The Relationship Between Sedentary Behaviour and State Anxiety in University

Students: An Experience Sampling Study

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Abstract

Background: Excessive sedentary behaviour has been shown to have detrimental effects on anxiety. This finding is especially relevant for highly sedentary groups, such as university students. While sedentary time has been shown to have a positive relationship with trait anxiety and anxiety disorders, research has paid little attention to state anxiety. Furthermore, it has not been tested whether there is a difference between mentally active and mentally passive sedentary behaviours. Similarly, no research has yet tested the influence of socially active sedentary behaviours. Hence, this paper aimed to investigate the relationship between the different kinds of sedentary behaviour and state anxiety in university students.

Method: An experience sampling study was conducted over nine days with 37 university students ($M_{age} = 20.68$, $SD_{age} = 2.19$, 73% female). Participants received three daily surveys on their Ethica App, measuring their level of state anxiety and their sedentary time. Visualised estimated marginal means and linear mixed models tested the associations between sedentary time and state anxiety.

Results: No significant relationship was found between state anxiety and total sedentary time. Similarly, no significant relationships were found between state anxiety and mentally active or socially active sedentary time. Mentally passive sedentary was found to have a negative effect on state anxiety, $B = -0.11$, $SE = 0.05$, $F(1, 632.303) = 4.63$, $p = .03$.

Conclusion: This study was the first study to use experience sampling to investigate the relationship between sedentary time and state anxiety. Neither total nor mentally active sedentary time was found to be associated with state anxiety. Similarly, socialising with being sedentary was not associated with state anxiety, questioning the social withdrawal theory. Future research may test if the unpredicted negative relationship between mentally passive sedentary time and state anxiety is mediated by screen time.

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

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The Relationship Between Sedentary Behaviour and State Anxiety

The recent Covid-19 pandemic has not only taken a toll on the physical health of the population and the economy (Borio, 2020) but also on mental health. For instance, a meta-analysis has found that the rates of anxiety disorders have risen from 7.3% to 25% globally during the pandemic (Chang et al., 2021). Interestingly, an increase in anxiety was not found for those who remained active during the lockdown (Chang et al, 2021). Moreover, studies have found that during the pandemic, physical activity has decreased while time spent sitting has increased due to lockdown restrictions, such as home office and closed outdoor and sports facilities (Stockwell et al., 2021). University students, a population already known for high sitting times prior to the pandemic restrictions, reported a three-hour increase in hours spent sitting daily (Bertrand et al., 2021; Cox et al., 2018; Clark et al., 2014).

Indeed, prolonged sitting time has been linked with detrimental effects on anxiety disorders by multiple studies (Allen et al., 2019; Edwards & Loprinzi, 2016; Hallgren et al., 2020; Teychenne et al., 2015). However, while trait anxiety and anxiety disorders have been researched, the scientific findings concerning state anxiety and prolonged sitting are limited to cross-sectional surveys, which fail to take into account within-person fluctuations (Allen et al., 2019; Felez-Nobrega et al., 2020; Teychenne et al., 2015; Padmapriya et al., 2016). Furthermore, the differences between different types of sedentary behaviours have not been extensively researched yet (Rebar et al., 2014; Teychenne et al., 2015). Thus, the aim of this study was to investigate the relationship between anxiety and sitting time in university students by considering within-person fluctuations.

Sedentary Behaviour

In scientific literature, prolonged sitting is known as sedentary behaviour. Sedentary behaviour is defined as "any waking behaviour characterized by an energy expenditure ≤1.5 METs while in a sitting or reclined posture." (Barnes et al., 2013, p. 55) In simpler terms, it refers to sitting without being otherwise physically active (Owen et al., 2011). Sedentary

behaviour is distinct from a lack of physical activity. That is, a person can engage in a sufficient amount of physical activity but still spend too much time sitting (Biddle et al., 2018; Owen et al., 2011). Behaviours that are usually sedentary in nature include watching television, using the computer either at work or in one's leisure time, and driving cars or using other means of transportation that require sitting (Owen et al., 2011).

Excessive sedentary behaviour can have various negative effects on both physical and mental health. Regarding physical health, individuals indulging in high amounts of sedentary behaviours have a higher risk of cancer, diabetes, hypertension, osteoporosis, and all-cause mortality (Biswas et al., 2015; Park et al, 2020). While there is no clear indication of dose-response effect for every outcome (Biddle, 2016), research found that the risk of death was higher when spending 9.5 hours or more being sedentary (Ekelund et al., 2019). This is concerning given that university students spend about 10 hours a day being sedentary (Castro et al., 2020). Concerning mental health, it was found that sedentary behaviour is associated with depression and anxiety (Allen et al., 2019; Huang et al., 2020; Teychenne et al., 2015).

Hallgren et al. (2020) suggest that different types of sedentary behaviour have different outcomes on mental health. They found that mentally passive sedentary behaviours, such as watching television, but not mentally active sedentary behaviours, such as occupational sitting, have a negative effect on mental health outcomes (Dempsey et al., 2018; Hallgren et al., 2019). In sum, sedentary behaviours seem to have detrimental effects on (mental) health outcomes. Recent research has stressed the importance of differentiating between types of sedentary behaviour and their influence on (mental) health.

Anxiety

Anxiety is one of the most common mental health problems with a global prevalence of 7.3%, which has risen to 25% during the Covid-19 pandemic (Baxter et al., 2013; Chang et al., 2021). It is more common in women than in men and most prevalent in young adults between the ages of 15 and 34 (Baxter et al., 2014). Anxiety is defined by "excessive and

persistent (yet often unrealistic) worry which can inhibit one's ability to carry out activities of daily living" (Teychenne et al., 2015, p. 2). More precisely, individuals with high levels of anxiety are fearful and avoidant of situations (e.g., social situations, large or unfamiliar places) they perceive as threats (Craske & Stein, 2016). The emotional symptoms of fear and distress lead to an activation of the fight or flight response and hence, are often accompanied by physiological symptoms. These include breathing and/or stomach issues, sweating, a pounding heart, and possibly fainting (Craske & Stein, 2016; Gale & Oakley-Browne, 2004). Persistent anxiety can negatively influence many aspects of a person's life, such as life satisfaction, social, family, and occupational functioning (Hoffman et al., 2008).

Anxiety can both be trait-like and state-like. If it is trait-like, an individual has a general tendency to perceive situations, persons, or objects as threats (Weeks et al., 2019). In this case, it is a stable feature of someone's personality and associated with constant high arousal (Saviola et al., 2020). Anxiety can also be state-like. State anxiety is a momentary reaction to a specific anxiety-inducing event and is associated with feelings of nervousness and apprehension, leading to a transient increase in sympathetic nervous system activity (Weeks et al., 2019). To conclude, anxiety is a common problem. It can be chronic, but it also can be a momentary experience.

Anxiety and Sedentary Behaviour

The literature on the relationship between sedentary behaviour and anxiety is mixed (Teychenne et al., 2015). Nevertheless, two meta-analyses concluded that there is moderate evidence for a positive relationship between sedentary behaviour and the occurrence of anxiety (Allen et al., 2019; Teychenne et al., 2015). That is, it is believed that sitting more is associated with an increase in anxiety symptoms. There is also some preliminary evidence for a cause-and-effect relationship between sedentary behaviour and anxiety (Blough & Loprinzi, 2018; Edwards & Loprinzi, 2016). In two randomized controlled interventions, it was found

that one week of induced sedentary behaviour has a large detrimental effect on anxiety

severity in young adults (Blough & Loprinzi, 2018; Edwards & Loprinzi, 2016).

There are several explanations as to why sedentary behaviour leads to anxiety. On one

hand, there are biological explanations (Teychenne et al., 2015). For instance, it was found

that sedentary behaviour in form of screen time may lead to sleep disturbances, which, in turn,

can trigger anxiety (Dworak et al., 2007; Hale & Guan, 2015). On the other hand, there are

psychological explanations. One psychological theory is the social withdrawal theory.

According to this theory, sedentary behaviours lead to anxiety as they often occur socially

isolated. This social isolation leads to increased feelings of anxiety (Teychenne et al., 2015;

Vancampfort, 2019).

Next to the literature investigating a general link between all kinds of sedentary

behaviours and anxiety, research has also not properly investigated if the context or the type

of sedentary behaviour is relevant (Rebar et al., 2014). Rebar et al. (2014) argue that the

relationship between anxiety and sedentary behaviour may be partially due to the cognitive,

instead of the physical, aspects of the behaviour. Similarly, Lee and Kim (2018) proposed

investigating the effect of sedentary behaviour on anxiety by differentiating between work-

related and not work-related sedentary behaviours. However, the few research papers that

investigated this have mixed results (Teychenne, 2015). On one hand, Rebar et al. (2014)

found that time spent sitting while using the computer and during transport was associated

with more severe anxiety, while TV watching was not. On the other hand, de Wit et al. (2011)

found that TV watching was linked to anxiety, but computer use was not.

While research concerning anxiety in this context is mixed, research has clearly

demonstrated that mentally passive sedentary behaviours (e.g., TV watching) are more

detrimental to depression than mentally active sedentary behaviours (e.g., office work)

(Dempsey et al., 2018; Hallgren et al., 2018; Hallgren et al., 2019; Hallgren et al., 2020). In

fact, Hallgren et al. (2018) found that engaging in mentally active sedentary behaviours can

even decrease the chance of depression. It seems worthwhile to investigate the effect of mentally active vs. mentally passive sedentary behaviour on anxiety as well because mental activity might reduce rumination, which is responsible for maladaptive cognitions in both depression and anxiety (Hallgren et al., 2019; McLaughlin & Nolen-Hoeksema, 2011).

Research on anxiety and its link to sedentary behaviour has often failed to clearly distinguish between state and trait types of anxiety. The research that has explicitly investigated the link between sedentary behaviour and state anxiety is extremely sparse. So far, only two studies have investigated the relationship between sedentary behaviour and state anxiety. Surprisingly, neither study found a link between these two concepts (Felez-Nobrega et al., 2020; Padmapriya et al., 2016). Notably, both studies used traditional cross-sectional designs. That is, they measured state anxiety retrospectively at one point in time. These traditional methods, however, are unsuitable to study state-like experiences, such as state anxiety in daily life. They are better equipped to study stable constructs as they cannot capture the within-person and between-person fluctuations of states, as states can vary across different situations, time, and people (Setia, 2016). Furthermore, these retrospective measurements are sensitive to recall bias as participants might report false or biased recollections of their past experiences (Montag et al., 2016; Wright, 2017). For these reasons, this study aimed to investigate the relationship between state anxiety and sedentary behaviour by using methods that can capture its fluctuations.

Another variable that should be investigated is social activity. As mentioned above, the social withdrawal theory suggests that sedentary time might have a detrimental effect on anxiety because they often involve little social interaction (Allen et al., 2019; Lee & Kim, 2018; de Wit et al., 2011). According to de Wit et al. (2011), this could explain why their study found no association between computer time and anxiety since computers are often used as platforms for social interaction. Vancampfort et al. (2019) found in their multi-country study that participants who spent three hours or more in sedentary behaviours were more

likely to experience loneliness. However, as of currently, no research has investigated if socially active sedentary behaviour has a negative effect on state anxiety. In sum, the research concerning the relationship between anxiety and sedentary behaviour needs to be refined. For one, studies need to investigate the effect of different types of sedentary behaviour, for example socially and mentally active sedentary behaviour. Also, more suitable methods should be used to investigate state anxiety.

Experience Sampling Methods

To avoid the previously described methodological limitations and advance the research on sedentary behaviours and state anxiety, this study employed experience sampling methods (ESM). ESM is a self-report measurement that helps researchers investigate moods, behaviours, and feelings as they occur in the daily lives of the participants (Myin-Germeys, 2018). According to Myin-Germeys (2018), using ESM allows researchers to investigate the experiences, feelings, and behaviours of their participants within the real-life context. This increases the ecological validity of the findings (Pejovic, 2016).

The use of ESM for this study was chosen for two main reasons. First, as described above, most of the research on sedentary behaviours and state anxiety has relied on cross-sectional designs, which are sensitive to recall bias (Wright, 2017). According to Pejovic (2016), the risk of recall bias is lower for ESM studies as the participants are questioned multiple times a day and hence, the period they must recall is shorter. Second, studies on state anxiety and sedentary behaviours have only measured state anxiety at one point in time (Felez-Nobrega et al., 2020; Padmapriya et al., 2016), failing to take within-person fluctuations into account. The repeated measurements in ESM studies allow researchers to understand the variability of psychological constructs (e.g., state anxiety) and assess within-person variations. In sum, ESM is the ideal method for this study as it reduces recall bias, leading to a more accurate picture of sedentary behaviours, and helps gain a deeper understanding of state anxiety by taking within-person fluctuations into account.

The Present Study

The aim of the present study was to investigate the association between daily sedentary time and state anxiety among university students by taking into account within-person fluctuations. University students were chosen as the target for multiple reasons. University is the transitional period where the prevalence of anxiety increases, as university students are confronted with social, financial, and academic challenges and changes that lead to feelings of anxiety (Breiter et al., 2015; Saleh, 2017). Moreover, this is also the period where physical activity begins to decline (Mun, 2007). In fact, it was found that university students spend around 10 hours a day being sedentary and their most prevalent behaviour was studying (Clark et al., 2014; Cox et al., 2018). Cox et al. (2018) concluded that university students experience high sedentary times.

The present study investigated the association between state anxiety and different types of sedentary time. Based on the above-described literature, the following research questions and expectations were formulated:

1.) What is the relationship between daily total sedentary time and state anxiety in university students?

It was expected that daily total sedentary time is positively associated with state anxiety.

2.) What is the relationship between daily mentally active sedentary time and state anxiety in university students?

It was expected that daily mentally active sedentary time and state anxiety are negatively associated.

3.) What is the relationship between daily mentally passive sedentary time and state anxiety in university students?

It was expected that daily mentally passive sedentary time and state anxiety are positively associated.

4.) What is the relationship between daily socially active sedentary time and state anxiety in university students?

It was expected that daily socially active sedentary time and state anxiety are negatively associated.

Methods

Design

The present study employed an experience sampling method (ESM) design. Notably, the present study was part of a bigger research project and therefore included questions, which were irrelevant to this paper. The study was approved by the Ethics Committee of the University of Twente (Case number: 211236). The study was pilot tested between the 25th and 27th October with eight participants. The study began on the 23rd of November and was conducted over nine days (see Table 1). On the first day, the participants only filled in the informed consent and demographics survey. From day two until day eight state anxiety was measured, while daily sedentary time was measured from day three until day nine retrospectively for the previous day (Table 1). In total, sedentary time and state anxiety were measured for a full week.

The study duration is within the normal range of ESM studies, which typically last for three days to three weeks (Conner & Lehman, 2012). A longer study duration was seen as too burdensome for the participants. Decreasing the burden for the participants reduces the likelihood of low response rates and participant drop-outs, which can otherwise result in an incomplete picture of the constructs and phenomena being studied (Conner & Lehman, 2012; Van Berkel et al., 2017).

Table 1

The Timeline of the Study Including All Variables, Triggers, Reminders, and Expiry Times

Day	Questionnaires	Variables	First Trigger	Expiry Time	Reminders
Day 1	Informed Consent		10am	None	12pm
	Demographics Survey	Gender			
		Age			
		Nationality			
		Mental Disorder			
Day 2	Morning	State Anxiety	7am	5 Hours	9am & 1pm
	Afternoon	State Anxiety	1-3pm	3 Hours	2 Hours
	Evening	State Anxiety	7-9pm	3 Hours	2 Hours
Day 3-8	Morning	Sedentary Time & State Anxiety	7am	5 Hours	9am & 1pm
	Afternoon	State Anxiety	1-3pm	3 Hours	2 Hours
	Evening	State Anxiety	7-9pm	3 Hours	2 Hours
Day 9	Morning	Sedentary Time	7am	5 Hours	9am & 1pm

Note. For the afternoon and evening surveys, the time of the reminders depended on the time the participants received their first random trigger.

Regarding the sampling frequency, four to ten measurements are the norm (Conner & Lehman, 2012). However, the sampling frequency of only three measurements a day was chosen as the questionnaires were quite time-consuming and it was considered more important to decrease participant burden. Concerning sampling strategy, interval contingent sampling was employed to measure daily sedentary time at fixed times throughout the day (Conner & Lehman, 2012; Myin-Germeys et al., 2018). It was chosen to measure sedentary

time as it is best used for behaviours that are recalled over an interval and are less susceptible to memory bias, such as reports of daily activity (Conner & Lehman, 2012).

To measure state anxiety, signal-contingent sampling was used. State anxiety was measured in a response to a signal occurring randomly within equal time intervals (Conner & Lehman, 2012). Signal-contingent sampling was chosen as it best suited for momentary experiences, such as state anxiety, due to its frequency, unpredictability, and lower risk of memory bias (Conner & Lehman, 2012). Furthermore, random sampling strategies allow for a more detailed and representative sample of the construct of interest and decrease reactivity (Myin-Germeys et al., 2018; Verhagen et al., 2016).

Participants

Due to the time restrictions of the research project a convenience sampling strategy was utilised to recruit participants. Convenience sampling is the most convenient and least time-consuming sampling method (Bornstein et al., 2013). The participants were recruited through the Test Subject Pool BMS (SONA) System of the University of Twente. Moreover, the research team invited their friends and family to participate. Participants met the inclusion criteria if they were enrolled at a university or university of applied sciences, were proficient in English, and were over 18 years old. The participants also had to have access to an iPhone or Android smartphone. Participation was entirely voluntary, and participants were able to withdraw from the study at any time without justification. Participants did not receive any training or feedback. Participants who joined the study via SONA received compensation in form of test-subject credits.

Regarding the sample size, Van Berkel et al. (2017) recommend using the estimated median of 19 participants in ESM studies as a guideline. Hence, the study aimed for 19 participants or more. A total of 84 participants responded to the survey. Of these 84 participants, 23 had to be excluded because they did not fill in the informed consent form. The average response rate of the 61 participants was rate was 76.85% and 68.3% of the

participants had a response rate of 70% or higher. Consequently, participants were removed from analysis when their response rate was lower than 70%. This finding is consistent with findings and recommendations by Van Berkel et al.'s (2017) meta-analysis.

Of the remaining 43 participants, six participants were excluded because they reported total daily sedentary times over 24 hours, which was deemed as impossible. The final sample of 37 participants had a high average response rate of 94% ($SD = 9.08$) (see Table 1). 73% of the participants were female ($n = 27$). The participants were between the ages 18 and 26 ($M_{age} = 20.68$, $SD_{age} = 2.19$). 56.8% of the participants were German ($n = 21$) and 18.9% were Dutch ($n = 7$). 83.8% of the participants reported no diagnosis with a mental disorder ($n = 31$) (see Table 2).

Table 2

Sociodemographic Characteristics of the Participants

Variable	*n*	*%*	*M*	*SD*
Gender: Male	10	27%		
Female	27	73%		
Age			20.68	2.19
Nationality: German	21	56.8%		
Dutch	7	18.9%		
Other-EU	5	13.5%		
Non-EU	4	10.8%		
Mental Disorder: Yes	6	16.2%		
No	31	83.8%		

Note. M = Mean, *SD* = Standard Deviation, *n* = Frequencies

Materials

Informed Consent

On the first day of the study, the participants received the informed consent and the demographic survey. The informed consent informed the participants about their rights, the purpose, duration, and the risks of the study (see Appendix A). The demographics survey assessed the gender, age, and nationality of the participant.

Sedentary Time Measurement

To measure self-reported daily sedentary time, a revised version of the Past-day Adult's Sedentary Time-University (PAST-U) questionnaire was used (see Appendix B). The original PAST-U questionnaire consists of nine items, which ask subjects how many minutes they spent sitting in different contexts and behaviours the past day (Clark et al., 2014). These contexts include work, study, travelling, eating, watching television, using the computer, socialising and other. According to Clark et al. (2014), the PAST-U questionnaire has shown acceptable validity when compared to a device-based measure of sedentary time ($r = .58$, 95%CI = 0.32–0.76). It also showed acceptable reliability (ICC = 0.50, 95% Cl = 0.39-0.7).

To assess daily mentally active and mentally passive sedentary behaviours, the PAST-U questionnaire was complemented with the framework from Hallgren et al. (2019). This framework helps divide different sedentary behaviours into mentally active vs mentally passive behaviours (Hallgren et al., 2019). However, as the framework by Hallgren et al. (2019) is more detailed and differentiated than the PAST-U questionnaire, some adjustments were made to the PAST-U questionnaire (see Appendix B). All items that could not be categorized into either mentally passive or mentally active sedentary were rewritten (see Table 3). For example, television viewing item was divided into one mentally active item and one mentally passive item. The mentally passive television viewing asked for time spent sitting or lying down watching TV or DVDs. The mentally active item measured time spent sitting or lying down while playing video games on the TV. Also, an additional item was

added to the adjusted PAST-U questionnaire asking for time spent sitting or lying down while engaging in a creative hobby (e.g., drawing or playing the guitar) as this was a neglected aspect in the original PAST-U).

Table 3

Revised PAST-U Divided into Mentally Active and Mentally Passive Sedentary Time Items

Mentally Active Items	Mentally Passive Items
Sitting for Study[a]	Mentally Passive Travel[b]
Sitting for Work[a]	Mentally Passive TV Use (e.g., Watching TV)[b]
Mentally Active Travel[b]	Mentally Passive PC (e.g., Netflix)[b]
Mentally Active TV Use (e.g., Gaming)[b]	Sitting for Eating[a]
Mentally Active PC Use (e.g., Gaming)[b]	
Sitting for Reading[a]	
Sitting for Socialising[b]	
Sitting Creative Hobbies[b]	

Note. This table includes both the original and the added/revised items of the revised PAST-U questionnaire used in this study.
[a] These items are the original items from the PAST- U questionnaire and have not been revised.
[b] These items were revised for the purpose of the current study.

To measure the variable daily total sitting time, the times reported for the various domains were summed up (Clark et al., 2014). To assess daily socially active sedentary behaviour, the sitting for socialisation item from the PAST-U questionnaire was used. The item asks participants to estimate the time they spent sitting down to socialise with other people. This included time on the phone, for instance, texting, calling, and chatting.

State Anxiety Measurement

The state anxiety measurement was derived from a previous experience sampling study on state anxiety (Cox et al., 2018). Cox et al. (2018) measured state anxiety with a single item ("How anxious do you feel right now?") on a visual analogue scale (VAS) from 0 ("not anxious at all") to 100 "(most anxious you could ever imagine feeling"). However, a scale from 0 – 10 was used to make the use of the VAS more convenient for the participants.

Compared to prevailing measurements of state anxiety, such as the State-Trait Inventory (STAI), VASs are more convenient (Davey, 2007; Williams, 2010). Specifically, the STAI is 40 items long and time-consuming and hence, places a lot of burden on participants (Davey, 2007; Labaste et al., 2019; Lemche et al, 2016). In contrast, VASs are a minimal burden to respondents and research as one-item scales are quickly administered and require no training (Berghmans et al., 2017; Williams et al., 2010). For this reason, VASs are ideal instruments for studies like the present one where multiple measurements are recorded (Williams et al., 2010).

Furthermore, the VAS for anxiety has been shown to have good psychometric properties (Davey et al., 2007; Berghmans et al., 2017; Facco et al., 2013; Labaste et al., 2019; Williams et al., 2010). The VAS for anxiety has adequate test-rest reliability (Williams et al., 2010). It has been shown to have good construct validity, as its scores correlate strongly with scales such as the STAI (Davey et al., 2007; Berghmans et al., 2017; Facco et al., 2013; Labaste et al., 2019; Williams et al., 2010). In sum, these research findings together suggest that the VAS provide is a valid and reliable measurement of state anxiety.

Applications and Software

The surveys were created and filled in by the participants using Ethica Data. Ethica is an online-based research platform. It is ideal for experience sampling as it allows researchers to send multiple surveys at random or fixed intervals to the smartphones of the participants via in-app notifications. It is also convenient for participants as they can use their own

smartphone devices. Furthermore, Ethica automatically anonymizes all the collected data ensuring the privacy of the participants.

Procedure

The participants took part in the study over a period of nine days. On day one of the study, participants registered for the study using the provided registration code. Five seconds after they registered the participants received the informed consent form. By ticking 'Yes' they declared that they have read the informed consent and actively consent to participate in this study and to the processing of their data. If they clicked no, the survey ended, and they were told they are free to delete the Ethica app off their phone. Afterwards, the participants filled in the baseline and demographics questionnaire.

From day two until day eight, participants filled in three questionnaires daily. In the morning they filled in the revised PAST-U questionnaire and the state anxiety item. The participants received the first trigger at 7 am and reminders at 9 am and at 11 am. The questionnaire expired after five hours at 12 pm. The participants needed about five to ten minutes to complete the morning survey. Notably, on day two of the study the morning questionnaire the participants only had to report their level state anxiety and not their sedentary time.

In the afternoon and evening, the participants filled in the state anxiety measure, which took about two minutes each time. The participants received the first trigger of the afternoon survey randomly between 1 pm and 3 pm. If the participants missed the first trigger, they received a reminder two hours after their first trigger. Participants received the first trigger of the evening survey randomly between 7 pm and 9 pm. A reminder was sent out two hours later if they did not respond to the first trigger. Both the afternoon and evening survey expired for the participants three hours after their first individual trigger. On the final day of the study, the participants only had to fill in the revised PAST-U questionnaire. Finally, the participants received a thank you notification for their participation.

Data Analysis

      For the data analysis the data was imported in SPSS (Version 27). The separate files were merged into one dataset. The first step was the remove the excluded participants. Next, the daily total, mentally active, and mentally passive sedentary time variables were computed. All sedentary time variables were divided by 60 to calculate hours instead of minutes. Finally, a measurement point and day variable were computed. The day variable was lagged one day behind for sedentary time as the sedentary time of any given day is associated with the state anxiety of the previous day. Afterwards, the descriptive statistics were calculated. For this, the means and standard deviations of all variables were calculated. In addition, a frequency table of the demographic information of the participants was created.

      To assess the reliability of the adjusted PAST-U questionnaire and the state anxiety item, a split-half reliability analysis was conducted (Larson & Csikzentmihalyi, 2014). That is, the first halves of the sedentary time and state anxiety observations were computed into new variables by calculating their means. The same was done for the second halves. The Spearman Rho of the correlation between the first halves and the second halves was computed. The guidelines for interpreting Spearman's Rho's by Prison and Haerling et al. (2014) were used. According to these guidelines, a rho from 0 to .2 is negible and a rho from .21 to .40 is considered weak. A rho from 41 to .60 is moderate, .61 to .80 is seen as strong, and .81 to 1 is a very strong coefficient (Prion & Haerling, 2014).

      For the statistical analyses, linear models with a first-order autoregressive covariance structure were used. This allowed for an averaged within-person testing of the associations. Linear mixed models are appropriate for multi-level and repeated measures data as they account for the fact that the observations are nested within participants and timepoints. This applied to the current as every participant has been assessed multiple times. First-order autoregression was used as it takes into account that observations close together in time (e.g., observations on day two and observations on day three) have a stronger correlation than

observations further away in time (e.g., observations on day two and observations on day eight). In the linear mixed models, the participants were set as the subject and the measurement point was set as the repeated measure in the linear mixed model. Estimated marginal means (EMMs) across participants and measurement points were computed and plotted for all variables and associations. To investigate the research questions, state anxiety was set as the outcome variable and daily total, mentally active, mentally passive, and social sedentary time were the fixed for covariates. For all linear mixed models an alpha of .05 was considered significant. Standardised beta coefficients were calculated for all significant associations to determine the effect size.

Results

Reliability Assessment

Before the descriptive analyses were conducted, the state anxiety and the sedentary time items were checked for reliability (see Table 3). Nine of the 14 items had strong to very strong reliability. Three items had moderate reliability, namely mentally passive TV use, mentally active PC use, and sitting for eating. The mentally passive travel idem only showed weak reliability (see Table 3).

Table 3

Spearman's Rho Correlations Between the First and Second Half per Item

Item	*n*	r_s	*p*	Interpretation
State Anxiety	19	.870	< .001	Very Strong
Sitting for Study	26	.622	< .001	Strong
Sitting for Work	26	.603	< .001	Strong
Mentally Active Travel	26	.687	< .001	Strong
Mentally Passive Travel	26	.240	.237	Weak
Mentally Active TV Use	26	.706	< .001	Strong
Mentally Passive TV Use	26	.510	.008	Moderate
Mentally Active PC Use	26	.478	.014	Moderate
Mentally Passive PC Use	26	.690	< .001	Strong
Sitting for Reading	26	.746	< .001	Strong
Sitting for Eating	26	.426	.030	Moderate
Sitting for Socialising	26	.787	< .001	Strong
Sitting for Creativity	26	.901	< .001	Very Strong
Other	26	.729	< .001	Strong

Note. n = Frequency, r_s = Rho's Correlation Coefficient

Descriptive Analyses

On a scale from 0 to 10, the sample had a mean state anxiety score of 2.40 (*SD* =

2.77), indicating that the mean state anxiety was on the lower end of the scale. That is, the

sample displayed on average low anxiety. Moreover, the plotted EMMs showed that

participant 20 had the highest state anxiety on average with an estimated mean score of 6.11

(see Figure 1). Furthermore, eight participants had an average state anxiety score of below 1.

State anxiety varied significantly across participants, $F(36, 144.43) = 16.24$, $p < .001$. As can

be seen in Appendix C, the mean level of state anxiety did not show strong fluctuations over the 21 timepoints. In fact, state anxiety did not show significant variance across timepoints, $F(20, 454.94) = 16.24, p = .073$.

Figure 1

Estimated Marginals of State Anxiety and Total Sedentary Time Across Participants
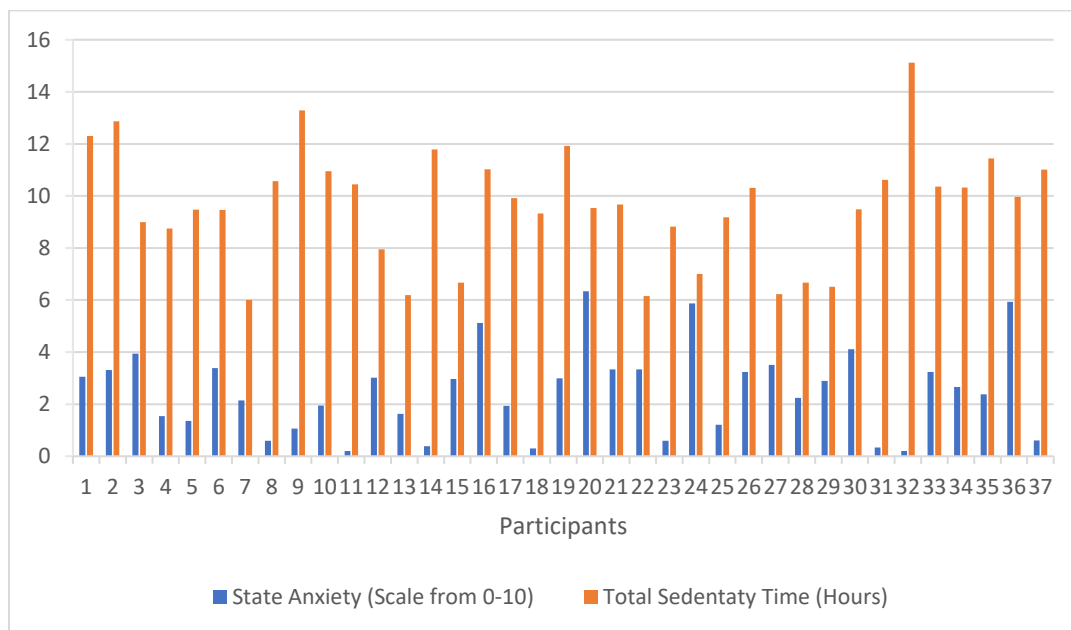
The mean score of sedentary time was 9.27 hours ($SD = 3.26$). As can be seen in Figure 2, the most sedentary time was spent studying with a mean of 2.27 hours. That is, the participants spent almost a quarter of the sedentary time studying (24%).

Figure 2

Distribution of the Behaviours Performed While Being Sedentary in Percentages
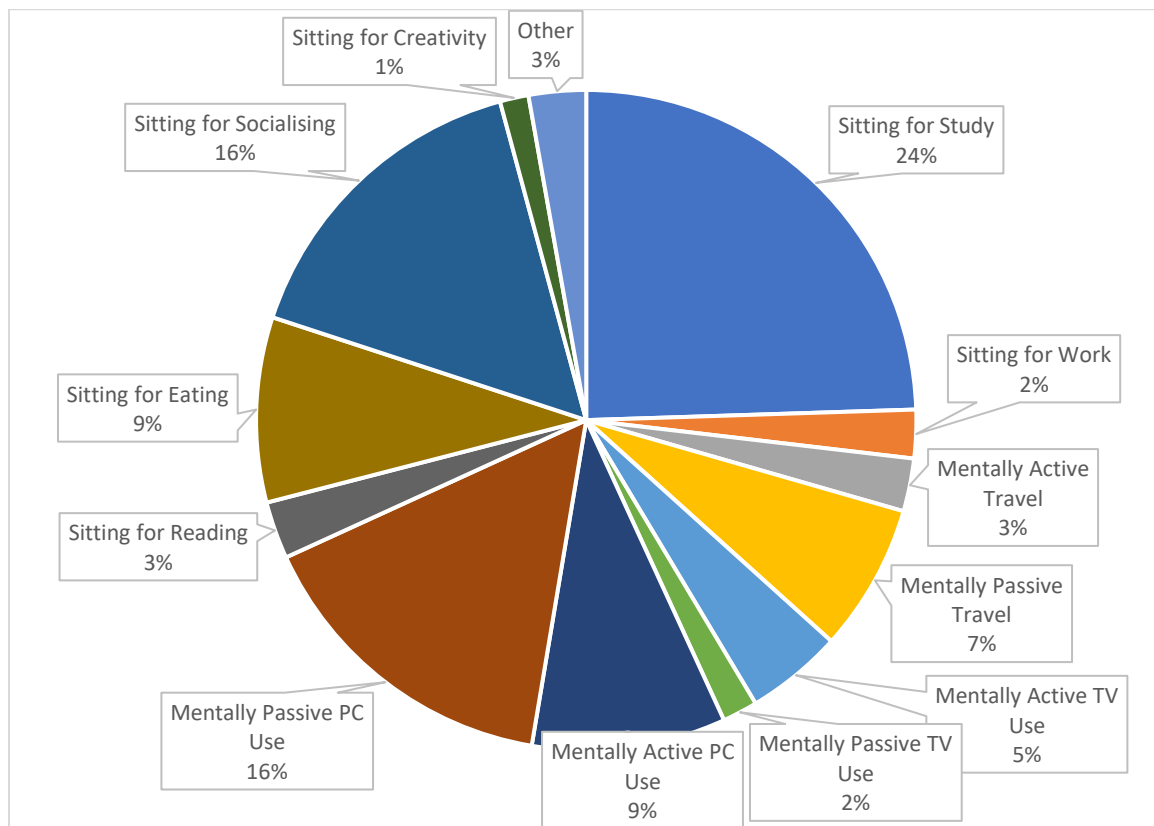
Moreover, the participants spent about 5.62 ($SD = 3.02$) hours daily engaging in mentally active sedentary behaviours. In contrast, participants spent approximately 3.4 hours engaging in mentally passive sedentary behaviours ($SD = 1.85$). That is, the participants spent on average more time in mentally active behaviours than mentally passive behaviours (see Figure 3).

Figure 3

Estimated Marginals of Mentally Active and Mentally Passive Sedentary Time Across
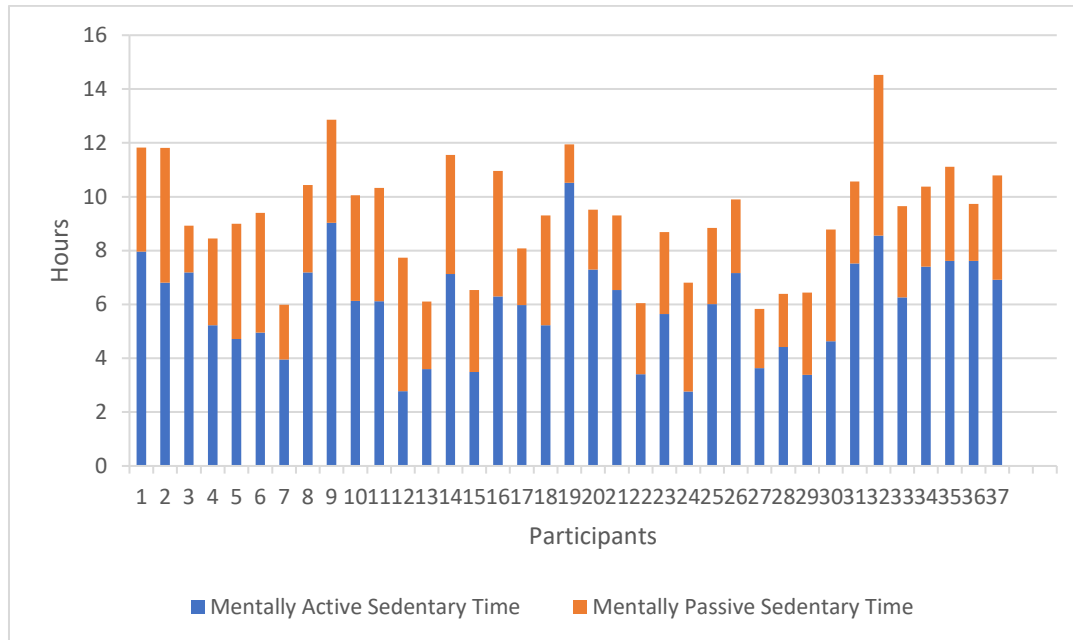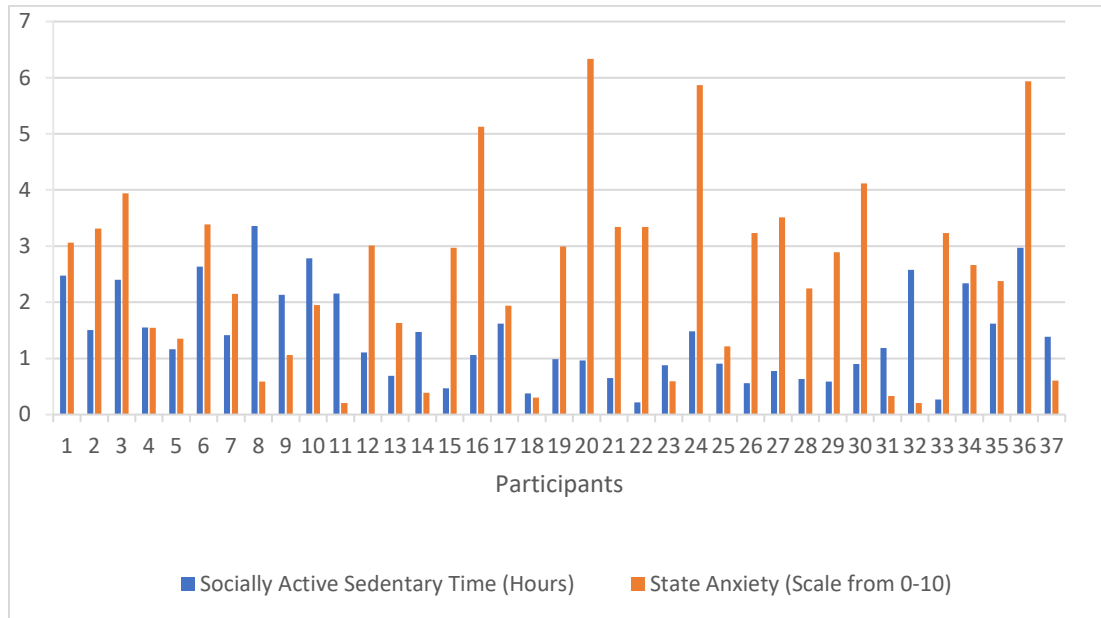
Participants

To illustrate, participant 19 spent a total of 11.92 hours in sedentary behaviours on average. The EMMs show that of these 11.92 hours, the participant spent an average of 10.52 hours engaging in mentally active sedentary behaviours and only 1.43 hours doing mentally passive behaviours (see Figure 3). Only two participants spent more on average mentally passive than mentally passive in their sedentary time. For example, participant 12 spent only 2.78 hours in mentally active behaviours but 4.96 hours in mentally passive behaviours on average (see Figure 3). Furthermore, the estimated marginal means of mentally active and mentally passive sedentary time over time showed that the estimated average of mentally active sedentary time was always higher than mentally passive sedentary time (see Appendix D). Mentally active sedentary time varied significantly over time, $F(20, 504.456) = 3.53$, $p = .009$, but not across participants, $F(36, 22.849) = 0.99$, $p = .525$. Mentally passive sedentary varied neither significantly over time, $F(20, 496.446) = 0.878$, $p = .616$, nor across participants, $F(36, 30.886) = 1.01$, $p = .488$.

Furthermore, the plotted EMMs of state anxiety and total sedentary time across participants give the initial impression that state anxiety and total sedentary time are not correlated (see Figure 1). This is best illustrated by participant 32 who engages on average in 15 hours of sedentary time daily but has a mean state anxiety score of only 0.21 (see Figure 1). On the other hand, participant 4 was an exception as he spent on average 7 hours a day being sedentary and had an estimated mean state anxiety level of 5.87 (see Figure 1). The EMMs of state anxiety and total sedentary time across confirm the initial impression that state anxiety and total sedentary time are not related as they move in a different fashion (see Appendix C).

The participants spent on average 1.46 ($SD = 1.46$) hours a day being sedentary to socialize with other people. The EMMs of socially active sedentary time and sedentary across participants showed that participant 8 had the highest estimated mean by spending 3.36 hours on average socializing while sedentary (see Figure 4). On the lower end, there is participant 22, who only spent an estimated 0.22 hours socializing while being sedentary. However, socially active sedentary did not show significant variations across participant, $F(36, 36.040) = 1.26$, $p = .265$.

Figure 4

Estimated Marginal Means of Socially Active Sedentary Time and State Anxiety Across

Participants

Furthermore, Figure 4 gives the impression that these socially active sedentary time

and state anxiety may be weakly negatively associated. That is, many participants who had a

low estimated average socially sedentary time had a higher mean state anxiety. Participant 20,

for instance, had a high estimated average state anxiety of 6.33 but only a low average

socially active sedentary time of 0.96 (see Figure 8). However, the results are not clear.

Participant 1, for instance, both had almost equally high state anxiety and socially active

sedentary time. The estimated marginal means across timepoints supported the impression

that social anxiety and socially active sedentary are negatively associated and they fluctuate in

an opposite fashion (see Appendix E). However, socially active sedentary did not show

significant variations across timepoints, $F(20, 507\text{-}672) = 1.21$, $p = .238$.

Associations Between Sedentary Time and State Anxiety

To investigate the research questions, an averaged within-person analysis was run

using linear mixed models. See Table 4, for an overview of the statistical test results.

Table 4

Overview of the Hypothesis Testing Results

Parameter	Estimate	Std. Error	Degrees of Freedom	*F*	Sig.	95% CL	
						LL	UL
			RQ 1				
Sedentary Time	-0.02	0.03	1, 541.844	0.40	.529	-0.08	0.43
			RQ 2				
Mentally Active St	0.02	0.03	1, 604.303	0.32	.574	-0.46	0.08
			RQ 3				
Mentally Passive St	-0.11	0.05	1, 632,303	4.63	.032	-0.21	-0.01
			RQ 4				
Socially Active St	-0.07	0.07	1, 616.166	1.05	.305	-0.21	0.064

Note. CL = Confidence Interval, LL = Lower Limit, UL = Upper Limit, RQ = Research Question, St= Sedentary Time, Dependent Variable = State Anxiety

Total Sedentary Time and State Anxiety

No significant relationship between total sedentary time and state anxiety was found, $B = -0.02$, $F(1, 541.844) = 0.40$, $p = .53$. That is, the linear mixed models confirmed the initial impression of the EMMs that hours spent in sedentary time did not predict the amount of state anxiety the participants experienced.

Mentally Active Sedentary Time and State Anxiety

No significant association between mentally active sedentary time and state anxiety was found, $B = 0.02$, $F(1, 604.303) = 0.32$, $p = .57$. In other words, participants who spent many hours engaging in mentally active sedentary behaviours did not experience more or less

state anxiety than participants who only spent a few hours with mentally active sedentary behaviours.

Mentally Passive Sedentary Time and State Anxiety

A significant negative relationship between mentally passive sedentary time and state anxiety was found, $B = -0.11$, $F(1, 632.303) = 4.63$, $p = .03$. Contrary to expectations, participants who spent more hours engaging in mentally passive sedentary behaviour experienced less state anxiety than those who only spent little time with mentally passive sedentary behaviours. The effect size for this association was small, $\beta = -0.10$, $SE = 0.44$. More precisely, a change of 1 standard deviation in daily mentally passive sedentary time was associated with a change of only -0.10 standard deviations in state anxiety.

Socially Active Sedentary Time and State Anxiety

No significant association between socially active sedentary time and state anxiety was observed, $B = -0.07$, $F(1, 616.166) = 1.05$, $p = .31$. That is, participants who spent a lot of time in socially active sedentary time did not report less or more state anxiety than participants who spent no or only a little time with socially active sedentary behaviours.

Discussion

This study aimed to investigate the relationship between daily sedentary time and state anxiety within a population of university students. For this purpose, this study posed four research questions. For the first, second, and fourth research questions, no relationships were observed. For the third research question, a positive relationship between mentally passive sedentary time and state anxiety was expected. Contrary to expectations, a significant negative relationship was found. That is, spending many hours with mentally passive sedentary behaviours was associated with a decrease in state anxiety. In sum, most relationships between sedentary behaviour and state anxiety were not significant with the exception of mentally passive sedentary behaviour.

Findings

Daily Sedentary Time and State Anxiety

No association between daily total sedentary time and state anxiety was found. This finding is consistent with the sparse existing research on a link between total sedentary time and state anxiety, which also found no link between the two (Felez-Nobrega et al., 2020; Padmapriya et al., 2016). The current study initially argued that a possible reason for this lack of evidence is that previous studies have employed cross-sectional survey designs (Felez-Nobrega et al., 2020; Padmapriya et al., 2016). However, despite the use of ESM to overcome the limitations of the traditional methods, this study found no link between state anxiety and total sedentary time. Therefore, the current study adds to the existing literature that sedentary time and state anxiety are also not associated in university students even when taking within-person fluctuations into account. Felez-Nobrega et al., (2020) argue that a possible explanation for this sedentary behaviour only affects enduring conditions and not momentary ones. This would explain why sedentary behaviour has been linked to trait-like anxiety conditions (Allen et al., 2019; Teychenne et al., 2015) but not to state anxiety (Felez-Nobrega et al., 2020; Padmapriya et al., 2016). In sum, this study supported the findings indicating no relationship between sedentary time and state anxiety.

Like total sedentary time, no association has been found between daily mentally active sedentary time and state anxiety. Daily mentally passive sedentary time, on the other hand, was found to have a significant relationship with sedentary time. Contrary to predictions, however, this relationship was negative. The more time the participants spent being mentally passive while sedentary, the lower was their level of state anxiety. Since no previous studies have yet tested the association between mentally active and mentally passive sedentary time, it is difficult to explain this finding. Nevertheless, one possible explanation for the negative relationship between mentally passive sedentary time could be the activities that were considered mentally passive. The participants spent on average 3.4 hours daily being mentally

passive. A little more than half an hour of this mentally passive sedentary was spent watching television and almost one and a quarter hour was spent with passive computer use. That is, more than half of their mentally passive sedentary time was spent with screen time. Mentally active sedentary time, in contrast, consisted mostly of studying and socialising.

According to two meta-analyses, there is enough evidence to conclude that sedentary time and anxiety are related. However, there is only insufficient evidence for an association between screen-time and anxiety as the associations were inconsistent between the studies analysed (Allen, 2018; Teychenne, 2015). For instance, de Wit et al. (2011) found that computer use was not associated with anxiety. Griffiths et al. (2010) even found that increased screen time reduced the risk of anxiety. To conclude, the fact that mentally passive sedentary time consisted mostly of screen time might explain why mentally passive sedentary time had a weak negative effect on state anxiety. However, these findings are far from consistent and conflicting results have also been reported analysed (Allen, 2018; Cao et al., 2011; Rebar et al., 2014; Teychenne, 2015). Thus, further research is warranted to investigate the relationship between mentally passive sedentary time, including screen time, and (state) anxiety.

Similar to total and mentally active sedentary time, no association between daily socially active sedentary time and state anxiety has been found. This finding has one main consequence. It questions the validity of the often-mentioned social withdrawal theory, which posits that sedentary behaviours might have negative effects on mental health outcomes because they often occur in social isolation (Allen et al., 2019; Lee & Kim, 2018; de Wit et al., 2011). Because if the social withdrawal theory were to hold, socially active sedentary time would have had a negative effect on state anxiety. However, it might also be the case that similar to total sedentary time, socially active sedentary time might simply not be related to state anxiety.

Sedentary Time

On average the participants spent a little over nine hours a day being sedentary. This finding is comparable to results from other studies measuring the sedentary time of students (Castro et al., 2020; Clark et al., 2014; Moulin et al., 2019). Most of this sedentary time was spent being mentally active compared to being mentally passive. No previous studies have yet tested the distribution of mentally active vs mentally passive sedentary among students. However, the finding that more time is spent in mentally active than in mentally passive sedentary is in accord with studies measuring sedentary time of adults from the general population (Hallgren et al., 2019; Werneck et al., 2021). Thus, the university students in this sample do not differ from the general population in terms of how much time is spent in mentally active and mentally passive sedentary time, respectively.

The participants spent on average about one and half hours daily engaging in socially active sedentary behaviours. This number is higher than in previous research. For instance, Clark et al. (2014) found that the students in their study spent less than half an hour daily socializing while sedentary. A possible reason for the higher levels of socially active sedentary time is that the socialization item from Clark et al. (2014) was revised. While Clark et al. (2014)'s item was phrased to only include in-person and interaction and time spent on the telephone, the item in the current study also included time spent chatting and texting (see Appendix B). More activities defined as socially active sedentary time might have led to higher and more precise estimates of how much time is spent socializing while sedentary.

State Anxiety

The participants reported on average low levels of state anxiety. This finding is only partially consistent with existing literature as the research on this topic is mixed. While some studies report high levels of state anxiety among students (Fanzoi et al., 2020; Otim et al., 2021), other studies found lower or even only mild levels of state anxiety among students (Cox et al., 2018; Ganley et al., 2021). Given that state anxiety is a momentary experience

that is highly dependent on the circumstances, one possible explanation for these findings is that the circumstances of the students varied between the studies.

For instance, it was found that exam periods or test anxiety predict higher levels of state anxiety (Bertrams et al., 2010; Ganley et al., 2021; Ozen et al., 2009). Most of the students of this sample were recruited from the University of Twente. The fact that their data was collected two weeks after the last exam period at the University of Twente could explain why state anxiety was low among the students at the given time. Another possible explanation is selection bias. This study warned participants about participating if they suffered from a mood or anxiety disorder. This might have deterred highly anxious people and thus, lowering the mean state anxiety. In sum, the average state anxiety was low in this sample of university students which may be due to the lack of exam stress at the period of data collection or selection bias.

Limitations and Strengths

The current had multiple strengths that set itself apart from previous studies. For one, the present study employed ESM to investigate the relationship between sedentary time and state anxiety to overcome the limitations posed by traditional cross-sectional research (Conner & Lehman, 2012; Myin-Germeys et al., 2018; Pejovic, 2016). Another strength of the current study was that the PAST-U questionnaire by Clark et al. (2014) was revised based on the framework from Hallgren et al. (2019). This allowed the measurement of mentally active and mentally passive sedentary time, for which no questionnaire existed before. Apart from the mentally passive travel item, all items showed moderate to very strong reliability. It should be noted, however, that many participants had unrealistic sedentary time, questioning the sedentary times measured by the PAST-U. Hence, the revised PAST-U questionnaire needs another pilot study aimed at improving its implementation. A final strength of this study was the high response rate. According to Van Berkel et al. (2017) ESM studies usually have around 19 participants and aim for a response rate of 70% or higher. This study had a final

total of 37 participants with an average response rate of 94%. The advantage of a high sample size and response rate is an accurate and complete picture of the constructs studied (Van Berkel et al., 2017).

However, the study also had some limitations, which cast some doubt on the findings of this study. The main limitation was that there seems to have been a misunderstanding of the PAST-U questionnaire among the participants. Many participants had sedentary times which were deemed as unrealistic with six participants having sedentary times of 24 hours more. This should not have been possible as the PAST-U questionnaire explicitly asked to only report main sedentary activities and not over-lapping side activities so sedentary could not be over 24 hours. This is an issue that was also partially addressed by Clark et al. (2014), who stated that the incidences of some certain sedentary behaviours may be underreported if they were not the main activity. However, according to Clark et al. (2014), this should not have affected total sedentary, which was the case in this study. A possible reason for this is that the participants simply overlooked or did not remember the explanatory text as it was quite lengthy. A possible solution to this redesigning the PAST-U questionnaire in a way that reminds the participants of only reporting their main activity. For example, the explanatory could be shortened, or a small reminder could be added after every item. Another limitation is that the data collection took place during a single and uneventful period (i.e., no exam period), which may have affected the level of state anxiety. In the future it is advisable to collect data for a longer period and also collect information on the context of the participants (e.g., exam period etc.)

Future Research

This study has provided new insights into sedentary time and its relationship with state anxiety. Nevertheless, more research is needed to further investigate the findings and overcome the limitations of the study. One research recommendation is further investigating the unpredicted finding that mentally passive sedentary time and state anxiety are negatively

associated. It would be interesting to test what variables mediated or moderated this relationship. As mentioned above, a possible mediator might have been screen time. However, since the research is conflicted in that regard (Allen, 2018; Cao et al., 2011; Rebar et al., 2014; Teychenne, 2015), future research should investigate the relationship between mentally passive sedentary time and (state) anxiety and test what role screen time plays in that relationship.

Another important area of interest in future research should be the relationship between socially active sedentary time and trait anxiety or anxiety disorder. While the current research found no association between socially active sedentary time and state anxiety, this could be because sedentary behaviour only affects more enduring anxiety constructs (e.g., trait anxiety or anxiety disorder) and not momentary ones. Furthermore, given that the social withdrawal theory of why sedentary time has a detrimental effect on mental health outcomes is still widely distributed in literature (Allen et al., 2019; Lee & Kim, 2018; de Wit et al., 2011), this theory needs more scientific evidence. That is, it should be investigated if the social withdrawal theory holds and is able to explain the relationship between sedentary behaviour and mental health.

Conclusion

To conclude most relationships between sedentary behaviour and state anxiety were not observed in this sample of university students. Only mentally passive sedentary time was shown to have a significant negative relationship with state anxiety. The results on total sedentary time and state anxiety are consistent with the existing literature. Thus, this study adds additional support to the notion that state anxiety and sedentary time are not related even when examining the within-person fluctuations of state anxiety. The unpredicted negative relationship between mentally passive sedentary time and state anxiety may be due to screen time but further research is needed to investigate this. The lack of a significant relationship between socially active sedentary time and state anxiety casts doubts on the social withdrawal

theory. Hence, further research is needed to investigate if this theory holds. In sum, only mentally passive sedentary time was significantly associated with state anxiety in this sample of university students.

References

Allen, M. S., Walter, E. E., & Swann, C. (2019). Sedentary behaviour and risk of anxiety: A systematic review and meta-analysis. *Journal of Affective Disorders*, *242*, 5–13. https://doi.org/10.1016/j.jad.2018.08.081

Baxter, A. J., Vos, T., Scott, K. M., Ferrari, A. J., & Whiteford, H. A. (2014). The global burden of anxiety disorders in 2010. *Psychological Medicine*, *44*(11), 2363–2374. https://doi.org/10.1017/s0033291713003243

Berghmans, J. M., Poley, M. J., van der Ende, J., Weber, F., van de Velde, M., Adriaenssens, P., Himpe, D., Verhulst, F. C., & Utens, E. (2017). A Visual Analog Scale to assess anxiety in children during anesthesia induction (VAS-I): Results supporting its validity in a sample of day care surgery patients. *Pediatric Anesthesia*, *27*(9), 955–961. https://doi.org/10.1111/pan.13206

Bertrams, A., Englert, C., & Dickhäuser, O. (2010). Self-control strength in the relation between trait test anxiety and state anxiety. *Journal of Research in Personality*, *44*(6), 738–741. https://doi.org/10.1016/j.jrp.2010.09.005

Bertrand, L., Shaw, K. A., Ko, J., Deprez, D., Chilibeck, P. D., & Zello, G. A. (2021). The impact of the coronavirus disease 2019 (COVID-19) pandemic on university students' dietary intake, physical activity, and sedentary behaviour. *Applied Physiology, Nutrition, and Metabolism*, *46*(3), 265–272. https://doi.org/10.1139/apnm-2020-0990

Biddle, Bennie, de Cocker, Dunstan, Gardiner, Healy, Lynch, Owen, Brakenridge, Brown, Buman, Clark, Dohrn, Duncan, Gilson, Kolbe-Alexander, Pavey, Reid, Vandelanotte, . . . Vincent. (2019). Controversies in the Science of Sedentary Behaviour and Health: Insights, Perspectives and Future directions from the 2018 Queensland Sedentary

Behaviour Think Tank. *International Journal of Environmental Research and Public Health*, *16*(23), 4762. https://doi.org/10.3390/ijerph16234762

Biswas, A., Oh, P. I., Faulkner, G. E., Bajaj, R. R., Silver, M. A., Mitchell, M. S., & Alter, D. A. (2015). Sedentary Time and Its Association With Risk for Disease Incidence, Mortality, and Hospitalization in Adults. *Annals of Internal Medicine*, *162*(2), 123–132. https://doi.org/10.7326/m14-1651

Blough, J., & Loprinzi, P. D. (2018). Experimentally investigating the joint effects of physical activity and sedentary behavior on depression and anxiety: A randomized controlled trial. *Journal of Affective Disorders*, *239*, 258–268. https://doi.org/10.1016/j.jad.2018.07.019

Borio, C. (2020). The Covid-19 economic crisis: dangerously unique. *Business Economics*, *55*(4), 181–190. https://doi.org/10.1057/s11369-020-00184-2

Bornstein, M. H., Jager, J., & Putnick, D. L. (2013). Sampling in developmental science: Situations, shortcomings, solutions, and standards. *Developmental Review*, *33*(4), 357–370. https://doi.org/10.1016/j.dr.2013.08.003

Cao, H., Qian, Q., Weng, T., Yuan, C., Sun, Y., Wang, H., & Tao, F. (2011). Screen time, physical activity and mental health among urban adolescents in China. *Preventive Medicine*, *53*(4–5), 316–320. https://doi.org/10.1016/j.ypmed.2011.09.002

Castro, O., Bennie, J., Vergeer, I., Bosselut, G., & Biddle, S. J. H. (2020). How Sedentary Are University Students? A Systematic Review and Meta-Analysis. *Prevention Science*, *21*(3), 332–343. https://doi.org/10.1007/s11121-020-01093-8

Chang, J. J., Ji, Y., Li, Y. H., Pan, H. F., & Su, P. Y. (2021). Prevalence of anxiety symptom and depressive symptom among college students during COVID-19 pandemic: A

meta-analysis. *Journal of Affective Disorders*, *292*, 242–254.

https://doi.org/10.1016/j.jad.2021.05.109

Clark, B., Pavey, T., Lim, J., Gomersall, S., & Brown, W. (2014). Past-day recall of sedentary

time: Validity of a self-reported measure of sedentary time in a university population.

Journal of Science and Medicine in Sport, *18*, e35.

https://doi.org/10.1016/j.jsams.2014.11.223

Cox, R. C., Sterba, S. K., Cole, D. A., Upender, R. P., & Olatunji, B. O. (2018). Time of day

effects on the relationship between daily sleep and anxiety: An ecological momentary

assessment approach. *Behaviour Research and Therapy*, *111*, 44–51.

https://doi.org/10.1016/j.brat.2018.09.008

Craske, M. G., & Stein, M. B. (2016). Anxiety. *The Lancet*, *388*(10063), 3048–3059.

https://doi.org/10.1016/s0140-6736(16)30381-6

Davey, H. M., Barratt, A. L., Butow, P. N., & Deeks, J. J. (2007). A one-item question with a

Likert or Visual Analog Scale adequately measured current anxiety. *Journal of*

Clinical Epidemiology, *60*(4), 356–360. https://doi.org/10.1016/j.jclinepi.2006.07.015

de Wit, L., van Straten, A., Lamers, F., Cuijpers, P., & Penninx, B. (2011). Are sedentary

television watching and computer use behaviors associated with anxiety and

depressive disorders? *Psychiatry Research*, *186*(2–3), 239–243.

https://doi.org/10.1016/j.psychres.2010.07.003

Dempsey, P. C., Biddle, S. J. H., Buman, M. P., Chastin, S., Ekelund, U., Friedenreich, C. M.,

Katzmarzyk, P. T., Leitzmann, M. F., Stamatakis, E., van der Ploeg, H. P., Willumsen,

J., & Bull, F. (2020). New global guidelines on sedentary behaviour and health for

adults: broadening the behavioural targets. *International Journal of Behavioral*

Nutrition and Physical Activity, *17*(1). https://doi.org/10.1186/s12966-020-01044-0

Dworak, M., Schierl, T., Bruns, T., & Strüder, H. K. (2007). Impact of Singular Excessive Computer Game and Television Exposure on Sleep Patterns and Memory Performance of School-aged Children. *Pediatrics*, *120*(5), 978–985. https://doi.org/10.1542/peds.2007-0476

Edwards, M. K., & Loprinzi, P. D. (2016). Experimentally increasing sedentary behavior results in increased anxiety in an active young adult population. *Journal of Affective Disorders*, *204*, 166–173. https://doi.org/10.1016/j.jad.2016.06.045

Ekelund, U., Tarp, J., Steene-Johannessen, J., Hansen, B. H., Jefferis, B., Fagerland, M. W., Whincup, P., Diaz, K. M., Hooker, S. P., Chernofsky, A., Larson, M. G., Spartano, N., Vasan, R. S., Dohrn, I. M., Hagströmer, M., Edwardson, C., Yates, T., Shiroma, E., Anderssen, S. A., & Lee, I. M. (2019). Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis. *BMJ*, l4570. https://doi.org/10.1136/bmj.l4570

Facco, E., Zanette, G., Bacci, C., Sivolella, S., Cavallin, F., & Manani, G. (2011). Validation of visual analogue scale for anxiety (VAS-A) in dentistry. *International Journal of Oral and Maxillofacial Surgery*, *40*(10), 1058. https://doi.org/10.1016/j.ijom.2011.07.111

Felez-Nobrega, M., Bort-Roig, J., Briones, L., Sanchez-Niubo, A., Koyanagi, A., Puigoriol, E., & Puig-Ribera, A. (2020). Self-reported and activPALTM-monitored physical activity and sedentary behaviour in college students: Not all sitting behaviours are linked to perceived stress and anxiety. *Journal of Sports Sciences*, *38*(13), 1566–1574. https://doi.org/10.1080/02640414.2020.1748359

Franzoi, I. G., Sauta, M. D., & Granieri, A. (2020). State and Trait Anxiety Among University Students: A Moderated Mediation Model of Negative Affectivity, Alexithymia, and Housing Conditions. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.01255

Gale, C., & Oakley-Browne, M. (2004). Generalised anxiety disorder. *Evidence-Based Mental Health*, *7*(2), 32–33. https://doi.org/10.1136/ebmh.7.2.32

Ganley, C. M., Conlon, R. A., McGraw, A. L., Barroso, C., & Geer, E. A. (2021). The effect of brief anxiety interventions on reported anxiety and math test performance. *Journal of Numerical Cognition*, *7*(1), 4–19. https://doi.org/10.5964/jnc.6065

Griffiths, L. J., Dowda, M., Dezateux, C., & Pate, R. (2010). Associations between sport and screen-entertainment with mental health problems in 5-year-old children. *International Journal of Behavioral Nutrition and Physical Activity*, *7*(1), 30. https://doi.org/10.1186/1479-5868-7-30

Hale, L., & Guan, S. (2015). Screen time and sleep among school-aged children and adolescents: A systematic literature review. *Sleep Medicine Reviews*, *21*, 50–58. https://doi.org/10.1016/j.smrv.2014.07.007

Hallgren, M., Dunstan, D. W., & Owen, N. (2019). Passive Versus Mentally Active Sedentary Behaviors and Depression. *Exercise and Sport Sciences Reviews*, *48*(1), 20–27. https://doi.org/10.1249/jes.0000000000000211

Hallgren, M., Nguyen, T. T. D., Owen, N., Stubbs, B., Vancampfort, D., Lundin, A., Dunstan, D., Bellocco, R., & Lagerros, Y. T. (2019). Cross-sectional and prospective relationships of passive and mentally active sedentary behaviours and physical activity with depression. *The British Journal of Psychiatry*, *217*(2), 413–419. https://doi.org/10.1192/bjp.2019.60

Hallgren, M., Nguyen, T. T. D., Owen, N., Vancampfort, D., Smith, L., Dunstan, D. W., Andersson, G., Wallin, P., & Ekblom-Bak, E. (2020). Associations of interruptions to leisure-time sedentary behaviour with symptoms of depression and anxiety. *Translational Psychiatry*, *10*(1). https://doi.org/10.1038/s41398-020-0810-1

Huang, Y., Li, L., Gan, Y., Wang, C., Jiang, H., Cao, S., & Lu, Z. (2020). Sedentary behaviors and risk of depression: a meta-analysis of prospective studies. *Translational Psychiatry*, *10*(1). https://doi.org/10.1038/s41398-020-0715-z

Kubey, R., Larson, R., & Csikszentmihalyi, M. (2014). Experience Sampling Method Applications to Communication Research Questions. *Journal of Communication*, *46*(2), 99–120. https://doi.org/10.1111/j.1460-2466.1996.tb01476.x

Labaste, F., Ferré, F., Combelles, H., Rey, V., Foissac, J., Senechal, A., Conil, J., & Minville, V. (2019). Validation of a visual analogue scale for the evaluation of the postoperative anxiety: A prospective observational study. *Nursing Open*, *6*(4), 1323–1330. https://doi.org/10.1002/nop2.330

Lee, E., & Kim, Y. (2018). Effect of university students' sedentary behavior on stress, anxiety, and depression. *Perspectives in Psychiatric Care*, *55*(2), 164–169. https://doi.org/10.1111/ppc.12296

Lemche, A. V., Chaban, O. S., & Lemche, E. (2016). Trait anxiety but not state anxiety level associates with biomarkers for hypertension in the metabolic syndrome. *Psychophysiology*, *53*(6), 914–920. https://doi.org/10.1111/psyp.12623

Letter to the Editor: Standardized use of the terms "sedentary" and "sedentary behaviours." (2013a). *Mental Health and Physical Activity*, *6*(1), 55–56. https://doi.org/10.1016/j.mhpa.2012.06.001

Letter to the Editor: Standardized use of the terms "sedentary" and "sedentary behaviours."

(2013b). *Mental Health and Physical Activity*, *6*(1), 55–56.

https://doi.org/10.1016/j.mhpa.2012.06.001

McLaughlin, K. A., & Nolen-Hoeksema, S. (2011). Rumination as a transdiagnostic factor in

depression and anxiety. *Behaviour Research and Therapy*, *49*(3), 186–193.

https://doi.org/10.1016/j.brat.2010.12.006

Montag, C., Duke, I., & Markowetz, A. (2016). Toward Psychoinformatics: Computer

Science Meets Psychology. *Computational and Mathematical Methods in Medicine*,

2016, 1–10. https://doi.org/10.1155/2016/2983685

Moulin, M. S., Truelove, S., Burke, S. M., & Irwin, J. D. (2019). Sedentary time among

undergraduate students: A systematic review. *Journal of American College Health*,

69(3), 237–244. https://doi.org/10.1080/07448481.2019.1661422

Myin-Germeys, I., Kasanova, Z., Vaessen, T., Vachon, H., Kirtley, O., Viechtbauer, W., &

Reininghaus, U. (2018). Experience sampling methodology in mental health research:

new insights and technical developments. *World Psychiatry*, *17*(2), 123–132.

https://doi.org/10.1002/wps.20513

Otim, M. E., al Marzouqi, A. M., Subu, M. A., Damaj, N., & Al-Harbawi, S. (2021).

Prevalence of Generalised Anxiety Disorders Among Clinical Training Students at the

University of Sharjah. *Journal of Multidisciplinary Healthcare*, *Volume 14*, 1863–

1872. https://doi.org/10.2147/jmdh.s317828

Owen, N., Sugiyama, T., Eakin, E. E., Gardiner, P. A., Tremblay, M. S., & Sallis, J. F.

(2011). Adults' Sedentary Behavior. *American Journal of Preventive Medicine*, *41*(2),

189–196. https://doi.org/10.1016/j.amepre.2011.05.013

Padmapriya, N., Bernard, J. Y., Liang, S., Loy, S. L., Shen, Z., Kwek, K., Godfrey, K. M., Gluckman, P. D., Chong, Y. S., Saw, S. M., Meaney, M. J., Chen, H., & Müller-Riemenschneider, F. (2016). Association of physical activity and sedentary behavior with depression and anxiety symptoms during pregnancy in a multiethnic cohort of Asian women. *Archives of Women's Mental Health*, *19*(6), 1119–1128. https://doi.org/10.1007/s00737-016-0664-y

Park, J. H., Moon, J. H., Kim, H. J., Kong, M. H., & Oh, Y. H. (2020). Sedentary Lifestyle: Overview of Updated Evidence of Potential Health Risks. *Korean Journal of Family Medicine*, *41*(6), 365–373. https://doi.org/10.4082/kjfm.20.0165

Pejovic, V., Lathia, N., Mascolo, C., & Musolesi, M. (2016). Mobile-Based Experience Sampling for Behaviour Research. *Human–Computer Interaction Series*, 141–161. https://doi.org/10.1007/978-3-319-31413-6_8

Prion, S., & Haerling, K. A. (2014). Making Sense of Methods and Measurement: Spearman-Rho Ranked-Order Correlation Coefficient. *Clinical Simulation in Nursing*, *10*(10), 535–536. https://doi.org/10.1016/j.ecns.2014.07.005

Rebar, A. L., Vandelanotte, C., van Uffelen, J., Short, C., & Duncan, M. J. (2014). Associations of overall sitting time and sitting time in different contexts with depression, anxiety, and stress symptoms. *Mental Health and Physical Activity*, *7*(2), 105–110. https://doi.org/10.1016/j.mhpa.2014.02.004

Roy-Byrne, P. P., Davidson, K. W., Kessler, R. C., Asmundson, G. J., Goodwin, R. D., Kubzansky, L., Lydiard, R. B., Massie, M. J., Katon, W., Laden, S. K., & Stein, M. B. (2008). Anxiety disorders and comorbid medical illness. *General Hospital Psychiatry*, *30*(3), 208–225. https://doi.org/10.1016/j.genhosppsych.2007.12.006

Saviola, F., Pappaianni, E., Monti, A., Grecucci, A., Jovicich, J., & de Pisapia, N. (2020). Trait and state anxiety are mapped differently in the human brain. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-68008-z

Setia, M. (2016). Methodology series module 3: Cross-sectional studies. *Indian Journal of Dermatology*, *61*(3), 261. https://doi.org/10.4103/0019-5154.182410

Stockwell, S., Trott, M., Tully, M., Shin, J., Barnett, Y., Butler, L., McDermott, D., Schuch, F., & Smith, L. (2021). Changes in physical activity and sedentary behaviours from before to during the COVID-19 pandemic lockdown: a systematic review. *BMJ Open Sport & Exercise Medicine*, *7*(1), e000960. https://doi.org/10.1136/bmjsem-2020-000960

Teychenne, M., Costigan, S. A., & Parker, K. (2015). The association between sedentary behaviour and risk of anxiety: a systematic review. *BMC Public Health*, *15*(1). https://doi.org/10.1186/s12889-015-1843-x

van Berkel, N., Ferreira, D., & Kostakos, V. (2018). The Experience Sampling Method on Mobile Devices. *ACM Computing Surveys*, *50*(6), 1–40. https://doi.org/10.1145/3123988

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: Table 1. *Evidence Based Mental Health*, *19*(3), 86–89. https://doi.org/10.1136/ebmental-2016-102418

Weeks, P., Hayley, A., & Stough, C. (2019). Do individual differences in state and trait anxiety predict sleep difficulties in healthy older adults? *Personality and Individual Differences*, *144*, 141–146. https://doi.org/10.1016/j.paid.2019.03.004

Weger, M., & Sandi, C. (2018). High anxiety trait: A vulnerable phenotype for stress-induced depression. *Neuroscience & Biobehavioral Reviews*, *87*, 27–37. https://doi.org/10.1016/j.neubiorev.2018.01.012

Werneck, A. O., Hoare, E., Stubbs, B., van Sluijs, E. M., & Corder, K. (2021). Associations between mentally-passive and mentally-active sedentary behaviours during adolescence and psychological distress during adulthood. *Preventive Medicine*, *145*, 106436. https://doi.org/10.1016/j.ypmed.2021.106436

Williams, V. S., Morlock, R. J., & Feltner, D. (2010). Psychometric evaluation of a visual analog scale for the assessment of anxiety. *Health and Quality of Life Outcomes*, *8*(1), 57. https://doi.org/10.1186/1477-7525-8-57

Wright, K. B. (2006). Researching Internet-Based Populations: Advantages and Disadvantages of Online Survey Research, Online Questionnaire Authoring Software Packages, and Web Survey Services. *Journal of Computer-Mediated Communication*, *10*(3), 00. https://doi.org/10.1111/j.1083-6101.2005.tb00259.x

Appendix A

The Informed Consent Form

Thank you for participating in our study on sitting behaviour! Please read the following information thoroughly.

The goal of this research is to explore the relationship between sitting behaviour and mental health-related constructs. With your participation in this research, you will help us contribute to the scientific knowledge of sitting behaviour and its relationship to mental health.

You are eligible to participate in this study if you are at least 18 years old, proficient in English, and enrolled at a university or university of applied sciences.

The study will be conducted over a period of nine days. At the start of the study, you will be asked to fill out a baseline questionnaire with questions about demographics and personality traits. This questionnaire will take about ten minutes to fill out. After that, you will receive three short questionnaires daily via the Ethica App. Please make sure that the notifications on your device for Ethica are turned on.

Participation in this study is not expected to pose any risks. One possible consequence is an increased awareness of your daily mood, behaviour, academic pressure, and feelings. For this reason, please consider your participation in this study carefully if you are sensitive to these topics. This might be especially relevant for you if you are diagnosed with or suspected to have a mood and/or anxiety disorder.

Your participation in this study is entirely voluntary. If you wish to withdraw from this research, you can do so at any time without giving a reason. All your answers will be treated confidentially. That is, all personal data will be anonymized and will not be published and/or given to a third party. Hence, the data will be used for this study only. The study has been approved by the Ethics Committee of the University of Twente. If you have any questions or concerns before, during or after your participation, do not hesitate to contact the researchers:

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I hereby declare that I have fully read and understand the text above and I am willing to participate in this study. By ticking 'Yes', I actively consent to participate in this study and the processing of my data.

Appendix B

Adjusted PAST-U Questionnaire

We are going to ask you about particular **activities** you did **yesterday** while **sitting down** or **lying down**. Please note that this **does not include sleeping**, either in bed or if you fell asleep while doing another activity, for example watching television.

We are going to ask you about different times when you may be sitting or lying down: when studying, working, travelling, watching TV, using the computer, and doing other activities. For each of these, only count the time this was your **main activity.** For example, if you watched TV and ate dinner at the same time, this might be TV or mealtime, but not both. Your answers can be given in minutes. Try to report only the time you spent sitting or lying down and do not take into account the time you spent getting up for breaks (e.g. coffee, bathroom).

Sitting for study

ST 1. **How long** were you **sitting** while studying yesterday? (include the time at university, during lectures, tutorials, meetings, group discussions, self-study, study from home, etc.)

Sitting for work

ST 2. **How long** were you **sitting** at your workplace or working from home in a paid position yesterday? (Examples: babysitting, sitting at the reception, minding a stall/shopm data entry/administrative paperwork, tutoring, etc.)

Sitting for Transport

ST 3a. Thinking again of yesterday, please estimate the **total** time that you spent **sitting** to travel from one place to another **driving yourself**. Please **include sitting and waiting** for transport. Do **not** include any time you were standing up while travelling or waiting.

ST 3b. Thinking again of yesterday, please estimate the **total** time that you spent **sitting** to travel from one place to another **not driving yourself/using public transportation**. Please **include** sitting and waiting for transport. Do **not** include any time you were standing up while travelling or waiting.

Television Viewing

ST 4a. Please estimate the **total time** you spent sitting or lying down to watch TV or DVDs? This **does not include** Video-on-Demand watching.

ST 4b. Please estimate the total you spent sitting or lying down to play games on the TV, such as PlayStation/Xbox yesterday?

Computer, Internet, Electronic Games

ST 5a.   Please estimate the **total time** yesterday that you spent sitting or lying down and **using the computer actively**. (For example, include time spent playing games, reading, online shopping on your smartphone/tablet/computer).

ST 5b.   Please estimate the **total time** yesterday that you spent sitting or lying down and **using the computer passively.** (For example, including time spent watching Video On Demand (e.g. YouTube, Netflix), scrolling through social media.

Sitting for reading

ST 6.   Please estimate the total time yesterday that you spent sitting or lying down while reading **during your leisure time**. Include reading in bed but do not include time spent reading for paid work or for study.

Sitting for eating

S7.   Please estimate the total time yesterday that you spent sitting down for eating and drinking, including meals and snack breaks.

Sitting for socializing

ST8.   Please estimate the **total time** yesterday that you spent sitting down to socialize with friends or family, regardless of location (at university, at home or in a public place). **Include** time spent on the phone (e.g. calling, chatting, texting etc.).

Sitting for Creative Hobbies

ST9.   Please estimate the **total time** you spent sitting or lying down engaging in creative hobbies (e.g., drawing, playing the guitar etc.).

Sitting/lying for other purposes

ST8.   We are interested in any other sitting or lying down that you may have done that you

have not already told us. For example, this **could include**; playing board games, listening to

music or for religious purposes. Please estimate the **total time** that you spent sitting or lying

down engaging in these actions. (**DO NOT include** time that you have told us about in the

previous answers).

Appendix C

Estimated Marginals Means of State Anxiety and Total Sedentary Time Across Timepoints
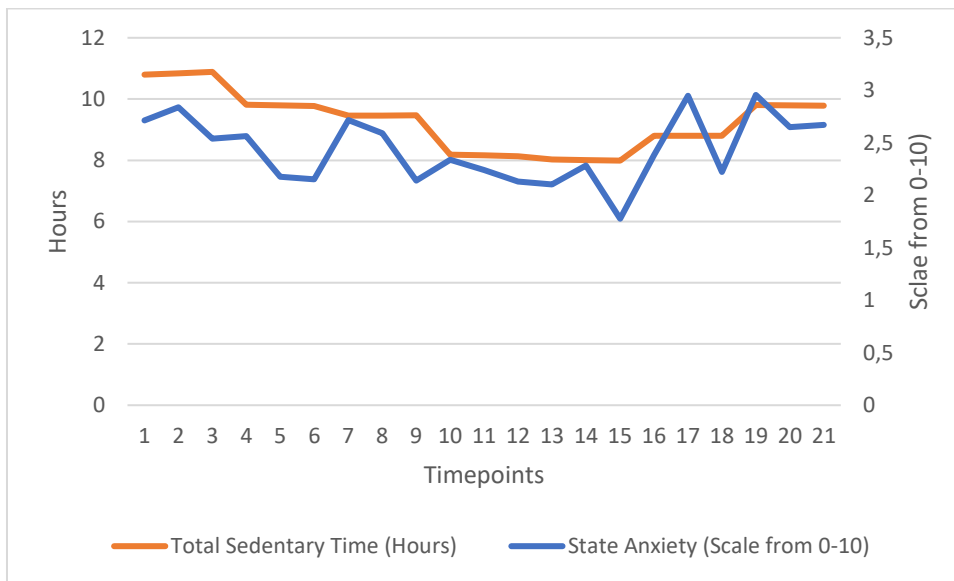
Note. The y-axis was changed from 10 to 3.5 for state anxiety to allow for
a better comparison between state anxiety and total sedentary time

Appendix D

Estimated Marginals Means of Mentally Active and Mentally Passive Sedentary Time Across Timepoints
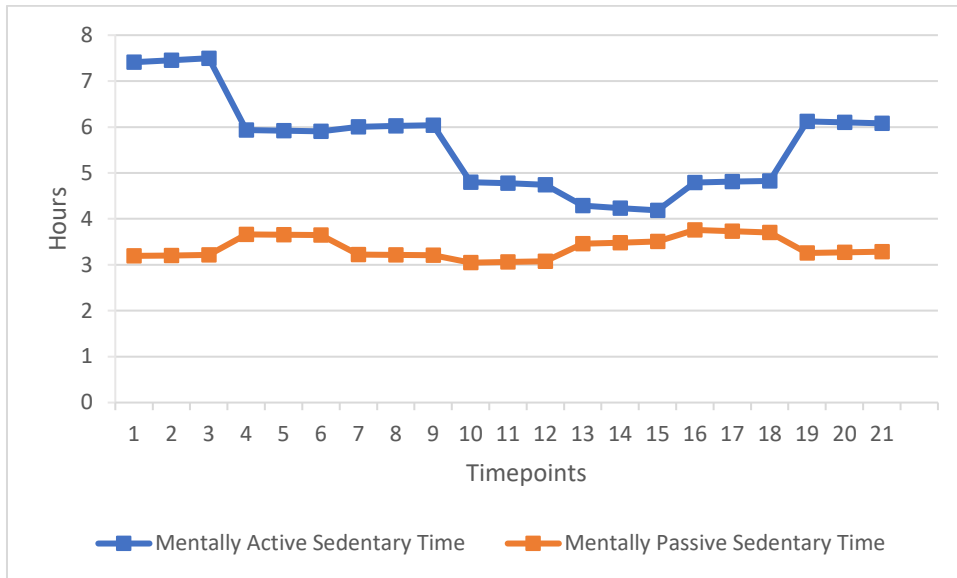
Appendix E

Estimated Marginals Means of Socially Active Sedentary Time Across Timepoints