults: Opportunities for the health care system*. National Academies Press. https://www.ncbi.nlm.nih.gov/books/NBK557971/

Ousman, Y. I., & Nazir, T. (2023). Loneliness among University students as a growing cocnerne. *Journal of Family Counseling and Education*, 8(2), 85-99. https://doi.org/10.32568/jfce.1312556

Özdemir, U., & Tuncay, T. (2008). Correlates of loneliness among university students. *Child and Adolescent Psychiatry and Mental Health*, 2(1). https://doi.org/10.1186/1753-2000-2-29

Palmer, C. A., & Alfano, C. A. (2017). Sleep and emotion regulation: An organizing, integrative review. *Sleep Medicine Reviews*, 31, 6-16. https://doi.org/10.1016/j.smrv.2015.12.006

Snijder, T. A. B., Bosker, R. J. (2012) Multivevel analysis: An introduction to basic and advanced multilevel modeling (2nd ed.). Sage

Steare, T., Gutiérrez Muñoz, C., Sullivan, A., & Lewis, G. (2023). The association between academic pressure and adolescent mental health problems: A systematic review. *Journal of Affective Disorders*, 339, 302–317. https://doi.org/10.1016/j.jad.2023.07.028

Trull, T. J., & Ebner-Priemer, U. (2014). The Role of Ambulatory Assessment in Psychological Science. *Current Directions in Psychological Science*, 23(6), 466-470. https://doi-org.ezproxy2.utwente.nl/10.1177/0963721414550706

Twenge, J. M., Spitzberg, B. H., Campbell, W. K. (2019). Less in-person social interaction with peers among U.S. adolescents in the 21st century and links to loneliness. *Journal of Social and Personal Relationships*, 36(6), 1892-1913. https://doi-org.ezproxy2.utwente.nl/10.1177/0265407519836170

University of Twente. (n.d.). *Twente Intervention and Interaction Machine (TIIM)*. BMS Lab. retrieved 16. April 2025. https://www.utwente.nl/en/bmslab/infohub/tiim/

van Winkel, M., Wichers, M., Collip, D., Jacobs, N., Derom, C., Thiery, E., Myin-Germeys, I., Peeters, F. (2017). Unraveling the Role of Loneliness in Depression: The Relationship Between Daily Life Experience and Behavior. *Psychiatry*, 80(2), 104-117. https://doi-org.ezproxy2.utwente.nl/10.1080/00332747.2016.1256143

Vasileiou, K. Barnett, J., Barreto, M., Vines, J., Atkinson, M., Long, K., Bakewell, L., Lawson, S., Wilson, M. (2019). Coping with loneliness at University: A qualitative interview study with students in the UK. *Mental Health & Prevention*, 13, 21-30. https://doi.org/10.1016/j.mhp.2018.11.002

Verhagen, S. J. W., Hasmi, L., Drukker, M., van Os, J., Delespaul, P. A. E. G. (2016). Use of the experience sampling method in the context of clinical trials. *Evidence-Based Mental Health*, 19(3), 86-89. https://doi.org/10.1136/ebmental-2016-102418

Verster, J. C., Sandalova, E., Garssen, J., & Bruce, G. (2021). The use of single-item ratings versus traditional multiple-item questionnaires to assess mood and health. *European Journal of Investigation in Health, Psychology and Education*, 11(1), 183–198. https://doi.org/10.3390/ejihpe11010015

Wang, L., Zhang, Q., Maxwell, S. E., Bergeman, C. S. (2020). On standardizing within-person effects: Potential problems of global standardization. *Multivariate behavioral research*, 53(3), 382-403. https://doi.org/10.1080/00273171.2018.1532280

Wilhelm, P., & Schoebi, D. (2007). Assessing mood in daily life. *European Journal of Psychological Assessment*, 23(4), 258-267. https://doi.org/10.1027/1015-5759.23.4.258

Yue, L., Zhang, D., Sui, L., Li, D., Wang, M., Wang, W., Xue, M., Hao, J., Zhang, L., Wu, M. (2025). The mediating effects of sleep quality in the relationship between loneliness and depression among middle-aged and older adults. *Scientific Reports*, 15(1). https://doi.org/10.1038/s41598-025-93681-3

Zahedi, H., Sahebihagh, M. H., & Sarbakhsh, P. (2022). The Magnitude of Loneliness and Associated Risk Factors among University Students: A Cross-Sectional Study. *Iranian Journal of Psychiatry*, 17(4), 411–417. https://doi.org/10.18502/ijps.v17i4.10690

Appendix A

Study Instructions

Thank you for signing up for our study!

Please follow these instructions (page 1&2) to start your participation:

1. **Downloading TIIM for Android**
    I. Go tot he play store for Android.
    II. Type in the search bar „TIIM".
    III. Select the TIIM app.
    IV. When download menu opens, select -DOWNLOAD-.
    V. After downloading has finished you can open the app.

OR

Downloading TIIM for IOS
    I. Go the the App store for IOS. Type in the search bar „TIIM". Select on the TIIM app.
    II. Select -DOWNLOAD-.
    III. Accept the download with your apple ID.
    IV. After downloading has finished you can open the app.

The app is free, so don't worry about the mention for payment.

2. **Creating an Account**
    I. The app will ask to login. Select -CREATE AN ACCOUNT-.
    II. Fill in your details.
    III. Then, press -CREATE ACCOUNT-.
    IV. To log in just fill in your E-Mail address and password.

3. **Subscribing to sth study**
    I. To subscribe to a study, select the QR code icon on the right side of your screen.
    II. You can type the voucher code -> find code on page 3 of this document.
    III. Then, press -SUBMIT-.
    OR
    I. Scan the QR code that you have received from the researcher. Both methods will send you to a subscription page.
    II. Select -CONTINUE-.
    III. Here you can also confirm if you would like to subscribe the mentioned E-Mail.
    IV. Press -CONTINUE-.
    V. The researcher will contact you when you can start the study

4. Editing Settings
    I.   In the app on the left, select -SETTINGS-.
    II.   Allow for push, E-Mail notificatios, and data collection from Healthkit
    III. If you would like to, you can select that you would like to join other TIIM studies in the future. You can always change the settings.
    IV.   To unsubscribe from a study, select -UNSUBSCRIBE- next tot he study.
    V.   If you want to delete your data, please contact the researcher or ask the researcher for your USER ID and then contact the BMS-Lab dashboard support.
    VI.   Press -SAVE-.

When you start using the app, you will see a pop up asking if you would like to join other TIIM studies. This will allow researchers in the future to invite you to join their studies. You can always decline the invitation and change this setting in options.

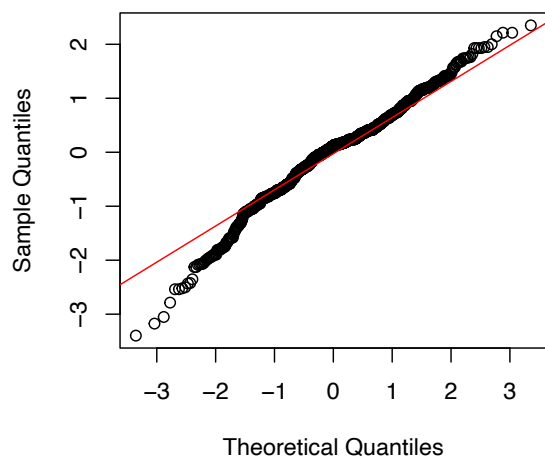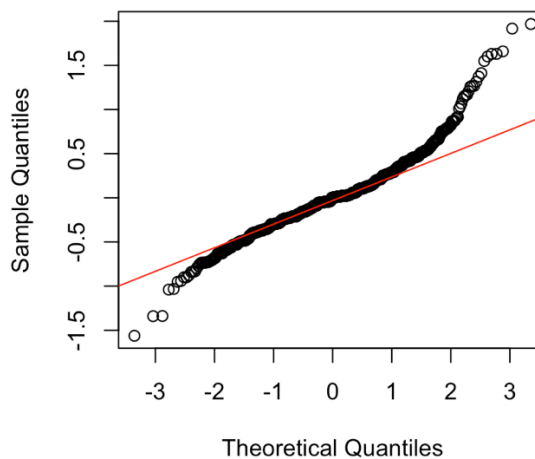<u>Enrolement Code</u>

VOUCHER CODE

ZJ6TL

Appendix B

Q-Q plot

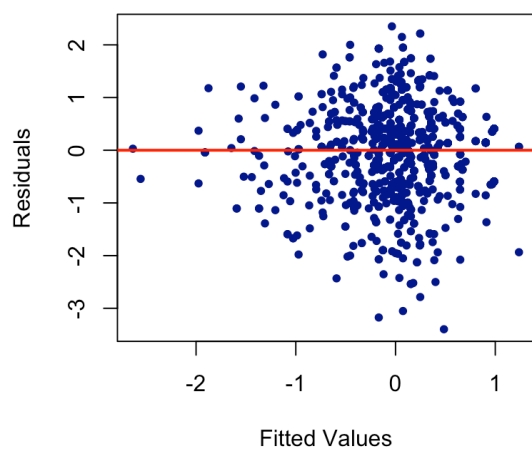**Q–Q Plot Residuals – Model 1**

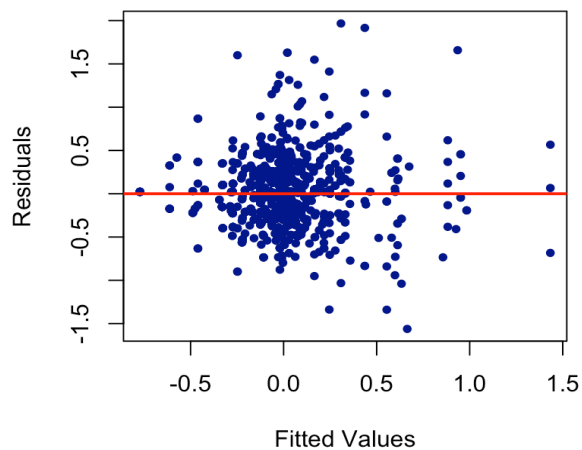**Q-Q Plot Residuals - Model 2**

Appendix C

Residuals vs Fitted values

Residuals vs Fitted Values - Model 1

Residuals vs Fitted Values - Model 2

Appendix D

Residuals over time

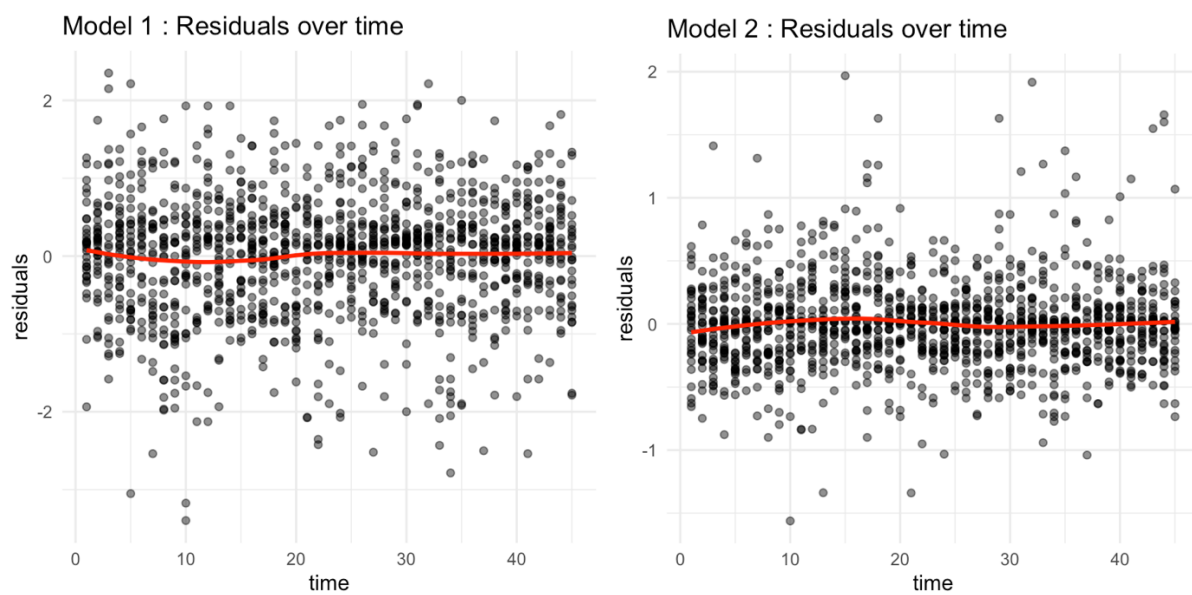Model 1 : Residuals over time

Model 2 : Residuals over time

AI statement

During the preparation of this paper, the author used ChatGPT to make minor revisions for conciseness and clarity of writing as well as for brainstorm and ideation. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the work.