

**Examining the Relationship Between Sedentary Time and State Anxiety in University
Students, Considering the Impact of Mental Activity and Contexts: An Exemplary
Sampling Study**

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Abstract

Background: High sedentary time can negatively affect mental health. Literature reviews show inconsistent research on the relationship between sedentary behaviour and state anxiety. Especially university students have increased sedentary time and are at increased risk of anxiety. Therefore, this paper aims to examine the relationship between sedentary time and state anxiety over time, and how contexts of occupation, transportation, and leisure, and mentally active and passive sedentary activities moderate this relationship. Experience Sampling Methodology (ESM) was used to enhance detailed insights into the dynamics of the relationship and moderators.

Methods: A 14-day ESM study was conducted with 25 university students ($M_{age} = 21.68$, $SD_{age} = 2.61$, 56% male). Participants received three daily questionnaires, assessing sedentary time over the past 30 minutes, state anxiety levels, contexts, and mentally active and passive activities. Linear mixed models were conducted to analyse the data.

Results: No significant relationship was found between sedentary time and state anxiety. Similarly, no moderation effects of the contexts or mental activity were found. However, results indicated significant main effects of the contexts of occupation, $b = 0.66$, 95%CI = [0.05, 1.28], and leisure, $b = -0.59$, 95%CI = [-1.14, -0.04], and mental activeness, $b = 0.76$, 95%CI = [0.15, 1.36], on state anxiety.

Conclusion: This study found no significant relationship between sedentary time and state anxiety over time. However, the context of occupation and mental activeness were linked to increased state anxiety, whereas the leisure context was associated with lowered state anxiety. Future research may explore the associations over a longer period to enhance a detailed understanding of sedentary activities and contexts on state anxiety.

Keywords: Sedentary Behaviour, State Anxiety, Contexts, Mental Activity, Experience Sampling Methods, University Students

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Examining the Relationship Between Sedentary Time and State Anxiety in University Students, Considering the Impact of Mental Activity and Contexts: An Exemplary Sampling Study

We all know that we sit too much and that it has bad consequences for our health. Because of technological developments and other modernisations in our daily lives, people are led to sit for extended periods. The circumstances that encourage people to sit more often are especially in Western societies predominant (Smith et al., 2018). According to the definition of Tremblay et al. (2017), sedentary behaviour refers to any activity that requires an energy expenditure of maximally 1.5 METs during waking hours while being in a seated or reclined body position. Next to that, the term *sedentary time* describes the time spent in sedentary behaviour (Jingjie et al., 2022). Particularly university students are most inclined to increased physical inactivity and sedentary behaviour (Moulin et al., 2019; Edelman et al., 2022). Their high levels of sedentary time and reduced levels of physical activity are due to extended time studying, increased screen time, and sitting in classes (Carballo-Fazanes et al., 2020) which in turn heightens students' risk of deteriorated mental health. Results of meta-regression analyses demonstrate that the sedentary time of university students has increased over the past 10 years significantly (Castro et al., 2020). According to Castro et al. (2020), self-reported data from university students have shown that university students on average have a sedentary time of nearly 10 hours per day. Other studies have revealed that university students spend on average 7 to 9 hours in sedentary behaviour (Edelman et al., 2022; Castro et al., 2020). Compared to the prevalence of adults' sedentary time, which is on average 6 hours per day, these numbers show that university students' sedentary time is significantly higher (Edelman et al., 2022). Additionally, literature indicates that high amounts of sedentary time are associated with anxiety symptoms. Therefore, sedentary behaviour is a reason for alarm, especially for university students who sit at a higher rate (Teychenne et al., 2017).

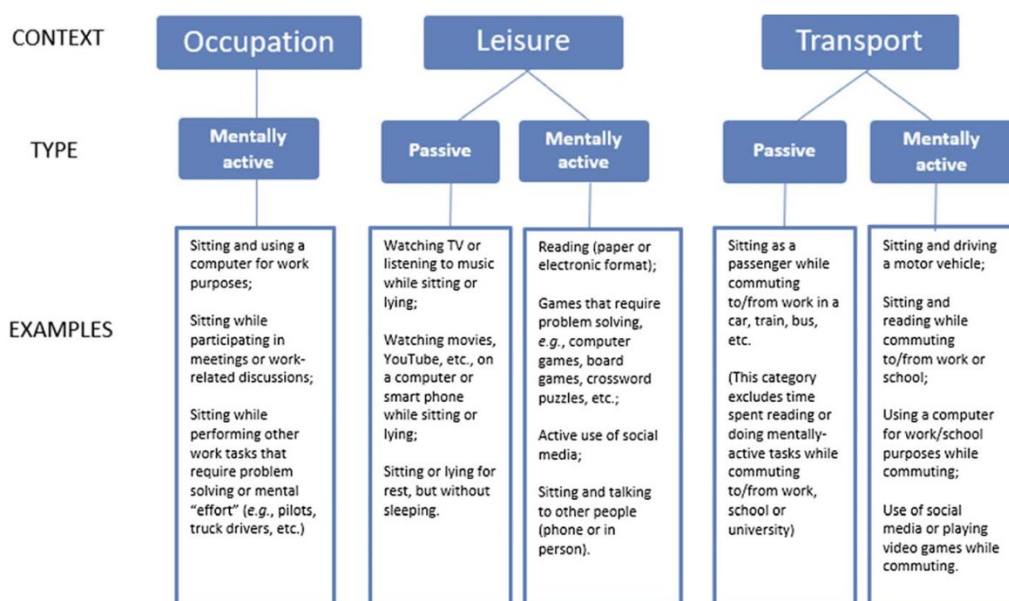
When applying the definition of sedentary behaviour to daily life, it means people sitting without being otherwise physically active (Owen et al., 2011). People sit while doing different things in different contexts, like sitting in a car, watching TV, sitting at a desk, and many more (Owen et al., 2011). Especially young people spend a higher amount of time on screen-based behaviour for studying but also for leisure, which is associated with increased sedentary time, e.g. studying in front of computers, and scrolling through social media while reclining on the couch (Tang et al., 2021). Hallgren et al. (2020a) categorised the different activities that are included in the concept of sedentary behaviour into two types. One type is

mentally active sedentary behaviour which includes activities that require more cognitive effort like reading newspapers or books, computer use, etc. The second category is *mentally passive* sedentary behaviour which includes activities that occur commonly during leisure time like watching TV and talking to people while being in a seated or reclined position (Hallgren et al., 2020a). Next to that, Hallgren et al. (2020a) developed a framework for differentiating sedentary behaviour into specific contexts which are occupation, leisure, and transport (see Figure 1). A longitudinal study by Hallgren et al. (2018) shows that mentally passive sedentary behaviours are linked to increased depressive symptoms, whereas mentally active sedentary behaviours are linked to the prevention of depressive symptoms. According to Chen et al. (2022), differences were found between the risk of anxiety and the activities and contexts that were done during sedentary time. Additionally, the study of Castro et al. (2020) suggests a positive relationship between higher rates of sedentary time and symptoms of anxiety and depression.

Hallgren et al. (2020a) warn against grouping the diverse behaviours together and thus recommend considering both the type (mentally active or mentally passive) and the behavioural context in future research. The framework of Hallgren et al. (2020a) is increasingly acknowledged in other study fields as well. The use of the framework can help guide future research and interventions in anxiety in university students by investigating the relationship between daily context-specific sedentary time and anxiety considering the types of sedentary behaviour.

Figure 1

Framework to examine sedentary behaviour in three different contexts, differentiated between mentally active and mentally passive sedentary activities.



Note. From Passive Versus Mentally Active Sedentary Behaviors and Depression, Hallgren, M., Dunstan, D. W., & Owen, N, (2020), *Exercise and Sport Sciences Reviews*, 48(1), 20–27 <https://doi.org/10.1249/JES.0000000000000211>

Research that has been conducted in various countries has shown that the majority of university students experience general feelings of anxiety at an overwhelming level (Short et al. 2021). The characteristics of anxiety are tension and perceptual worrying because of persistent concerns and intrusive thoughts. Next to that, it also includes a disproportional amount of fear and worry related to daily situations which in turn lead to the development of adverse predictions and expectations about the future. These repeated behaviour patterns of disproportional worrying result in detrimental health outcomes like disturbed sleep patterns, and impaired cognitive capacity (Tan et al., 2023). Additionally, anxiety can be *state-like* or *trait-like*. General feelings of state anxiety refer to events that seem frightening, e.g. exams or presentations, and induce anxiety followed by momentary reactions to these events. It is related to feelings of apprehension and nervousness, which in turn lead to increased activities of the sympathetic nervous system (Weeks et al., 2019). Therefore, state anxiety can be described as reactions directly associated with negative situations at a certain moment, whereas trait-anxiety refers to an overall tendency (Spielberger et al., 1984, as cited in Felez-Nobrega, 2020). Previous research indicates that only trait anxiety is affected by sedentary time (Allen et al., 2019; Teychenne, 2015). While the association between sedentary behaviour and trait anxiety has been researched, findings related to sedentary time and state

anxiety are limited to cross-sectional studies (Allen et al., 2019; Felez-Nobrega et al., 2020; Teychenne et al., 2015; Padmapriya et al., 2016).

Suffering from anxiety feelings has a substantial impact on university students in different ways. Affected students often experience poorer educational outcomes because of difficulties in studying which in turn causes strengthened anxiety to achieve better performance (Short et al., 2021). Moreover, students suffering from mental health problems, including anxiety, are inclined with twice the probability of leaving university prematurely in comparison to university students without mental health problems (Short et al., 2021). Surveys revealed that about 63% feel overwhelming anxiety at some time in the last 12 months and that it is suggested to affect increasing numbers of students in the future (Tan et al., 2023). Investigations indicated that high amounts of sedentary time increase the risk of heightened anxiety levels and decreased mental well-being (Casanova et al., 2023). Especially sitting without any interruptions for body movement, has negative health effects (Hallgren et al., 2020a). Studies have shown that the combination of high sedentary time and low physical activity contributes to increased odds of anxiety (Schuch et al., 2019).

Literature reviews show that there is inconsistent or insufficient research on the relationship between sedentary behaviour and state anxiety (Kandola et al., 2021). Additionally, the differences between mentally active and mentally passive sedentary activities have not been sufficiently researched yet (Rebar et al., 2014; Teychenne et al., 2015). However, different studies that used self-report tools to investigate the relationship between sedentary time and anxiety reveal sedentary behaviour as a risk factor for anxiety (Kandola et al., 2021). There are multiple explanations for this association. It was revealed that screen-based sedentary behaviour can lead to disturbed sleep patterns, which in turn, lead to an increased risk of heightened anxiety levels (Dworak et al., 2007; Hale & Guan, 2015). Moreover, provides the social-withdrawal theory an explanation for the association between sedentary time and anxiety. According to this theory, sedentary behaviours lead to increased anxiety since they are often characterised by social isolation. Being socially isolated can trigger anxiety symptoms (Teychenne et al., 2015). Since university students spend high amounts of time sitting in different contexts, e.g. sitting in classes, or spending time on social media while sitting, there is little known about how the amount of sedentary time in different contexts impacts levels of anxiety. Nevertheless, research indicates that different forms of sedentary behaviours, in particular mentally active and mentally passive sedentary behaviours, have different outcomes on mental health. Mentally active activities are related to

the protection against decreased mental well-being and mentally passive behaviours are associated with an increased risk of deteriorated mental health (Hallgren et al., 2020a).

The current research will use the data collection design of experience sampling methodology (ESM) in order to investigate possible associations between sedentary time and state anxiety. ESM represents a powerful tool to investigate the possible impact of different contexts and types of sedentary behaviour on state anxiety levels. Using ESM could contribute to examining the assumption of previous inconsistent research on sedentary time and anxiety since it allows researchers to conduct numerous measurements of several constructs such as state anxiety at different points in time and different contexts. ESM represents a technique that uses structured self-reports of participants (Myin-Germeys et al., 2018). With the help of the self-reports, ESM can examine levels of state anxiety, mentally active and passive sedentary behaviour, and different contexts occurring in daily life. Participants are required to answer structured questions multiple times daily. The approach of ESM was developed based on the concept of Barker (1968) which states that behaviour needs to be assessed in the contexts in which it occurs to be understood. The use of it avoids retrospective recall bias and facilitates the assessment of temporal associations and variability (Myin-Germeys et al., 2018). Therefore, ESM was chosen as the data collection method for the current study. It will contribute to a detailed understanding of sedentary behaviour in different contexts and associated mental states by increasing the detection of variability and changes. The use of ESM in research on sedentary behaviour closes another gap since there are limited ESM studies on this topic.

The current study investigates the relationship between sedentary time and state anxiety, considering different behavioural contexts and mentally active and passive activities. The amount of sedentary time is measured during the past 30 minutes at each assessment point since it enhances capturing the immediate effects of the distinct contexts and activities of sedentary behaviour. Moreover, recall bias can be avoided regarding recalling in which context the participant was in and whether the sedentary activity was active or passive. To facilitate the examination of variability and dynamics of possible associations, the design of ESM is used. Additionally, the study focuses on university students since research has shown that this population group experiences higher rates of general anxiety feelings compared to other populations. The study aims to address the identified gaps by focusing on the following research questions:

RQ1: How do sedentary time and state anxiety associate over time in university students?

RQ2: To what extent moderate mentally active and mentally passive sedentary activities the relationship between sedentary time and state anxiety over time in university students?

RQ3: To what extent moderates the context of sedentary activities the relationship between sedentary time and state anxiety over time in university students?

Methods

Design

The current study used ESM to investigate associations between sedentary time in mentally active and mentally passive forms in different contexts, and short-term effects on state anxiety. Participants completed three repeated questionnaires each day on 14 consecutive days. Notably, the study was part of a broader research project of multiple researchers. Therefore, the questionnaires included items that were not relevant to this paper. To enable a reliable and effective approach to investigate the variables of interest, participants used the app “m-Path” on their smartphones. A time-contingent approach was used which required the participants to respond to each questionnaire within fixed time frames each day of the study. The questionnaires were designed to be completed within 2-3 minutes each, to reduce the burden on the respondents.

This design allowed for comprehensive longitudinal data collection on the variability of state anxiety, sedentary time, and its different activity forms and contexts within university students. The start of the study was on the 8th of April 2024 at 10 am and ended on the 23rd of April 2024 at 10 pm. This data collection period builds a sufficient time frame for identifying any associations between the variables of interest, as well as for time comparison of the weeks between every participant. Moreover, according to van Berkel et al. (2017), this time frame falls within the suggested period for an ESM study of one to four weeks.

The permission for the study was granted by the Ethics Committee of the University of Twente (reference number: 240234).

Participants

The test subject recruitment was organised and administered through convenience sampling via the online system SONA of the University of Twente, WhatsApp, and Discord. For completing the study, the respondents were rewarded with 3 SONA points. Participation in the current study was voluntary and a consent form was filled out by each participant on the first day of the study to ensure the ethical guidelines (see Appendix A). The inclusion criteria that were relevant for the recruitment of participants included being 18 years or older and being enrolled at a university or any other higher education institution (hbo,

Fachhochschule). Additionally, it was required to understand the English language sufficiently, be able to stand for at least 30 minutes at a time without any support, and have access to and be willing to install and use a smartphone with internet access for the period of the study. If these criteria were not met, the participants were excluded from the study.

The final sample size of the current study included $N=25$. According to the literature review of Van Berkel et al. (2017), a median number of 19 participants and recruiting at least 20 participants appears reasonable. Sixteen participants were excluded from the original sample size, which was 41 participants, due to a response rate lower than 50% (Conner & Lehman, 2012; Kang, 2013). The sample's age range was from 18 to 29 years ($M = 21.68$, $SD = 2.61$). The majority of the participants were German with 56%, and Dutch with 28%. See Table 1 for all sample characteristics.

Table 1

Sample Characteristics N=25

Characteristics	<i>N</i>	%
Gender		
Male	14	56
Female	11	44
Nationality		
German	14	56
Dutch	7	28
Other	4	16
Occupation		
Enrolled at a university	24	96
Enrolled at another higher education institution	1	4

Materials

"m-Path"-App

To meet the requirements of the current used ESM approach, like complex designs and functionalities, good accessibility, and user-friendliness, the application *m-Path* was utilised. M-Path allows for providing repeated measurements on respondents' smartphones. Users receive notifications about completing questionnaires. Moreover, information like the informed consent and demographical information can be attained through m-Path.

Baseline Questionnaire

On the first day of the study, the baseline questionnaire (see Appendix B) was sent to the participants. It included items regarding demographical information like age, gender, nationality, current occupation, the ability to stand for at least 30 minutes without any support, and SONA ID, if applicable.

Repeated Questionnaires

Participants were asked to respond to items asking about their sedentary time over a preceding 30-minute period to assess any short-term effects on state anxiety levels (see Appendices C and D). Here, the item “*Over the past 30 minutes before the notification, how many minutes have you been in a sitting or reclining position?*” was used. Additionally, the question: “*Over the past 30 minutes, in which context were you in?*” was posed for which participants could choose from the answer options: *Leisure, Transportation, or Occupation/Study*. A follow-up question was asked to identify the type of sedentary behaviour: “*During the past 30 minutes, what activity did you spend the most time engaged in?*” depending on the previous response. This item was necessary to categorise the sedentary behaviour in mentally active or mentally passive. The framework of Hallgren et al. (2020a) was used as the basis for these items. The use of this framework allowed to formulation of context-specific sedentary behaviours in mentally active and passive forms. The items were posed to capture the most detailed understanding of participants’ sedentary activities during the 30-minute interval.

Within the same period of 30 minutes, participants’ levels of state anxiety were assessed by the item: “*How anxious do you feel right now?*”. This item was derived from the study of Cox et al. (2018) who measured momentary anxiety with a single item on a visual analogue scale (VAS) from 0 to 100, which is equivalent to “not anxious at all” to “most anxious you could ever imagine” (Cox et al., 2018). In the current study, the VAS was adjusted from 0 to 10 because of more convenience for participants.

In comparison to the widely used State-Trait Anxiety Inventory (STAI), the use of VAS was more suitable for the current study. Because the STAI-State includes 20 items to measure current anxiety levels, it would have put more burden on participants to answer (Abend et al., 2014). Additionally, VAS is considered to be less disruptive, and suitable for online recording and monitoring of state anxiety levels (Abend et al., 2014).

Moreover, the VAS has good psychometric properties. It has a high correlation with the STAI-State, indicating that there is a convergent validity of the VAS and an adequate test-

retest reliability (Abend et al., 2014). It has proven to be a valid, reliable, and rapid method for the measurement of state anxiety (Abend et al., 2014). Therefore, the VAS was a suitable measurement method for the current study.

Procedure

After every measurement was integrated into m-Path, a pilot test was set over three days. Subsequently, the present study was published on the SONA system of the University of Twente, as well as shared via social media and text messaging. After participants signed up for the study, they obtained a description of the study. Moreover, each participant was instructed on how to download and use the app, log in to the study, and how the notifications of the app can be turned on.

On the 8th of April, the recruited participants received the baseline questionnaire (see Appendix B) in which they also were asked to accept the informed consent to continue with the several measurements. In the next 14 days, the participants received daily notifications to respond to three repeated questionnaires scheduled at 10 am, 3 pm, and 8 pm. For every questionnaire, a reminder was sent to the participants after one hour after the first notification and each questionnaire expired after two hours. At the end of each questionnaire, thanks were expressed to the participants for responding to the questions. In case a participant did not complete a questionnaire, this was seen as missing data. In sum, this procedure allowed for an accurate investigation and measurement of sedentary time and state anxiety.

The full timeline of the ESM design can be found in Figure 2.

Figure 2*Timeline of the ESM design*

Day	10am-12pm	3pm-5pm	8pm-10pm	Name test	Number	Total amount
8-4	1			Baseline Questionnaire	1	1
9-4	3	3	3	Morning Questionnaire at 10am	2	13
10-4	2	3	3	Repeated Questionnaire at 3pm and 8pm	3	14
11-4	2	3	3	Only Total Sedentary Time for the Final Day	4	1
12-4	2	3	3			
13-4	2	3	3			
14-4	2	3	3			
15-4	2	3	3			
16-4	2	3	3			
17-4	2	3	3			
18-4	2	3	3			
19-4	2	3	3			
20-4	2	3	3			
21-4	2	3	3			
22-4	2	3	3			
23-4	4					

Data Analysis

After the data collection period, data was downloaded from m-Path to Excel for data preparation and cleaning. During data collection, 44 observations per participant were gathered. In some cases, participants mistakenly reported the sedentary time for the 30-minute sedentary time item in hours instead of minutes. Therefore, the data needed to be corrected manually when this misunderstanding occurred.

In Excel, the data was organised to import it later into SPSS (29th version). The data for mentally active and passive sedentary activities were turned into a dichotomous variable,

with mentally active behaviours coded as 1 and passive behaviours coded as 0. Next to that, the categorical variable of context (occupation/study, leisure, transportation) was turned into three dummy variables for each context. For that, the presence of a context was coded as 1 and the absence as 0. A data point was coded as missing data if participants indicated that were not sitting.

After finalising data preparation and cleaning, the dataset was imported into SPSS. For descriptive statistics, means, standard deviations, and ranges were calculated for the variables of interest. Next to that, the frequencies and percentages for the context variables and the mental activeness variable were calculated.

To assess the reliability, a split-half reliability analysis was executed for the 30-minute sedentary time item as well as for the VAS item measuring state anxiety. For the split-half reliability analysis including the sedentary time item, the observations for sedentary time were divided into two halves (week one and week two), and the total scores of each half were computed. For each half, a total score variable was constructed. Pearson's correlation coefficient was used to compute the correlation between week one and week two which provided the initial reliability estimate. In order to account for the split-half design, the correlation coefficient was modified by the Spearman-Brown formula. The same procedure was followed for analysing the reliability of the state anxiety item.

Estimated marginal means (EMMs) were calculated for state anxiety and sedentary time for each participant and across timepoints. The EMMs were imported into and visualised through Excel. In order to get a more qualitative analysis of the association between state anxiety and sedentary time and to investigate the variance of the sample, three participants with the highest response rate (100%, 98%, and 98%) were looked at exploratively.

To answer the RQs, linear mixed models (LMMs) were utilised because of their ability to handle missing data and to deal with observations clustered within participants dependent on the measuring point which is common in ESM studies (Brown, 2021). The LMMs were conducted with a first-order autoregressive covariance (AR1). AR1 was utilised because it takes into account that observations that are close together in time, have a stronger correlation. Five LMMs were performed to investigate the associations between state anxiety, sedentary time, contexts, and mentally active sedentary activities. In each LMM analysis, participants were selected as the subjects and the points of measurement as the repeated measure. To investigate the research questions, state anxiety was set as the dependent variable, and sedentary time as the covariate. In order to examine the moderation effects,

interaction terms were created between sedentary time and mental activeness, and between sedentary time and either occupation/study, leisure, or transportation.

For all statistical analyses, a p-value of $< .05$ was considered as the significance threshold for determining statistical significance.

Results

Descriptive statistics

The data collection includes in total 824 observations out of 1100, which underpins the extensive range and thoroughness of the data retrieval. The average response rate was 79.8%. The mean sedentary time of the preceding 30 minutes, the sedentary time, was 21.36 ($SD = 10.96$), indicating that the participants on average spent 21.36 minutes sitting in the preceding 30 minutes.

The contexts in which sedentary activities varied. Most observations occurred during leisure contexts with 55.7% (459 observations), followed by activities in occupation/study contexts with 34.8% (287 observations). The fewest observations occurred in the context of transportation with a frequency of 9.5% (78 observations). With regard to mental activeness, most activities were classified as active with 55.2% (455 observations), passive with 25.8% (213 observations), and not sitting with 18.9% (156 observations). Lastly, the average score of state anxiety was 1.97 ($SD = 2.27$), thus at the lower end of the scale, since scores can range from 0 to 10.

The split-half reliability analysis about the sedentary time item revealed acceptable reliability ($r = .71$). Regarding the reliability of the VAS item measuring state anxiety, the split-half reliability was high ($r = .86$).

Estimated Marginal Means

Concerning the visualisation in Figure 3, it seems that each participant had on average relatively high amounts of sedentary time in the preceding 30 minutes with relatively low levels of state anxiety. This illustration is in line with the outcomes of the descriptive statistics. Moreover, it can be assumed that higher means of sedentary time in the preceding 30-minute period are not related to higher means of state anxiety in this sample. Sedentary time fluctuated approximately between 15 and 30 minutes, whereas state anxiety fluctuated between 0 and 5 which is a narrower range compared to sedentary time.

When visualising the EMMs for sedentary time and state anxiety over time (see Figure 4), it seems like there were more fluctuations in sedentary time than in state anxiety levels. Sedentary time fluctuated somewhere between 15 and 30 minutes, and state anxiety remained

relatively stable between levels of 0 to 3. The higher fluctuations and broader range of sedentary time indicated higher variation compared to state anxiety.

Figure 3

Estimated marginal means for sedentary time and state anxiety for each participant

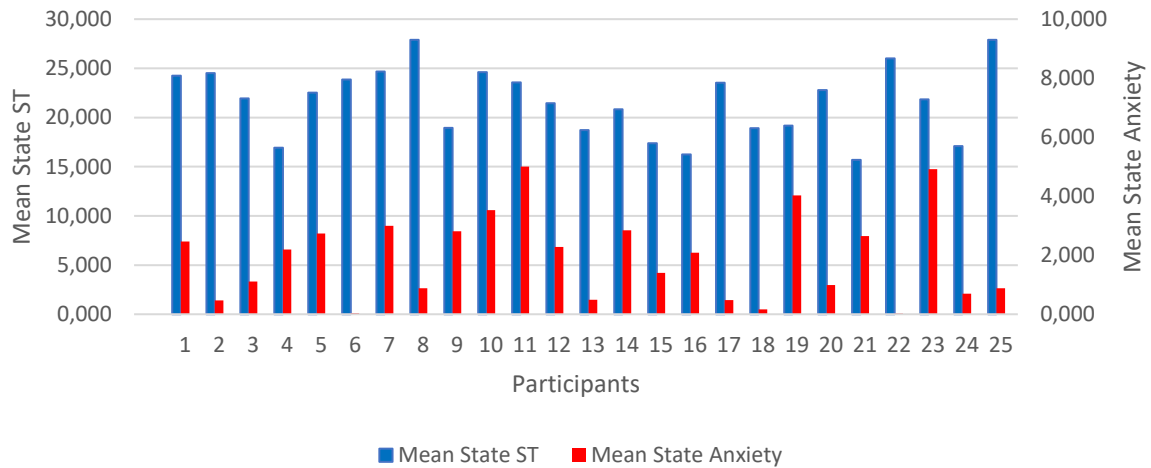
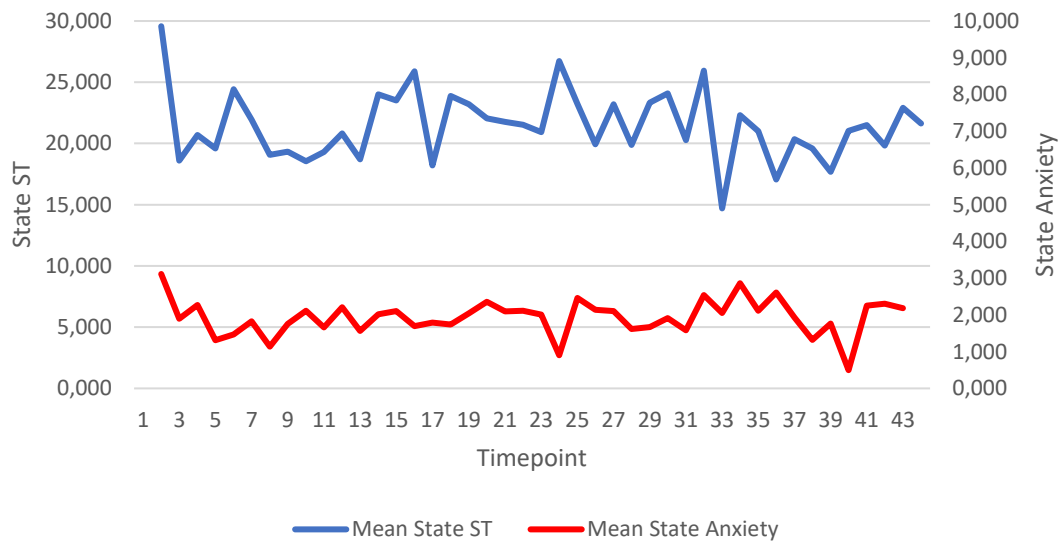


Figure 4

Variation of mean sedentary time and state anxiety across timepoints



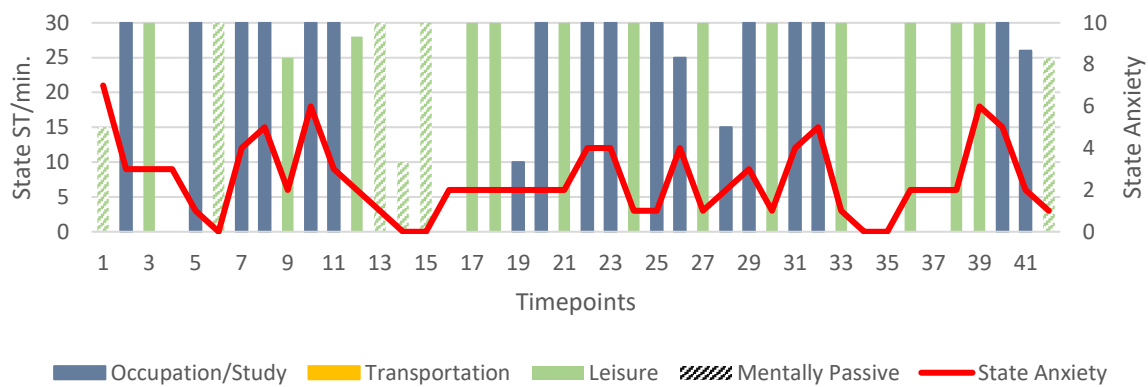
Individual Variation

When investigating the visualisation of the variation for Participant 1 (see Figure 5), there seem to be high fluctuations over time. It can be suggested that there was high variability, with periods of consistently very low or very high amounts of sedentary time. Next to that, one can suggest that levels of state anxiety also fluctuated highly. It seems like at some timepoints, there was a correlation between higher amounts of sedentary time and

higher levels of state anxiety, but this occurred inconsistently. Additionally, it can be observed that state anxiety levels were lower at the weekends (timepoints 13-18, 34-39) combined with more passive activities in the context of leisure. The participant executed on the majority of the timepoints mentally active behaviours, which seem to be often accompanied by higher state anxiety in the occupation/study context.

Figure 5

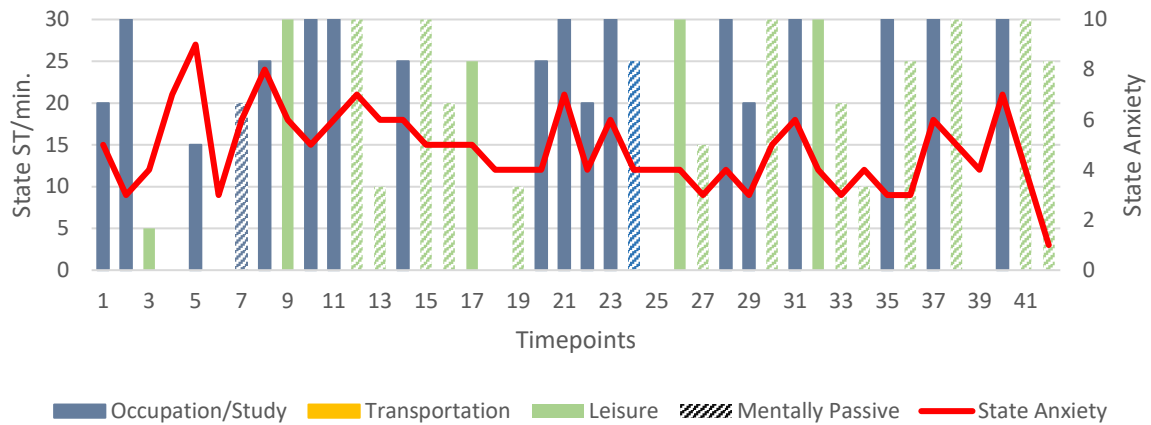
Variation across timepoints for Participant 1



When looking at the data of Participant 23 (see Figure 6), it seems like there are high fluctuations in sedentary time and state anxiety similar to Participant 1. It can be suggested that there were irregular sedentary time patterns because there were both very low and very high amounts of sedentary time observed. As for Participant 1, there seem to be some correlations between increases in sedentary time and state anxiety levels, but inconsistently. Moreover, it can be observed that higher state anxiety appeared in the context of occupation/study while the participant had higher sedentary time and was mentally active (timepoints 5, 7, 20-23, 31 37, 40). It seems like the leisure contexts were often combined with lowered levels of state anxiety and mentally passive activities (e.g. timepoints 15-19, 32-34, 41-42).

Figure 6

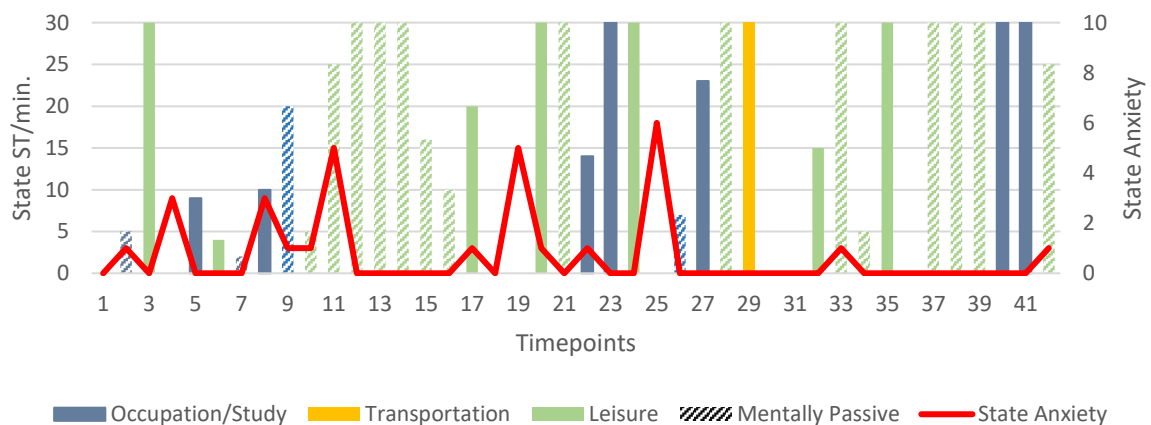
Variation across timepoints for Participant 23



Lastly, when investigating the data of Participant 24 (see Figure 7), it seems like there were high fluctuations in sedentary time in the beginning, and later stabilised. The participant indicated very low and very high amounts of sedentary time. Additionally, the state anxiety levels seem relatively low and stable. Comparing the high variability in sedentary time to the relatively low variability in state anxiety levels, there was no high correlation between the variables. When considering the contexts and mental activity of the participant, it can be observed that mentally passive activities in the leisure context often correspond to state anxiety levels of 0. Higher levels of state anxiety are at some points (timepoint 5, 8, 26) related to the context of occupation/study, but that seems to be inconsistent.

Figure 7

Variation across timepoints for Participant 24



Inferential statistics

To examine the association between sedentary time and state anxiety, and the moderating effects of the type and contexts on that relationship, five linear mixed models were conducted. Table 2 displays an overview of the statistical test results.

The first model which included sedentary time and state anxiety revealed an estimate of $b = 0.01$, indicating a slight positive effect of sedentary time on state anxiety. However, the confidence interval $95\%CI = [-0.01, 0.02]$ suggests that the relationship could be either positive or negative, indicating an insignificant relationship.

The results of the model testing for a moderating effect of mental activeness on the relationship between sedentary time and state anxiety revealed the indication that higher amounts of mental activeness are related to higher levels of state anxiety with a significant main effect, $b = 0.76$, $95\%CI = [0.15, 1.36]$. Nevertheless, there was an insignificant moderation effect found, $b = 0.01$, $95\%CI = [-0.02, 0.03]$.

Three different linear mixed models were run to investigate whether the three contexts have moderating effects on the relationship between sedentary time and state anxiety.

The first model tested the moderating effect of the context occupation/study on the relationship between sedentary time and state anxiety. There was a significant main effect of the context on state anxiety, that indicated the association between being in the context of occupation/study and increased levels of state anxiety, $b = 0.66$, $95\%CI = [0.05, 1.28]$. Next to that, there was a non-significant moderating effect of the context revealed, $b = 0.02$, $95\%CI = [-0.01, 0.04]$.

The outcome of the model analysing the interaction between the context of leisure and the relationship between sedentary time and state anxiety revealed that there was a significant main effect of the context, $b = -0.59$, $95\%CI = [-1.14, -0.04]$. The negative estimate indicated that the context of leisure is related to decreased levels of state anxiety. However, there was no significant moderating effect found, $b = -0.02$, $95\%CI = [-0.04, 0.01]$.

The results from the third model that tested for the moderating effect of the context transportation of the relationship between sedentary time and state anxiety showed no significant main effect of the context on state anxiety, $b = 0.32$, $95\%CI = [-0.46, 1.1]$. Next to that, there was a non-significant moderating effect found, $b = -0.03$, $95\%CI = [-0.07, 0.01]$.

Table 2

Estimates for Fixed Effects for Linear Mixed Models

Linear Mixed Models	<i>b</i>	<i>SE</i>	<i>t</i>	<i>p</i>	95%CI
Model 1					
Intercept	1.82	.18	10.28	<.001	[1.48, 2.17]
Sedentary time	0.01	.01	1.16	.265	[- 0.01, 0.02]
Model 2					
Intercept	1.66	.19	8.65	<.001	[1.28, 2.04]
Sedentary time	- 0.01	.01	-1.54	.125	[- 0.03, 0.003]
Mental Activeness	0.78	.31	2.45	.014	[0.15, 1.36]
Sedentary time * Mental Activeness	0.01	.01	.77	.442	[- 0.02, 0.03]
Model 3					
Intercept	1.71	.19	9.16	<.001	[1.34, 2.08]
Sedentary time	- 0.01	.01	- .97	.335	[- 0.02, 0.01]
Context Occupation/Study	0.66	.31	2.12	.036	[- 0.05, 1.28]
Sedentary time * Context Occupation/Study	0.02	.01	1.57	.117	[- 0.01, 0.04]
Model 4					
Intercept	2.17	.24	9.06	<.001	[1.7, 2.64]
Sedentary Time	0.01	.01	1.62	.107	[- 0.003, 0.03]
Context Leisure	- 0.59	.28	-2.01	.036	[- 1.14, - 0.04]
Sedentary Time * Context Leisure	- 0.02	.01	-1.36	.175	[- 0.04, 0.01]
Model 5					
Intercept	1.79	.19	9.45	<.001	[1.42, 2.16]
Sedentary Time	0.01	.01	1.4	.163	[- 0.004, 0.02]
Context Transportation	0.32	.4	.81	.416	[- 0.46, 1.1]
Sedentary Time * Context Transportation	- 0.03	.02	-1.56	.119	[- 0.07, 0.01]

Note. Dependent variable: State Anxiety.

Discussion

The current study investigated whether sedentary time affects the state anxiety levels of university students over time, considering different behavioural contexts and types of sedentary activities. There was no significant relationship found between sedentary time and state anxiety, indicating that there are no short-term effects of sedentary time on state anxiety levels observable in this sample. By examining the second and third research questions, neither the contexts nor mental activeness moderate the relationship between sedentary time and state anxiety. However, there were significant effects of the contexts of occupation/study and leisure found, as well as an effect of mental activeness on state anxiety.

Findings

There was no relationship found between sedentary time and state anxiety. The visualisations show no consistent or stable patterns. While sedentary time has higher fluctuations, state anxiety levels remained relatively stable, illustrating that sedentary time does not affect levels of state anxiety. Next to that, the relatively low levels of state anxiety in this sample could be explained by the fact, that the study took place in a relatively uneventful time (e.g. no exam period). This could have led to effects on levels of state anxiety. Moreover, differences between the participants in their sedentary time and state anxiety levels can be observed. It seems like the participants have different relations between their state anxiety levels and amounts of sedentary time. According to Felez-Nobrega et al. (2020), a possible explanation for the insignificant relationship between sedentary time and state anxiety could be that sedentary behaviour does not affect momentary emotional conditions related to anxiety. Sedentary behaviour has not been linked to state anxiety (Felez-Nobrega et al., 2020; Padmapriya et al., 2016), but to trait anxiety (Allen et al., 2019; Teychenne et al., 2015). The current study contributes to the existing research on sedentary behaviour and state anxiety, that there was no connection found between the two. It supports the findings of previous studies that no state-like conditions of anxiety are affected by sedentary behaviour. When interpreting the visualisations of the participants with the highest response rate, the levels of state anxiety remained relatively stable, showing no dependence on sedentary time. Even if there were increased fluctuations in sedentary time, levels of state anxiety seemed to be not affected by that. The on average stable levels of state anxiety also indicate a possible trait-like association instead of short-term behavioural changes. However, the use of ESM adds new insights into the limited research on the association between sedentary behaviour and anxiety, and how contexts and mentally active and passive sedentary activities affect the relationship.

By capturing the data of the participants in real time, the design enabled the recording of immediate fluctuations in state anxiety levels in response to sedentary time, considering the effects of the contexts and mentally active and passive activities. This facilitated the examination of short-term effects that might have been overlooked by studies relying on less frequent measurements.

Regarding the second research question, there was no moderation effect of mental activeness on the relationship between sedentary time and state anxiety found. The absence of the moderation effect is in line with the findings that there is no significant relationship between sedentary time and state anxiety. Therefore, it is unlikely that adding moderator variables has an effect since it typically does not alter the fundamental absence of the association. Moderator variables usually affect the direction or strength of an existent association. Thus, without an existent relationship, it is improbable that adding moderator variables would have significant effects. However, the results showed an association between being mentally active and higher levels of state anxiety, independent of sedentary time. This association was also observed in the individual visualisations of the participants with the highest response rates. The visualisations displayed that mentally active sedentary activities were often accompanied by heightened levels of state anxiety, whereas mentally passive activities were more often connected to lowered state anxiety. This finding indicates that the increased mental effort and concentration associated with mental activeness represents a crucial factor in affecting state anxiety levels without the interaction of sedentary time. The finding aligns with research on the effect of mental activeness on mental health. Research on mental activity related to state anxiety is limited, but Hallgren et al. (2018) revealed comparable findings about mentally active and passive sedentary activities on depression. It was revealed that mentally active sedentary behaviours are associated with an increased risk of depression, whereas mentally passive activities are related to the prevention of depression. Although Hallgren et al. (2018) focused on depression and not on state anxiety, the underlying mechanisms might be similar where increased mental effort leads to the heightened risk of depression and anxiety.

The findings related to the third research question revealed that there were no moderation effects of the different contexts. Nevertheless, there was a significant main effect of the context occupation/study on state anxiety found, which indicates that being in the context is related to heightened state anxiety levels. This could be connected to academic pressure and performance anxiety because of deadlines, high workloads, or the achievement of high grades. These approaches to explanation can also be connected to the effect of mental

activeness on state anxiety levels. Next to that, there was a negative effect of the leisure context found, which expresses that being in the context is associated with decreased state anxiety. This result can be related to the previously described effects since leisure can be seen as the opposite of occupation/study because leisure involves typically more relaxing activities that require less cognitive effort. Leisure often gives the possibility to recharge and recover from previous more demanding activities. Therefore, a possible explanation for the association between the context of leisure and state anxiety levels could be that leisure reduces anxiety levels by providing mental relaxation. This finding and explanation can also be supported by the visualisations since lowered state anxiety levels were observed during mentally passive activities in the leisure context.

Moreover, there was neither a significant effect on state anxiety nor a significant moderating effect on the relationship between sedentary time and state anxiety in the transportation context found. This could be due to the mostly limited duration and neutrality of the context. When considering the individual visualisations, the transportation context did merely occur across the timepoints which also indicates that it represents a rather temporary limited context. Therefore, being in the transport context might not trigger strong emotions that could affect state anxiety. The results confirm, among other studies, the findings of Chen et al. (2022) that different contexts exhibit different effects on anxiety. Since there is limited research on the relationship between sedentary time and state anxiety, there is also insufficient research on the impact of different contexts and types of sedentary behaviour on state anxiety.

Strengths and Limitations

The present study employed an Experience Sampling Method (ESM) to examine the relationship between sedentary time and state anxiety which builds a significant strength. This design allowed for increased accuracy and a more detailed data collection. By conducting the data over two weeks with three measurements per day, the requirements of the scientific scope were met by an extensive and detailed data set. Additionally, fluctuations and variability of the variables were precisely captured by using ESM. Moreover, the inclusion of the framework of Hallgren et al. (2020a) allowed for a modern conceptualisation of sedentary behaviour by categorising it into distinct contexts and distinguishing between mentally active and mentally passive sedentary behaviour. With regard to the present study, the ESM design allowed for the examination of these contexts and types across each participant and timepoint.

The limitations of the study include the technical difficulties with working with the application m-Path that occurred during the data collection period. One problem was that

several data regarding the amount of sedentary time needed to be changed from hours into minutes because participants recorded their sedentary time incorrectly. Because of this, the data could be inaccurate regarding the assessment of sedentary time. Moreover, the function in m-Path of setting an expiration time for the questionnaire was unknown for the first two days of data collection. Therefore, participants had the opportunity to respond to the questionnaires, although they were no longer applicable because of the questionnaire schedule. This might have led to limited accuracy and inconsistency in reporting which could have affected the results negatively. The third difficulty that occurred while working with m-Path was errors in scheduling. In the first week (Tuesday and Wednesday), some questionnaires were incorrectly scheduled leading to decreased temporal validity. Participants' experiences could not have been correctly reflected by their responses. This is especially problematic in examining effects on state anxiety since it requires time-sensitive measures. Next to that, it could have increased missing data and lowered response rates.

Another limitation of the study is the duration of the data collection period. Although the duration of two weeks is within the suggested time frame for an ESM study (Berkel et al., 2017), the study did not assess how the contexts and mentally active and passive sedentary behaviours might influence students' state anxiety in different periods of an academic year. Different phases like exam periods or holidays might have different effects on university students' state anxiety levels. When extending the data collection period and including e.g. exam periods and holidays, more comprehensive insights into how state anxiety levels fluctuate in responding to sedentary behaviour in varying contexts and cognitive activity over time.

Recommendations for Future Research

The current study contributed to the research on sedentary behaviour in relation to state anxiety, by gaining new insights and addressing several gaps. To gain a more detailed understanding of possible associations, further research is needed to examine the findings and overcome the limitations of the study.

One recommendation is to do more research on the associations between the types of sedentary time, contexts of occupation/study and leisure, and state anxiety. It might be possible to gain deeper insights into the relationships when extending the data collection period and including, e.g. exam periods and holidays. Next to that, a more profound understanding of how mentally active sedentary activities have an impact on state anxiety levels could be gained by adding specific activities (e.g. studying, sitting in a lecture/tutorial,

etc.). An experimental study could be conducted where participants are randomly assigned to simulated contextual settings, like occupation, transportation, and leisure. In these contexts, participants would have to execute different types of sedentary activities (mentally active and mentally passive tasks). Before and after each session, the levels of state anxiety would be measured through self-reports and physiological measurement tools. This experimental study could provide deeper insights into how different contexts and types of sedentary activities affect state anxiety and address the research gap of mainly observational studies.

Conclusion

In conclusion, the findings of the current study on the relationship between sedentary time and state anxiety, focusing on contexts and mental activeness of sedentary behaviour, revealed that sedentary time does not influence state anxiety levels. However, the context of occupation/study and mentally active sedentary activities are associated with heightened state anxiety, whereas the leisure context is related to lowered state anxiety. These findings give insight into students' daily lives and highlight the importance of the setting and nature of activities. Moreover, it is crucial to consider the different contexts and mental activity when examining how sedentary behaviour is associated with anxiety levels. By taking into account the mentioned limitations and recommendations of the present study, a more detailed understanding of how the contexts and types of sedentary activities affect state anxiety could be gained.

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Appendix A

The Informed Consent

Dear participant,

We would like to thank you for taking part in our study!

This study is conducted by Roos A.S. Kruk, Paula H. Naber, Ariya Solan, Edgar G. Avanisian and Mats O. Tebarth, and supervised by Gerko Schaap from the Department of Psychology, Health & Technology at the University of Twente.

The scope of this study is to investigate the relationship between daily sitting time and several variables including mood, stress and anxiety. You will help us address research gaps and contribute to a growing body of evidence regarding associations between sitting time and well-being.

To participate, you need to be at least 18 years old, enrolled in a university or other higher education institution (HBO, Fachhochschule), and have proficient English language skills. Additionally, you need to be able to stand for at least 30 minutes a day and have access to and be willing to use a smartphone capable of running an app for the duration of the study.

For this study, we ask you to respond to four daily questionnaires for a duration of 14 consecutive days. On the first day of assessment, you will be asked to complete a baseline questionnaire. For the following days, you are required to respond to daily repeated questionnaires, scheduled at 10:00, 14:00, 18:00, and 21:00, each open for 2 hours.

Specifically, the questionnaire at 10:00 will ask you to retrospectively report on your sitting time from the previous day, while the remaining three questionnaires will ask you about specific conditions such as mood, stress, and anxiety. All questionnaires will be completed via the m-Path app.

There are no physical risks associated with this research project. Regarding the time period of two weeks, you may have timely constraints and not enough energy to constantly fill in the questionnaires. If any of these cases apply, you may withdraw at any given time as your participation in this study is voluntary. In the case of additional complaints, you can contact

the researcher(s).

Keep in mind that in the case of early withdrawal, you will **not be granted any SONA credits**.

All personal data will be anonymised and kept confidential. The data will only be used for the purpose of this study and will be stored on researchers' devices for a period of two years.

Please do not hesitate to contact the researchers if you have any questions or concerns before, during or after your participation:

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Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee Information & Computer Science: ethicscommittee-CIS@utwente.nl

Do you agree to all of the above-mentioned statements and confirm that you consent to take part in this study and for your data to be used for future research as described?

Please select one of the following options:

- I agree
- I disagree

Appendix B

Baseline Questionnaire

Demographics	Question	Answer options
Item 1	What is your gender?	1) Female 2) Male 3) Other 4) Prefer not to say
Item 2	What is your age?	Numerical value
Item 3	What is your nationality?	1) Dutch 2) German 3) Other, please specify:
Item 4	What is your current occupation?	1) Enrolled at a university 2) Enrolled at another higher education institution (HBO, Fachhochschule) 3) Other
Item 5	Are you able to stand for 30 minutes at a time without any support?	1) Yes 2) No
Item 6	If you are participating via Sona, please indicate your SONA ID	Numerical value

Appendix C

Repeated Questionnaire Measuring Total ST (PAST-U), 30-min ST, Context/Type, and States Scheduled at 10am

For clarification:

In this survey, we are only interested in behaviour while you were sitting or lying down and being awake! Standing or other positions are not of interest here! Furthermore, sport in a seated position is also not of interest here as we are investigating sitting behaviour without physical activity!

Total ST (PAST-U)	Questions	Answer options
Item 1	How long were you sitting while <u>studying/working yesterday</u> ? (Include the time at University, during lectures, tutorials, meetings, group discussions, study/work from home, etc.)	Numerical value
Item 2	How long were you sitting for <u>transportation/travelling yesterday</u> ? (Include sitting and waiting for transport. Do not include any time you were standing up while travelling or waiting.)	Numerical value
Item 3	How long were you sitting or lying down while <u>watching TV, internet-use</u> or <u>playing video games yesterday</u> ? (Include watching TV, playing video games, internet-use for activities that were not for studying or working purposes, like social media, Netflix, YouTube, online shopping, etc.)	Numerical value
Item 4	How long were you sitting or lying down while <u>reading</u> during your leisure time yesterday ? (Include reading in bed but do not include time spent reading for work or study)	Numerical value
Item 5	How much time did you spend sitting down for <u>eating</u> and drinking yesterday ?	Numerical value
Item 6	How much time did you spend yesterday sitting down to <u>socialize</u>	Numerical value

with friends or family, regardless of location?

(Include at University, at home, or in a public place, etc. Include time on the telephone)

Item 7

How much time did you spend **yesterday** in any other sitting or lying behaviour that you may have done but not yet told us about? (e.g., hobbies such as doing arts and crafts, playing board games, listening to music, or religious purposes)

Numerical value

30-min ST

Item 1

Over the past 30 minutes before the notification, how many minutes have you been in a sitting or reclining position?

Numerical value

Context

Item 1

Over the past 30 minutes, in which context were you in?

- 1) Leisure
- 2) Transportation
- 3) Occupation/Study

Type

Item 1 (Follow-up Leisure)

During the past 30 minutes, what activity did you spend the most time engaged in?

- Playing games like video games, board games, etc, or reading a book, newspaper, or something else.
- Actively using social media or socializing and talking with people (Phone or in person).
- Watching TV, movies, YouTube, Netflix, etc, or listening to music, or just resting in a seated or reclined position without sleeping.
- Eating and drinking while in a seated or reclined position
- Not sitting

Item 2 (Follow-up Transportation)

During the past 30 minutes, what activity did you spend the most time engaged in?

- Sitting and driving a motor vehicle.

- Sitting and reading or using a computer/smartphone for work/university purposes while commuting/travelling.
 - Using social media or playing video games while commuting/travelling
 - Just sitting as a passenger, or eating/drinking while commuting/travelling
 - Not sitting
- Item 3 (Follow-up Occupation/Study)** During the past 30 minutes, what activity did you spend the most time engaged in?
- Sitting and using a computer for work or study purposes.
 - Sitting while participating in a meeting, tutorial, or other work/study-related event.
 - Sitting in your work/study environment but not engaged in work or study-related tasks (e.g., socializing, eating/drinking etc).
 - Not sitting

State Stress

Item 1

What number describes your stress over the past 30 minutes?

Scale of 0 to 10, 0 being no stress and 10 being worst stress possible (11-point-likert scale)

State Mood

Item 1

Over the past 30 minutes, to what extent did you feel active?

- 1) Not at all
- 2) A little
- 3) Moderately
- 4) Quite a bit
- 5) Extremely

Item 2

Over the past 30 minutes, to what extent did you feel upset?

- 1) Not at all
- 2) A little
- 3) Moderately
- 4) Quite a bit

		5) Extremely
Item 3	Over the past <u>30 minutes</u> , to what extent did you feel attentive?	1) Not at all 2) A little 3) Moderately 4) Quite a bit 5) Extremely
Item 4	Over the past <u>30 minutes</u> , to what extent did you feel afraid?	1) Not at all 2) A little 3) Moderately 4) Quite a bit 5) Extremely
<u>State Anxiety</u>		
Item 1	“How anxious did you feel over the past <u>30 minutes</u> ?”	Visual Analogue Scale (VAS), ranging from 0 “not anxious at all” to 10 “most anxious you could ever imagine”

Appendix D

Repeated Questionnaire Measuring 30-min ST, Context/Type, and States Scheduled at 3pm and 8pm

For clarification:

In this survey, we are only interested in behaviour while you were sitting or lying down and being awake! Standing or other positions are not of interest here! Furthermore, sport in a seated position is also not of interest here as we are investigating sitting behaviour without physical activity!

30-min ST	Questions	Answer options
Item 1	Over the past <u>30 minutes</u> before the notification, how many minutes have you been in a sitting or reclining position?	Numerical value
<hr/>		
Context		
Item 1	Over the past <u>30 minutes</u> , in which context were you in?	<ol style="list-style-type: none"> 1) Leisure 2) Transportation 3) Occupation/Study
<hr/>		
Type		
Item 1 (Follow-up Leisure)	During the past <u>30 minutes</u> , what activity did you spend the most time engaged in?	<ul style="list-style-type: none"> - Playing games like video games, board games, etc, or reading a book, newspaper, or something else. - Actively using social media or socializing and talking with people (Phone or in person). - Watching TV, movies, YouTube, Netflix, etc, or listening to music, or just resting in a seated or reclined position without sleeping. - Eating and drinking while in a seated or reclined position - Not sitting
Item 2 (Follow-up Transportation)	During the past <u>30 minutes</u> , what activity did you spend the most time engaged in?	<ul style="list-style-type: none"> - Sitting and driving a motor vehicle. - Sitting and reading or using a computer/smartphone for work/university purposes while commuting/travelling.

- Item 3 (Follow-up Occupation/Study)** During the past 30 minutes, what activity did you spend the most time engaged in?
- Using social media or playing video games while commuting/travelling
 - Just sitting as a passenger, or eating/drinking while commuting/travelling
 - Not sitting
 - Sitting and using a computer for work or study purposes.
 - Sitting while participating in a meeting, tutorial, or other work/study-related event.
 - Sitting in your work/study environment but not engaged in work or study-related tasks (e.g., socializing, eating/drinking etc).
 - Not sitting

State Stress

Item 1

What number describes your stress over the past 30 minutes?

Scale of 0 to 10, 0 being no stress and 10 being worst stress possible (11-point-likert scale)

State Mood

Item 1

Over the past 30 minutes to what extent did you feel active?

- 1) Not at all
- 2) A little
- 3) Moderately
- 4) Quite a bit
- 5) Extremely

Item 2

Over the past 30 minutes, to what extent did you feel upset?

- 1) Not at all
- 2) A little
- 3) Moderately
- 4) Quite a bit
- 5) Extremely

Item 3

Over the past 30 minutes, to what extent did you feel attentive?

- 1) Not at all
- 2) A little
- 3) Moderately
- 4) Quite a bit
- 5) Extremely

Item 4

Over the past 30 minutes, to what extent did you feel afraid?

- 1) Not at all
- 2) A little
- 3) Moderately
- 4) Quite a bit
- 5) Extremely

State Anxiety**Item 1**

“How anxious did you feel over the past 30 minutes?”

Visual Analogue Scale (VAS), ranging from 0 “not anxious at all” to 10 “most anxious you could ever imagine”