Tired of Sitting – Exploring the Relationship Between Sedentary Behaviour and Fatigue In University Students Using Experience Sampling

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Abstract

Background: During the last decade, students have been spending more and more time with sitting and laying down. This was reinforced by the Covid-19 pandemic from 2020. Previous research has shown that this behaviour - sedentary behaviour - increases mental states such as depression, anxiety, and also fatigue. Students already show elevated levels of fatigue due to an irregular sleeping schedule and stress and the increased sedentary time among this group may increase fatigue even further. Additionally, research in the last years has suggested that the mental activity of people while being sedentary may influence the relationship between sedentary time with mental health. It has been suggested that mentally passive behaviour may strengthen the relationship of sedentary time and depression, whereas mentally active behaviour may weaken it. The aim of this study was to investigate the relationship between sedentary time and state fatigue. Additionally, the moderating influence of being either mentally passive or active while being sedentary was explored.

Method: An experience sampling self-report study was conducted over a period of nine days with 27 students from higher education (M_{age} = 21.3, SD_{age} = 1.35 years, 66.6% female). Participants used the Ethica app and received four questionnaires per day, assessing their main mental state while being sedentary since the last measurement and their state fatigue. Additionally, every first questionnaire of a day measured the total sedentary time of the last 24 hours. Linear mixed models and estimated marginal means were employed to investigate the relationship between sedentary time and fatigue, and how this relationship was moderated by mental activity.

Results: Sedentary time showed a weak positive relationship with state fatigue (B = 0.049, $F(1,140) = 4.22$, p = .042). The interaction between being mentally passive and sedentary also showed a weak positive relationship with fatigue (B = 0.111, $F(1, 412) = 11.17$, p = .001), whereas the interaction effect between being mentally active and sedentary decreased fatigue (B = -0.111, $F(1, 412) = 11.17$, p = .001). Being mentally passive alone decreased fatigue, whereas being mentally active alone increased fatigue.

Conclusion: Sedentary time indeed slightly increases fatigue. This relationship seems to be reinforced by being mentally passive and weakened by being mentally active. The separate relationship of mental activity was reverse to the interaction effect, suggesting that the

underlying theoretical construct may benefit from treating fatigue as multidimensional. Further factors influencing the results, as well as strengths and limitations are discussed and future research suggested.

Keywords: Sedentary Behaviour, Fatigue, Mental Activity, Experience Sampling Methods, Students

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Introduction

During the last decades, sitting for longer periods of time became a substantial part of our lives (Owen, et al., 2010). During the Covid-19 pandemic, the total sitting time per day has increased worldwide, while physical activity decreased (Ammar, et al., 2020; Meyer, et al., 2020). 2020 and 2021 were marked by lockdowns, the temporary closing of stores, sports facilities, and institutions in Europe, contact restrictions, and working from home. The prolonged sitting time does not only pose a risk to physical health, but also to mental well-being, as sedentary time has been linked to fatigue and depressive symptoms several times (Hoare, et al., 2016; Saunders, et al., 2020; Wennberg, et al, 2015). Even though causality between sedentary time and fatigue is difficult to establish (Biddle, et al., 2019; Engberg, et al., 2017, Hallgren, et al., 2018), university students increased sedentary behaviour may be related to elevated fatigue, endangering their academic performance and qualifications (Law, 2007, Sajadi, et al, 2016; Smith, 2018). This relationship may be further influenced by the type of activity that students perform while being sedentary. Recent findings suggest that being mentally active or passive may influence the relationship between sedentary time and fatigue (Hallgren, Dunstan, Owen, 2020). Therefore, the goal of this study was to investigate the relationship between sedentary time, mental activity, and fatigue among students more closely.

Sedentary Behaviour

Sedentary behaviour has been 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). It is usually associated with watching TV, travelling, gaming, or occupation (Owen, et al., 2010). Students seem to be more prone to prolonged sedentary time than other young adults (Bertrand, et al., 2021). According to a review by Castro, et al. (2020), students spent between 7.3 and 10.7 hours per day sitting or in a reclining posture. This duration most likely increased further during the Covid-19 period (Bertrand, et al., 2021). Most of the students' sedentary time was usually spent in front of a computer, followed by sitting in class, and using the mobile phone. How the type of sedentary behaviour changed during the pandemic is not yet clear. A German study suggested that screen time among younger people may have increased (Paschke, et al., 2021). However, more studies need to be conducted to investigate the precise effect of the restrictions during the pandemic on sedentary behaviour.

In the last years, it was proposed to take into account the degree of mental activity, either passive or active, while being sedentary (Hallgren, et al., 2018; Kikuchi, et al. 2014). According to these authors, mentally active sedentary behaviour includes activities that require higher cognitive effort, such as reading or working on a computer. Mentally passive behaviour on the other hand includes activities that require less attention, such as watching TV or browsing through social media while relaxing on the couch. According to Hallgren, Dunstan, and Owen (2020) and Hallgren, et al. (2018), mentally active sitting may not have a strong negative relationship with mental health and may even be a preventive factor. Mentally passive behaviour on the other hand is associated with an increase in depressive symptoms.

Possible explanations are, that mental activity is related to engagement and reward, thereby buffering the consequences of sedentary behaviour on mental health (Hallgren, et al., 2018), whereas passive activities may be socially isolating, thereby removing a person from positive social stimuli (Hallgren, Dunstan, Owen, 2020). Both papers also include the possible influence of biological factors. Overall, considering the moderating effect of being mentally active or passive on the relationship between sedentary time and mental health is still novel, and further studies are needed to investigate this moderation and its working. Up until this point, the papers by Hallgren, et al. (2018), Hallgren, Dunstan, and Own (2020), and Kikuchi, et al., (2014) have focused on the relationship between mentally activity, sedentary time and depression. Fatigue has not yet been closely investigated in the light of this framework. Depression and fatigue are two closely related concepts and fatigue is often a prime symptom of the mood disorder (Corfield, et al., 2016; Dittner, et al., 2004). Therefore, the studies on depression and sedentary time are useful and necessary starting points to investigate fatigue, a frequent phenomenon with potentially serious consequences.

Fatigue and Sedentary Behaviour

Although less frequently than depression, fatigue has been linked to sedentary behaviour (Wennberg, et al., 2015). Brady, et al. (2021) found that increased exercise and decreased sedentary time decreased reported levels of fatigue, which was further supported by Kowalsky, et al. (2021). The latter also proposed that light to moderate exercise about once an hour decreased mental fatigue after sitting. Additionally, walking for about 2 or 3 minutes every 30 minutes as a disruption of sedentary behaviour also seems to decrease fatigue (Ekelund, et al., 2016). Hence, there seems to be a positive relationship between fatigue and sedentary behaviour,

even though cause and effect cannot be assumed, as fatigue may also increase sedentary time (Meeus, et al., 2011). Overall, shorter periods of sedentary behaviour seem to have a less strong association with fatigue than longer sedentary time.

Defining Fatigue

Up until now, there is no common definition of fatigue, though many versions share fundamental aspects, such as subjectivity and persistence (Dittner, et al., 2004). Mota and Pimenta (2006) described fatigue as "An unpleasant physical, cognitive and emotional symptom described as a tiredness not relieved by common strategies that restore energy. Fatigue varies in duration and intensity and it reduces, to different degrees, the ability to perform the usual daily activities." (as cited in Engberg, et al., 2017). In addition to that, Shen, et al. (2006) defined it as "an overwhelming sense of tiredness, lack of energy and a feeling of exhaustion, associated with impaired physical and/or cognitive functioning; which needs to be distinguished from symptoms of depression, which include a lack of self-esteem, sadness and despair or hopelessness." (p. 70). It is different from sleepiness and tiredness, as it usually does not disappear after rest or sleeping, but is an intense and persistent feeling of exhaustion (Lasseter, 2009) which may fluctuate over the course of a day and week (Meeus, et al., 2011). Further, it can negatively affect daily routine and performance, paired with lethargy, disinterest, and a feeling of guilt for not being able to meet responsibilities and personal standards (Tiesinga, et al., 1996). Even though it often appears as a symptom of other illnesses and disorders, it is a separate mental state (Shen, et al., 2006). Law (2007) proposed that students experience higher levels of fatigue than other occupations. This may be due to the high levels of stress regarding performance (Doerr, et al. 2015) or their high levels of sedentary behaviour. Overall, even though the exact definition is still not clear, fatigue is considered a prominent and frequent state in students with significant impact on everyday life and functioning which may be connected to their elevated sedentary time.

Challenges in Measuring Sedentary Behaviour and Fatigue

Even though the connection between fatigue and sedentary behaviour may be established, there are many factors still unknown. To begin with, this relationship has not been closely investigated among students, even though they are especially prone to fatigue and sedentary behaviour (Law, 2007; Doerr, et al., 2015). Furthermore, it is still not entirely clear how and whether the relationship between sedentary time and fatigue differs depending on the degree of mental activity (Hallgren, Dunsten, Owen, 2020). In addition to that, behaviour and fatigue may

vary over the course of a day and a week. Capturing this dynamic characteristic may be necessary to clearly investigate this relationship and how the factors influence each other. Lastly, most studies on sedentary behaviour have been observational, using an accelerometer (Hallgren, Dunsten, Owen, 2020). This method does not capture what kind of sedentary behaviour participants engage in and thereby neglecting the context and mental activity. Regarding these uncertainties and gaps in research, some challenges become apparent.

First, a measure of sedentary behaviour needs to be found that captures both the duration of sedentary time and the whether people are mentally active or passive during that time. Secondly, fatigue is a highly subjective state (Aaronson, et al., 1999) and therefore cannot be captured by observational measures. Consequently, self-report measures are more suitable for measuring these variables. One major drawback of conventional self-report measures is that the answers are often influenced by a memory bias, leading to a reduced reliability and accuracy of the data (Castro, et al., 2020; Hallgren, Dunsten, Owen, 2020). Related to this, both fatigue and sedentary behaviour are variable over time. Hence, to establish a relationship, a single measure will not capture the dynamic processes and interactions between these variables. Consequently, a measure is needed that allows multiple consecutive self-report assessments. Thereby, changes in fatigue can be captured, a more accurate assessment of the duration and mental activity can be reported, the memory bias is decreased, and the dynamic interplay of the variables may be assessed.

Experience Sampling Methods

Experience sampling method (ESM) is an innovative self-report measure that meets these requirements. It gained popularity due to the improvements of phones and technology (Conner & Lehman, 2012.; Pejovic, et al., 2016; van Berkel, et al., 2017) and provides ecologically valid measures by asking the same set of questions multiple times over a fixed time period (Eisele, et al. 2020). Usually, each questionnaire is assessing the time since the last questionnaire (Myin-Germeys, et al., 2018). Thereby, it decreases the risks of flawed data through a memory bias as the period that participants have to recall is a lot shorter (Pejovic, et al., 2016). According to Conner and Lehman (2012), this method is optimal for measuring behaviour in a natural setting without the influence of an experimenter. It is useful for measuring micro-processes such as fatigue and sedentary behaviour (Conner & Lehman, 2012; Pejovic, et al., 2016) that may be

highly dependent on the context (Myin-Germeys, et al., 2018). Lastly, ESM is especially useful for persons with fatigue, as the questionnaires are short and less of a burden to participants.

There is no predefined duration or number of questionnaires per day (Eisele, et al. 2020). Hence, previous ESM studies on fatigue serve as the fundament for an informed choice. For example the study by Stone, et al. (1997) used seven measures per day for seven days, whereas Meeus, et al. (2011) used three measures per day for six days. In comparison, Brys, et al. (2021) assessed fatigue ten times a day for seven days. Overall, Eisele, et al. (2020) did not find a significant effect of sampling frequency per day on the quality of the outcome among students. To summarize, ESM allows to measure fatigue and sedentary behaviour in their dynamic form, increases the reliability of the data, is able to collect high amounts of information through multiple measurements, and is easy and flexible to administer. Thereby, it meets all the challenges defined before.

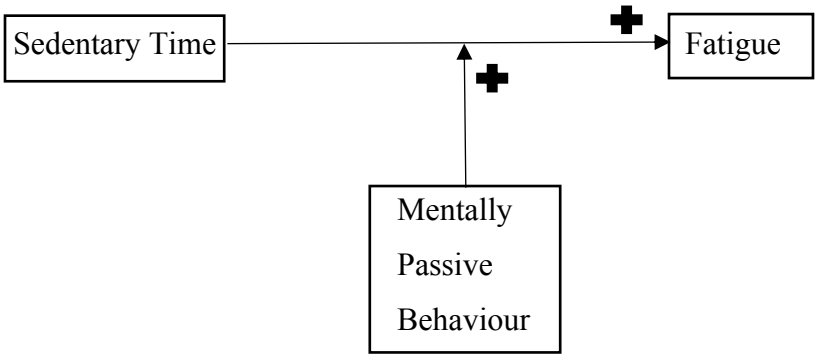
The Present Study

To recap, students are at risk for both high levels of sedentary time and elevated levels of fatigue. Still, not a lot is known about the relationship between these two factors and whether this relationship is influenced by being mentally active or passive. Additionally, these factors have not been measured in a way that takes into account the varying levels of fatigue and different types of sedentary behaviour. Hence, the goal of this study is to investigate these gaps in research by using ESM. Consequently, the research questions guiding the following process were: What is the real-time relationship between sedentary behaviour and fatigue in university students in their everyday life? Further, how is this relationship moderated by mentally active or mentally passive sedentary behaviour?

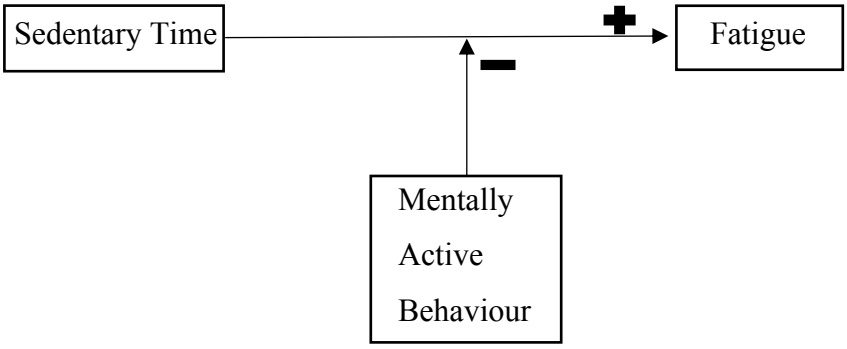
The answers to these questions were guided by the following hypotheses:

1. Sedentary time is positively associated with state fatigue in university students.

2. Mentally passive sedentary behaviour positively moderates the relationship between sedentary time and fatigue in university students.



3. Mentally active sedentary behaviour negatively not moderates the relationship between sedentary time and fatigue in university students.



The findings of this study can be used for multiple purposes. First, it may yield valuable insights into the current life style and mental health of students and lead to interventions with the potential to improve their health. Additionally, it can be used to inform not only health programmes, but also future studies. It may direct more attention to the issue of fatigue in university students and promote the use of ESM is future projects on mental states.

Methods

Design

Quantitative data was collected using experience sampling methods (ESM). To determine the sampling duration and frequency, previous Bachelor and Master thesis studies and research papers using ESM were consulted, leading to a total participation time of eight days with a

sampling frequency of four questionnaires per day, besides the first and the last day. The data collection took place in April and May 2021. For this, participants installed Ethica on their mobile phones or similar technical devices. Ethical approval was obtained from the BMS Ethics Committee at the University of Twente (reference number 210334).

Participants

For the data collection, multiple inclusion criteria were defined for the sample. The participants needed to be older than 18 years, be enrolled at a university or university of applied science, be proficient in English, and own a smartphone or similar device for the use of Ethica. No specific exclusion criteria were defined. A convenience sample was used by recruiting participants through the Test Subject Pool BMS (SONA) System of the University of Twente, as well as private messages. Van Berkelen, et al.(2017) suggested a sample size of approximately 19 to be sufficient. The final adjusted sample of this study consisted of 27 participants, which is sufficient according to the standard suggested above. 33% of them were male (n = 9) and 37% female (n = 18). The age ranged from 19 to 25 (M_{age} = 21.30, SD_{age} = 1.35). About half of all participants were German (51.9%, n = 14.), followed by 40.7% Dutch participants (n = 11), and 7.4% of the participants came from another country (n = 2). All participants were enrolled at a university or university of applied sciences.

Materials and Measures

Ethica

For this study, various materials and questionnaires were used. To begin with, participants were asked to install the Ethica app on a suitable technical device, such as their mobile phones. Ethica is an online-based service that offers the necessary features for experience sampling methods, such as frequent time triggers. Via this service, the informed consent form and all following questionnaires were distributed. Ethica automatically anonymized all incoming data and no information was collected that could be traced back to the participants. When looking at the study in the SONA system and also when first registering for the study in Ethica, participants were presented with an information sheet, describing all details, risks, ethical boundaries, and contact information concerning the study (Appendix A). After reading this, participants received the informed consent form (Appendix A). This consisted of six items, each item corresponding to one important part participants consented to. This was done to ensure that students were aware of what they were consenting to and to ensure active consent. If they

answered one of the consent questions with "no", they were considered not eligible for the study and Ethica terminated their participation.

Demographics and Trait Measures

The demographics questionnaire assessed the gender, age, and occupation of the participants. Additionally, they were asked whether they are from the Netherlands, Germany, or another country. Lastly, an item was added asking for any mental or physical condition the participant may have that influenced their energy level. The question was included, as mental and physical health conditions such as depression or chemo therapy may influence the experience of fatigue (Aaronson, et al., 1999). Participants were not asked to indicate the type of condition to ensure privacy. This measure was not used for the main analysis, but served as a descriptive.

The Fatigue Assessment Scale (FAS) by Michielsen, et al. (2004) was used as a descriptive baseline measure of fatigue (Appendix B). It is a unidimensional questionnaire with 10 items, which are answered on a 5-point likert scale (Michielsen, et al., 2003; Michielsen, et al. 2004). It measures both impact and severity of fatigue (Whitehead, 2009) by assess the usual behaviour and feelings of fatigue in the participant. Later, the item scores can be combined into one overall sum score ranging between 10 and 50, with higher scores indicating higher levels of fatigue (Ho, et al., 2020). Results equal to 22 or higher are considered to indicate elevated fatigue, whereas anything lower than 22 is considered the norm for the general population (De Vries, et al., 2004).

The FAS has been validated in different populations and countries, including the general population of the Netherlands (Michielsen, et al., 2003; Michielsen, et al. 2004). During a validation study, it showed a good internal consistency (Cronbach's alpha = 0.90), strong evidence for a one-factor solution (construct validity) and significantly correlated with seven other fatigue measures, indicating a good concurrent validity (Michielsen, et al., 2003). In the current study, a Cronbach's alpha of .86 emerged, which is considered good (Tavakol & Dennick, 2011).

State Measures

The state measures assessed real-time fatigue, sedentary time, and mental fatigue (Appendix C). It must be noted that for the measure of sedentary behaviour and mental activity, no previously validated questionnaire was used, as these variables have not yet been measured

using a single validated tool. Hence, the items described in this section were derived from different validated questionnaires from previous studies, combined into a single questionnaire. State sedentary time was assessed by one item asking for the total number of hours spent in a sedentary state in the last 24 hours (Owen, et al., 2010). This item was only used in the morning to assess the sedentary time of the previous day. By using this longer timeframe, the risk of recall bias increases. On the other hand, it also allowed an equal spacing between measures and to capture all sedentary hours, also the once after the last assessment of a day. Furthermore, using a smaller number of items reduces the burden on participants (Eisele, et al., 2020; Stone, et al., 1997). Hence, equal spacing, complete assessment, and low participant burden were prioritized over recall accuracy.

The state mental activity was assessed by a single item. Participants were provided with a list of options that included both mentally active and mentally passive sedentary behaviours, like "reading", "watching Netflix/TV/YouTube /etc.", and "studying" (Table 1). Additionally, the option "other" was added. From this list, participants were able to select a single option. The question, answers, and categorization into passive or active mental activity were adapted from Hallgren, et al., (2018), and the Youth Leisure-time Sedentary Behaviour Questionnaire (YLSBQ; Cabanas-Sánchez, et al.2018).

Table 1.

Answer options for activity performed while being sedentary sorted into the categories mentally active and mentally passive.

Mentally Active	Mentally Passive
Reading	Socializing
Working on laptop/computer	Watching TV/Netflix/YouTube/etc.
Playing computer/video games	Listening to music
Playing a musical instrument	Travelling in a motorized vehicle
Doing crafts or arts	Being on social media

The second measure was state fatigue. To ensure a short assessment (Eisele, et al., 2020, Stone, et al., 1997), a unidimensional single-time measure was used, which was specifically designed for rapid assessment in ESM studies: "How fatigued do you currently feel?" (Van Hooff, et al., 2007) The answers range from 1 = "not at all" to 10 = "extremely". The scale was

tested and validated using university employees in the Netherlands. The measure showed good evidence for convergent validity as it correlated significantly with the POMS questionnaire and further items measuring fatigue (Van Hooff, et al., 2007). The authors also report evidence for discriminant validity, as it did not significantly correlate with items not measuring fatigue. Lastly, but the study shows evidence for this item to be similarly accurate as the six-item POMS scale (van Hooff, et al., 2007), besides its shortness. All in all, the daily questionnaires assessed sedentary behaviour in terms of duration and mental activity, whereas fatigue was measured in terms of severity.

Procedure

After an initial design was finished, a pilot test was conducted among three undergraduate students. Based on their input, the answer option "I did not sit or lay down" was added to the item assessing the type of sedentary behaviour. Furthermore, the questionnaires remained available for 1 hour, rather than 30minutes to increase the response rate. After that, the study was ready for publishing.

Both in the SONA system or through direct messages, participants first received some information about the content and goal of the study. They were asked to install the Ethica app on their phone or a similar device. In the app, they were asked to register with the provided study code to participate. After this step, the students were presented the information sheet, followed by the informed consent form (Appendix A).

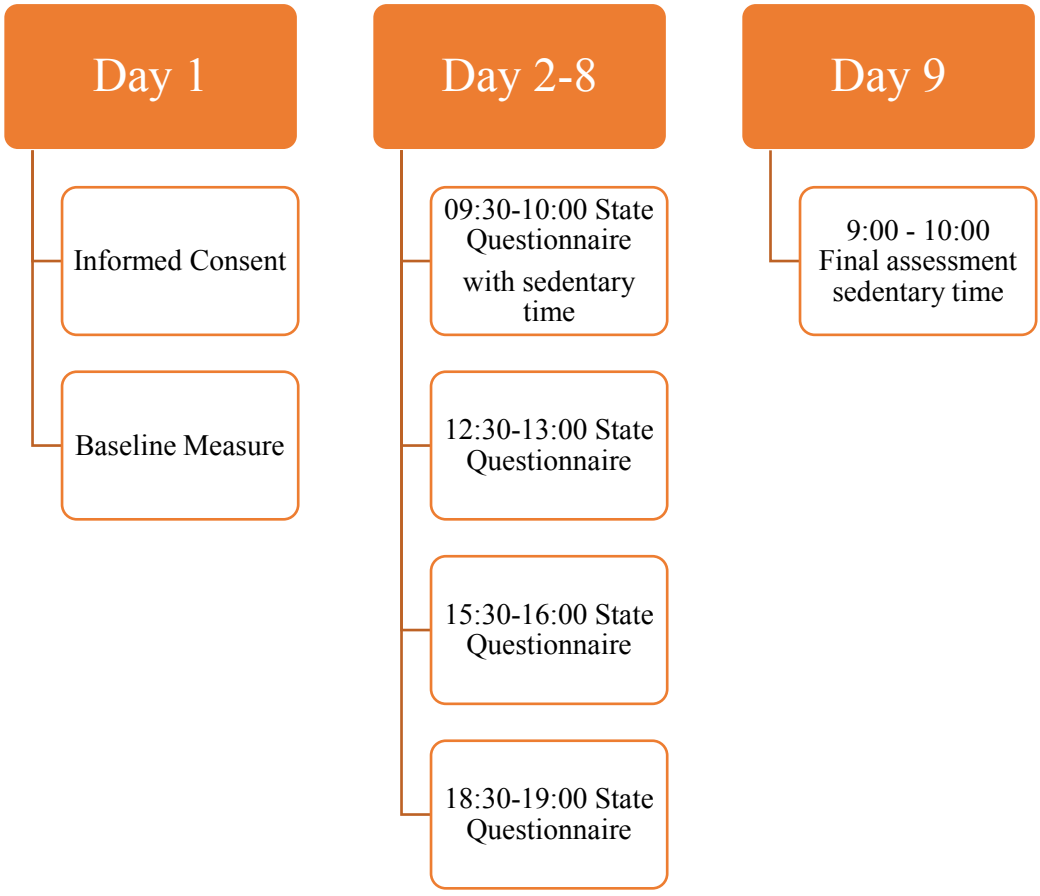
Right after actively consenting, participants received the questionnaire the items on demographic information and the items of the FAS (Figure 1) (Appendix B). Upon finishing this step, they once more received information about the further procedure. They were told that this marks the end of day one, and that they would receive four shorter questionnaires per day for the following seven days. Additionally, they were informed that these would take place in the morning, noon, afternoon, and evening.

For the following seven days, questionnaires were sent through the Ethica app to the participants between 9:30-10:00 in the morning, 12:30-13:00 at noon, 15:30-16:00 in the afternoon, and 18:30-19:00 in the evening (Figure 1). The morning questionnaire (Appendix C) included the item about the total sedentary time of the previous day, as well as the other daily measures. The other three daily questionnaires did not include the question about total sedentary time, as that item assessed the last 24 hours. For every item, an answer had to be given in order

to proceed. After approximately half of the participants finished their participation in the study, a logical error was discovered. Hence, the item about total sedentary time was added once more in the morning on the ninth day of the study. This was done because the indication of sedentary time referred to the previous 24h, so always to the previous day. Without adding this measure once more, the measures of mental activity and fatigue on the last day did not have a corresponding sedentary time. Hence, this addition increased the accuracy of the later analysis. For the participants that did not receive this last questionnaire, their average sedentary time was used. Each questionnaire was available for the participants for one hour and they received a notification about answering it right after it was published, as well as a reminder 30 minutes after it was published.

Figure 1

Timeline of the study for participants



Data Analysis Plan

The collected data was imported to Microsoft Excel for the first step of cleaning. After excluding unnecessary information, the data was transferred into two data files in *IBM SPSS Statistics* (Version 25). In line with Connor's and Lehmann's (2012) indication of common ESM practice, participants with a response rate of <50% were excluded from both data files. The first file included the data about the demographics of the participants and the items of the FAS. For the latter, the sum scores of the items were calculated per participant (De Vries, et al., 2004; Ho, et al., 2020). Descriptive statistics were run for gender, age, nationality, precondition, and the sum scores of the FAS.

The second data file in SPSS included the items and data of the state measures: sedentary time in hours per 24 hours, the type of activity that was performed while being sedentary as indicators of mental activity, and state fatigue. A split-half reliability analysis with a Spearman-Brown Coefficient was applied to the items assessing sedentary time and state fatigue (Palmier-Claus, et al., 2011). For this, the first 14 observations of state fatigue and sedentary time of every participant were combined into new variables, and the rest of the observations of these fatigue and sedentary time were combined into new variables. Then, the correlation coefficient between the two new state fatigue variables was calculated, as well as for the two sedentary time variables. There are no strict guidelines on evaluating the Spearman-Brown Coefficient, though a score of .80 or higher is considered desirable (Lewis-Beck, et al., 2004).

Due to the longitudinal design, all data was clustered per participant and included information about between-person and within-person differences. Hence, simple regression analyses were not suitable for this data, is it would ignore the multi-level nature and reduce the richness of the data, increasing the risk of errors (Curran & Bauer, 2012). Furthermore, the time intervals were different for the measurements of fatigue and mental activity in comparison to sedentary time. For a correct regression, the data needed to be adjusted. Consequently, time lagged Linear Mixed Models with an first-order autoregressive covariance structure and estimated marginal means (EMMs) were used to answer the hypotheses.

Linear Mixed Models take into account clustering variables and repeated measures, here, participants and timepoints. First-order autoregressive covariance structure account for the fact that observations closer to each other may be correlated stronger to each other than with observations further removed. In other words, it adds a time correlation function to longitudinal

data. EMMs are useful to overcome missing data, as they give the means of a variable over a chosen factor, such as timepoint or participant. For this analysis they were plotted as a descriptive statistic for fatigue and sedentary time in hours over time and over participant. Lastly, all variables except for sedentary time were time lagged to always correlate the correct sedentary time with the other state measures of the same day. To be precise, the first measure of each day was about the total sedentary time of the previous day. Hence, the fatigue and mental activity measures of that previous day should be correlated with that sedentary measure on the following morning. Consequently, the timepoints for fatigue and mental activity were adjusted accordingly, and the sedentary time belonging to those timepoints was added to each observation.

For all Linear Mixed Models, fatigue was used as the dependent variable, participants set as the subjects, and timepoint was set as a repeated measure. For the first hypothesis, only sedentary time was added as a predictor. For the second hypothesis, the activities that participants performed while being sedentary were coded into a dummy variable, with 1 = mentally passive, and 0 = mentally active (see Table 1). The answer options "other" and "I did not sit or lie down" were coded as missing. This dummy was then added as a moderator to the initial Linear Mixed Model. For the third hypothesis the same procedure was used, but with 1 = mentally active and 0 = mentally passive. Even though two separate dummy variables were not strictly necessary, both were created to contribute to a clearer interpretation of the separate moderation effects. For all models, and alpha of .05 was used to determine statistical significance of relationships and all effect sizes were reported in their unstandardized form.

Results

Descriptive

Out of the 37 students that joined the study, 10 had to be excluded because of a response rate lower than 50%. On average, the remaining 27 participants answered the average response rate was 83.4%. The final data set included 770 timepoints. For a detailed overview over all descriptive statistics, see Table 2. Most of the participants did not report any precondition regarding their fatigue (88.9%). The mean of the sum scores of the FAS was 21.63, SD=5.81. This was a comparatively high score, suggesting elevated fatigue in multiple participants (De Vries, et al., 2004). The mean state fatigue was 3.25 (*SD* = 2.19). The average sedentary behaviour time was 11.86 hours (*SD* = 5.65).

Table 2

Means(M), Standard Deviations (SD), Frequencies (n), Percentages (%) and Minimum and Maximum in the Sample of All Relevant Variables

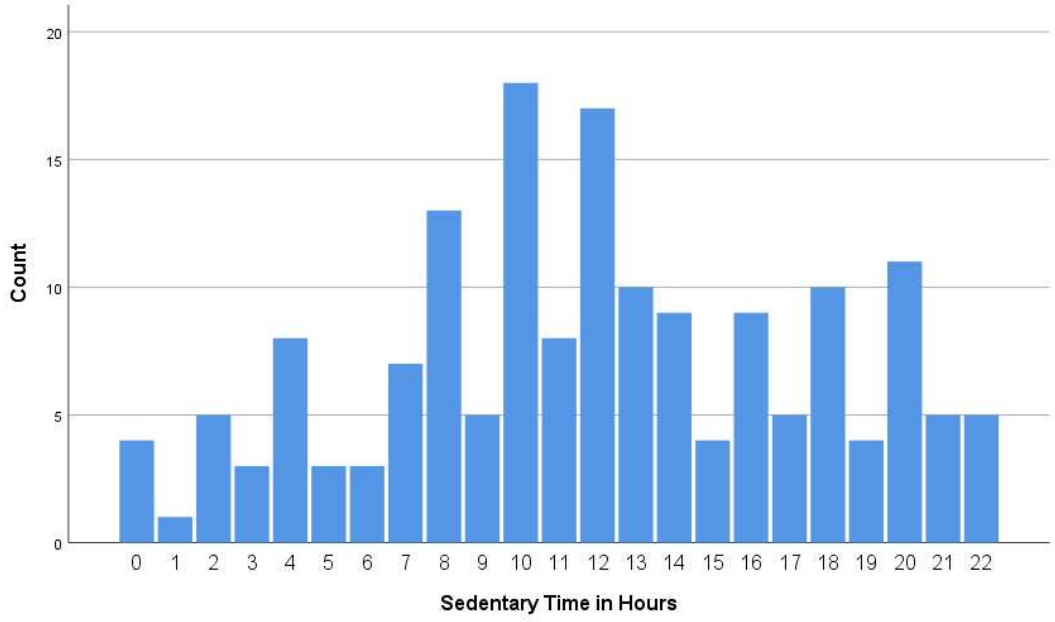
Variable	*n*	*%*	*M*	*SD*	*Min*	*Max*
Gender: Male	9	33.3				
Female	18	66.8				
Age			21.30	1.35	19	25
Nationality: Dutch	11	40.7				
German	14	51.9				
Other	2	7.4				
Occupation: Student	27	100				
Precondition: Yes	1	3.7				
No	24	88.9				
Prefer not to tell	2	7.4				
Trait fatigue (FAS)			21.63	5.81	12	33
Daily sedentary time in hours			11.86	5.65	0	22
Activity type: Active	277	52.2				
Passive	254	47.8				
State fatigue, *M* (*SD*)			3.25	2.19	0	10

Note. N=27, The fatigue assessment scale (FAS) and was used to measure trait fatigue. Sum-scores can range between 10 and 50.

Due to the high *SD* of sedentary time, the frequencies were plotted (Figure 2) and the median was calculated, which was 12 hours sedentary time per day and thereby similar to the mean. The range was broad, spanning 0 to 22 hours, with the distribution that was not clearly centred around the mean or median.

Figure 2

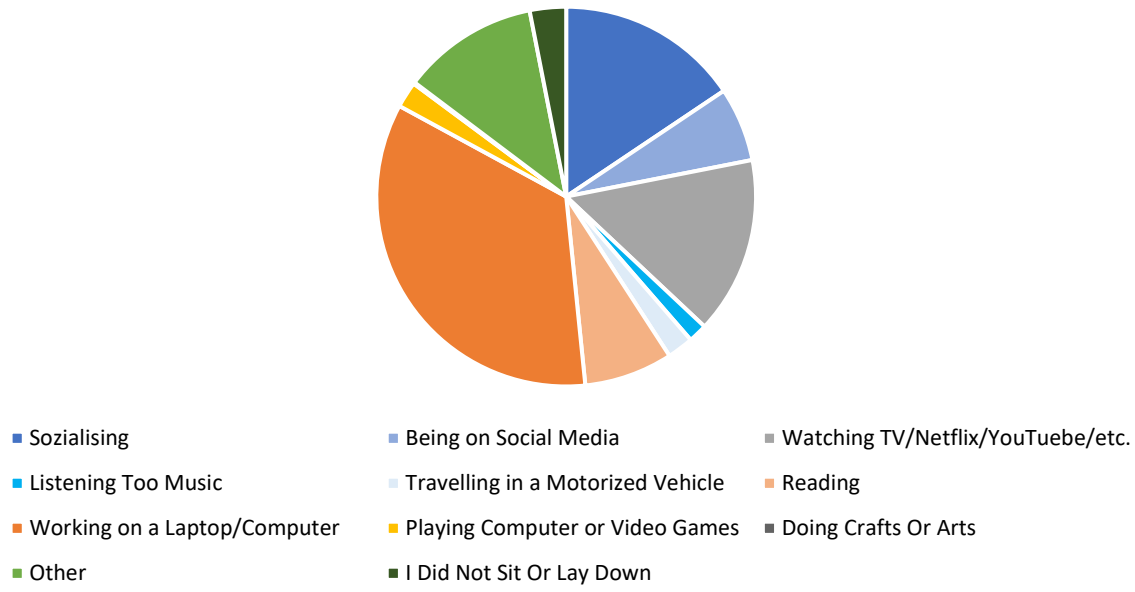
Frequency of sedentary time in hours



Overall, participants spent more time with mentally active tasks while being sedentary (52.2%) than with mentally passive ones (47.8%). The main activities that were performed were working on a laptop or computer (27.9%), socializing (12.6%), and watching TV/Netflix/YouTube, or any other streaming service (Figure 3).

Figure 3

Frequencies of Behaviours Performed While Being Sedentary



Reliability

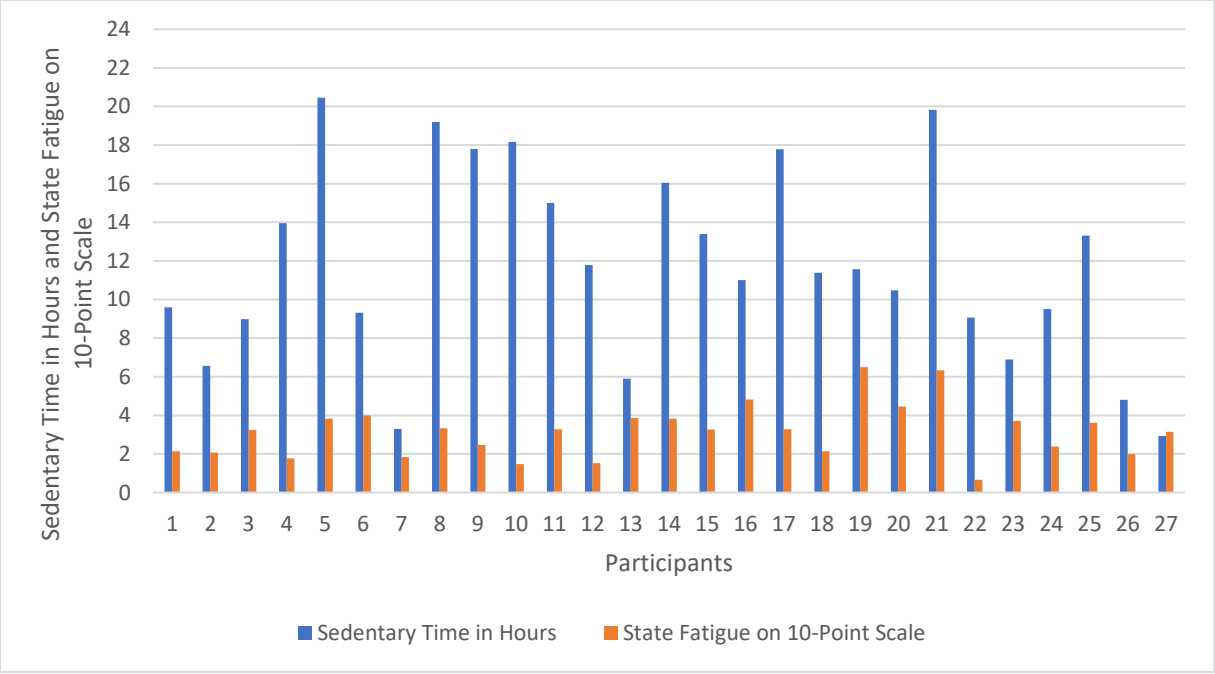
The Spearman-Brown Coefficient was calculated for the item assessing sedentary time and for the state fatigue item. For sedentary-time, a coefficient of $r = .826$ was found, which is considered desirable. For the state fatigue, a coefficient of $r = .464$ emerged, which may be considered insufficient.

Testing Hypothesis 1

For the first hypothesis, the relationship between sedentary time and fatigue was assessed. Sedentary behaviour time showed a weak but significant relationship of $b = 0.024$ with fatigue, $F(1,140) = 4.22$, $p = .042$ (see also Table 3). In other words, students seem to become slightly more tired with every hour they spend being sedentary. To get further insights into this relationship over both time and participants, EMMs were calculated and plotted. Figure 4 shows the EMMs of fatigue and sedentary time sorted by participant. Due to the only weak relationship between the two variables, the association was barely visible the depicted EMMs.

Figure 4

Estimated Marginal Means of Sedentary Behaviour Time and Fatigue Over Participants.



The correlation can be seen for example in participant 21, for whom higher sedentary time accompanied a higher state fatigue (Figure 5). At the same time, some clear deviations can

be seen, such as participants 8 to 10, where the relationship seems to be non-existent to nearly opposite (Figure 6). In general, both fatigue and sedentary time varied significantly over participants, with $F(26, 529) = 13.61$, $p < .001$ and $F(26, 435) = 84.71$, $p < .001$, respectively.

Figure 5

The Relationship Between Sedentary Time and Fatigue Over Time of Participant 21

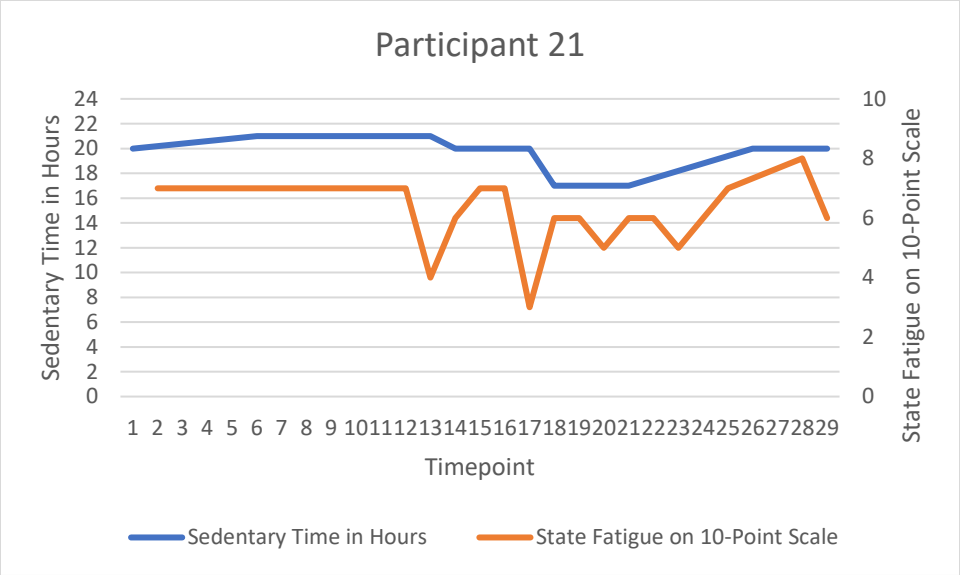


Figure 6

The Relationship Between Sedentary Time and Fatigue Over Time of Participant 10

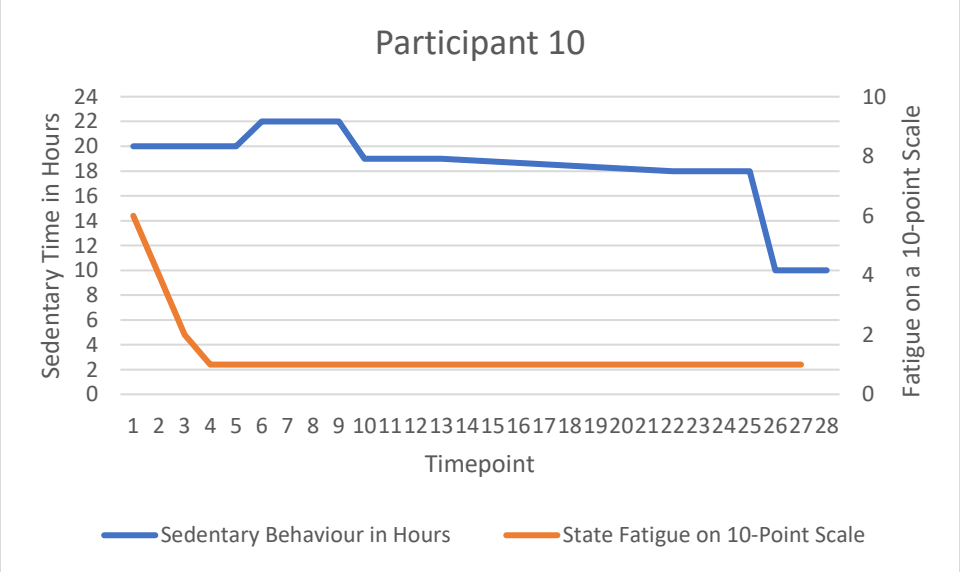
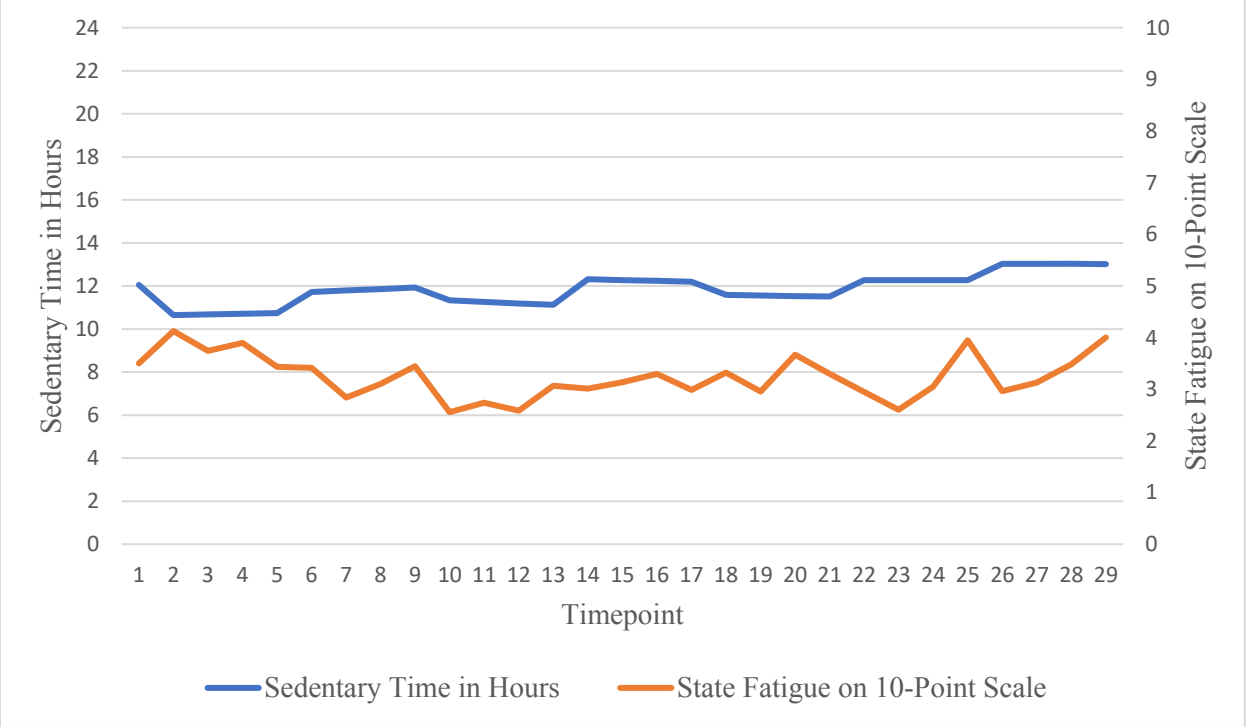


Figure 7 shows again fatigue and sedentary time, but with their EMMs over timepoints. In contrast to the EMMs over participants, the graphs over timepoints seem to move in a similar fashion over the time points, though the relationship seems to be weak. Fatigue did not significantly vary over time, $F(27, 339) = 0.97$, p=.512, whereas sedentary time did show significant variations, $F(28, 529) = 1.52$, $p = .044$.

Figure 7

Estimated Marginal Means of sedentary behaviour time and fatigue over time.



Hence, both graphs show that the estimated marginal means of total sedentary behaviour time and fatigue seem to be only slightly correlated, adding some support to the estimate of a weak relationship suggested by the linear mixed model.

Testing Hypothesis 2

For the second hypothesis, the relationship between sedentary time, being mentally passive, and fatigue was analysed. The results showed that the relationship between total sedentary behaviour time and fatigue was not significant anymore, $F(1, 248) = .19$, $p = .660$ (see also Table 3). Being passive had a significant negative association of $b = -1.426$ with fatigue, $F(1, 416) = 11.50$, $p = .001$, suggesting that being mentally passive reduces fatigue (see also

Table 3). Lastly, the interaction effect showed a significant positive effect of 0.107 on fatigue, $F(1, 420) = 11.31$, $p = .001$(see also Table 3). In other words, being both sedentary and mentally passive at the same time seemed to increase fatigue.

Testing Hypothesis 3

The third hypothesis focused on the buffering effect of being mentally active and sedentary time on fatigue. Hence, the other dummy variable that had mentally active activities coded as 1 was added as a moderator to the basic linear mixed model used in the first hypothesis. Both the separate relationships of total sedentary behaviour time and being mentally active with fatigue were significant, with $F(1, 200) = 17.28$, $p<.001$, and $F(1, 415) = 11.50$, $p = .001$, respectively. Total sedentary behaviour time had an effect size of $b = 0.121$ on fatigue, whereas being mentally active had an effect size of $b = 1.426$ (see also Table 3), so being sedentary longer increased fatigue, but being mentally active also increased fatigue. The interaction effect was $b = -0.111$ and significant, $F(1, 420) = 11.31$, $p = .001$ (see also Table 3). Hence, being mentally active while being sedentary decreased fatigue, in contrast to the two separate relationships.

Table 3.

Overview Of Results Of Hypotheses 1 - 3

Parameter	Estimate	Std. Error	Numerator df	Denomi-nator df	F	Sig	95% Confidence Interval	
							Lower Bound	Upper Bound
Hypothesis 1								
Intercept	2.684	0.317	1	135	71.304	.000	2.0555	3.313
Sedentary Time	0.0488	0.0238	1	140	4.222	.042	0.00185	0.0959
Hypothesis 2								
Intercept	3.320	0.405	1	218	67.286	.000	2.522	4.117
Sedentary Time	-.000586	0.0308	1	238	0.000	.985	-0.0612	0.06
Being Mentally Passive	-1.526	0.442	1	409	11.914	.001	-2.395	-0.657
Moderation Effect Sedentary Time and Mentally Passive	0.111	0.0333	1	412	11.170	.001	0.0458	0.177
Hypothesis 3								
Intercept	1.794	0.405	1	205	19.655	.000	0.996	2.591
Sedentary Time	0.111	0.0296	1	206	13.934	.000	0.0522	0.169
Being Mentally Active	1.526	0.442	1	409	11.914	.001	0.657	2.395
Moderation Effect Sedentary Time and Mentally Active	-0.111	0.0333	1	412	11.170	.001	-0.177	-0.0458

Note. N=27, Dependent Variable = State Fatigue

*$p < 0.05$

Discussion

This study was aimed at investigating the relationship between sedentary time and fatigue in students, with a focus on how this relationship is moderated by the type of activity that is performed while being sedentary. The first hypothesis stated that sedentary behaviour time has a positive relationship with fatigue and was accepted based on the weak relationship found in the results. The second hypothesis stated that being mentally passive strengthens this relationship. The results indeed showed a positive moderation effect, so sitting longer while being mentally passive indeed increases fatigue further. Hence, the second hypothesis was accepted. The third hypothesis stated that being mentally active weakens the relationship between sedentary behaviour time and fatigue. The results showed a significant moderation effect that decreases fatigue. Consequently, the third hypothesis was accepted. Based on these findings, the research questions stated in the beginning of this research could be answered to some degree. The real-time relationship between sedentary time and fatigue in university students is, that fatigue slightly increases with increased sedentary time. The degree of mental activity does significantly influence this relationship by strengthening it when being mentally passive and weakening it when being mentally active. Even though these answers to the initial research questions seem straight forward, the results suggest a more convoluted and complex reality. These results and the limitations of this study should be closely reflected upon, to evaluate the answers given to the research questions.

General Findings

Mean Trait Fatigue

When looking at the results, some aspects are important to mention. First, the sample showed a comparatively high mean trait fatigue, just below the mark of being elevated in comparison to normal levels (De Vries, et al., 2004). This finding was in line with the results of Law (2007) and Doerr (2015), who also reported higher fatigue levels among students. The circumstances of the Covid-19 pandemic may have elevated feelings of fatigue even further. Gonzales-Ramirez, et al. (2021) reported higher levels of exhaustion among students after moving to remote education due to the pandemic and Baroteszek, et al., (2020) reported higher levels of daytime fatigue in the general population during the pandemic as well, supporting the results of the present study. Taking into account that students already showed higher levels of fatigue prior to Covid-19 and the potential further increase during the pandemic, these results

underline the necessity to focus on the well-being of students as a risk group for fatigue, influence their performance and mental health (Law, 2007, Sajadi, et al, 2016; Smith, 2018).

Mean Sedentary Behaviour

When looking at the mean sedentary behaviour time, the sample showed a mean and median of approximately 12 hours per day, with some great variance. Some students seem to spend the majority of their day being sedentary, potentially because of lectures and other study-related activities in the home office, which was the most frequently reported behaviour (27.9%, see figure 3) . Looking back at earlier reviews of sedentary time in university students, Castro, et al. (2020) reported a lower average sedentary time per day in their review, ranging from about 7 to a bit more than 10 hours. The mean of the present study was more than one hour higher than the upper range of Castro, et al. (2020). One possible reason for this may be the decreased mobility due to the measures against the Covid-19 pandemic, such as closed universities and sports facilities. Bertrand, et al., 2021 conceptualized sedentary time in a similar way as the present study and reported an average of 8 hours of sedentary time per day prior to Covid-19, and about 11 hours of sedentary time per day during the pandemic.

Both the study by Bertrand, et al., (2021) and the present study conducted under the influence of the pandemic measures. Castro, et al. (2020) on the other hand reviewed papers that were not influenced by the events of the years 2020 and 2021, potentially explaining their reported lower sedentary time per day. Furthermore, their review included data from countries all over the globe, potentially including cultures with lower sedentary time. Overall, due to the large variations in sedentary time in the present study, comparisons with other studies should be tentative. It might be that sedentary time is influenced by other variables such as domain and leisure activities performed by the students, raising the need to investigate confounding variables in more detail. Still, sedentary time seems to take up a large amount of the waking time of students.

Evaluating The First Hypothesis – The Relationship Between Sedentary Time And Fatigue

Just like other mental states, fatigue seems to be influenced by sedentary time. Even though this relationship usually has been studied by measuring frequency and types of breaks from sedentary behaviour(Brady, et al., 2021; Kowalsky, et al, 2021; Wennberg, et al., 2015), increased sedentary time itself also seems to be positively associated with fatigue. The findings of the present study support the results of Giurgiu, et al. (2018), who reported decreased energy

levels in association with bouts of sitting of both ≤30 and ≥30 minutes. Furthermore, fatigue is closely related to depression, which was linked to sedentary behaviour quite frequently (de Wit, et al., 2010; Edwards & Loprinzi, 2016; Hallgren, et al., 2018; Hallgren, et al., 2020), so finding a similar relationship between fatigue and sedentary time came to no surprise. Still, causality cannot be established due to the self-report used in this study. In addition to that, Band, et al. (2017) found a significant effect of fatigue symptoms on physical activity, raising awareness to the possibility that the relationship between sedentary behaviour and fatigue may, at least, be bidirectional.

On the other hand, the effect size found in this study was quite small on a 10-point scale, seriously challenging the relevance of overall sedentary time for fatigue. Reflecting on the weak association in the present study and the significant findings of Giurgiu et al., (2018), measuring the duration of sitting bouts or sedentary time in shorter intervals than the 24 hours rhythm employed in the present study may be more accurate in investigating the relationship between sedentary time and fatigue. A longer time-interval between assessments increases the risk of recall bias, decreasing the reliability of the measurement (Pejovic, et al., 2016). The split-half reliability of the sedentary time measure was good though, in contrast to the item measuring fatigue. Hence, the weak relationship between sedentary time and fatigue may also be attributed to measurement error resulting from questionable reliability. Still, it may be concluded that sedentary time is positively associated with fatigue, both regarding shorter and longer time frames.

Evaluating The Second And Third Hypotheses – Mental Activity As A Moderator Of The Relationship Between Sedentary Time And Fatigue

The Moderation Effect

Moving on to the results of the second and third hypotheses, being mentally passive while being sedentary strengthened the relationship between sedentary time and fatigue, whereas being mentally active weakened it. These moderation effects are in line with the findings of multiple previous studies that reported lower depression scores when decreasing the mentally passive time (Hallgren, et al., 2018, Hallgren, Dunstan, Owen, 2020) and that suggested that being mentally active may offer a form of protection against the negative effects of prolonged sedentary behaviour (Hallgren, Dunstan, and Owen, 2020). With regards to fatigue being a common symptom of depression, it comes to no surprise that the results are similar. Hallgren,

Dunstan, and Owen (2020) explained the buffering effect of being mentally active with the innate human desire to learn and that mentally active sedentary behaviour often includes work and the productive interaction with others, which may also be rewarding and engaging. The sample of the present study consisted mainly of students, so it may be that their study-related, so mentally active, sedentary activities during the day met the innate joy for learning, thereby being rewarding and engaging and therefore leading to an interaction effect that decreased fatigue. Being mentally passive on the other hand lacks this positive effect and may therefore strengthen the relationship between sedentary time and fatigue (Hallgren, Dunstan, and Owen, 2020). Additionally, the most frequently mentally passive activity in the present study was watching Netflix, TV, or another streaming platform. Arndt, et al., (2013) reported increased fatigue after watching a video. Even though the exact mechanisms underlying relationship between mental activity, sedentary time, and fatigue, it may be recommended to decrease passive sedentary time to keep the potential consequences of prolonged sedentary time on fatigue to a minimum.

The Relationship Between Sedentary Time and Fatigue When Controlling For Mental Activity

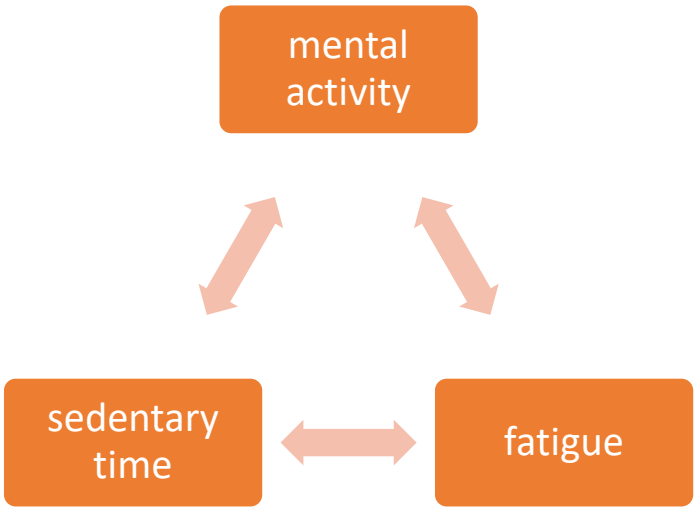
Next to the main finding of the moderation effects, the separate relationships between sedentary time and fatigue, and mental activity and fatigue were surprising. To begin with, the association between sedentary time and fatigue remained significant when controlling for being mentally active, but became insignificant when controlling for being mentally passive. Regarding the already weak association between sedentary time and fatigue, it may be that being mentally passive explained more of the variance in the model, thereby decreasing the significance of sedentary time. At the same time, being mentally active on its own increased fatigue in the sample, as well and sedentary time. This may be the reason why the relationship of sedentary behaviour with fatigue remained significant when controlling for being mentally active. This may suggest that a mediation model might be fitting to describe the relationships between all variables (Figure 8). On the other hand, due to the categories of mentally active and passive sedentary behaviour still being new, the link between sedentary time and mental activity has not yet been closely investigated. Hence, further research is needed to either support or disregard a mediation model.

Another factor that may explain the insignificance of the relationship between sedentary time and fatigue when controlling for mental activity is, that the item assessing fatigue was not very reliable according to the split-half analysis. Therefore, it might be that fatigue was not

accurately captured, causing relationships to become statistically insignificant. Overall, the relationship between sedentary time and fatigue seems to be influenced by other variables and has to be investigated more closely to establish significance when controlling for covariates.

Figure 8

Draft of mediation model for potential future studies



The Relationship Between Mental Activity And Fatigue When Controlling For Sedentary Time

Moving onto the direct relationship between mental activity and fatigue, the results were even more surprising. Compared to the moderation effect, the direct relationship between the two levels of mental activity and fatigue were opposite. In other words, being mentally passive on its own decreased fatigue, whereas being mentally active on its own increased fatigue. These findings go against the suggestions of Hallgren, et al., 2018 and Hallgren, Dunstan, Owen, 2020, as well as the findings of the present study regarding the moderation results. One possible explanations these surprising results may be, that the reported state fatigue was not unidimensional. Even though the fatigue item was reported to only measure one factor (Van Hooff, et al., 2007), fatigue is often divided into mental and physical fatigue (Michielsen, et al., 2004) and scales frequently measure at least these two dimensions, sometimes more. Therefore, it may be that being mentally passive or active has an influence on mental fatigue (van der Linden, et al., 2003), whereas sedentary behaviour may influence physical fatigue.

Under that assumption, it may be that mental inactivity decreases mental fatigue, because no cognitive resources are used and being mentally active increases fatigue because of the

depletion of mental energy (DeLuca, 2005). For example Zhan, et al., (2008) studied the effects of working on a screen and reported increased mental fatigue. Hence, mental activity may be related to mental fatigue, depending on how much cognitive energy has been used, offering a potential explanation to why being mentally active increased fatigue, whereas being mentally passive decreased fatigue.

At the same time, being physically active increases the sense of energy and the feeling of being awake (Puetz, 2006), while being sedentary may therefore decrease energy and increase fatigue (Taylor & Dorn, 2006), thereby offering an explanation for the relationship between sedentary time and physical fatigue found in this study. Why exactly the interaction effect between sedentary time and mental activity had a different direction than the relationship between mental activity and fatigue is unclear though. It may be that there is a form of interaction between the two levels of fatigue or that another variable influenced the relationships. In contrast, a more likely explanation for the findings may be measurement error. Mental activity was only assessed for the time that participants were sedentary, without having a precise indication of sedentary time. For example, it may be that a participant was sedentary for 11 hours in total on one day, but was only sedentary for one hour prior to the first measurement, and then sedentary for four hours between two other measurements. The degree and impact of mental activity on fatigue was considered the same for all intervals, potentially leading to flawed results. Additionally, it was not assessed what participants did while not being sedentary, which may also have affected fatigue. Consequently, even though the suggested relationships and interactions explaining the findings would be interesting to explore in more detail, measurement error may have played a role in them. Hence, it is important to reflect on the different limitations and strengths of this study.

Limitations and Strengths

As already mentioned, the materials and procedure used in this study may have benefitted from some adjustments to increase the reliability and accuracy of the data. First of all, sedentary time was measured every 24 hours rather than at every measurement points. This was done to decrease the burden on participants (Eisele, et al., 2020; Stone, et al., 1997) , having equal spacing between the measurement times, and to capture all sedentary times. At the same time, this may have increased the memory bias, decreasing reliability and validity of the data (Pejovic, et al., 2016). Furthermore, a more frequent assessment would have offered the opportunity to

analyse the relationships between sedentary time, mental activity, and fatigue more precisely. On the other hand, the item assessing sedentary time did show a good reliability in the split-half analysis, suggesting that the reliability was not diminished to a great extent by memory bias.

Secondly, mental activity was treated as a dichotomous and the conceptualization was based on few previous studies and questionnaires (Cabanas-Sánchez, et al.2018; Hallgren, et al., 2018). Due to the relatively new distinction of mentally active and mentally passive sedentary behaviour, no predefined lists of behaviours belonging to each of the categories was available. Looking back, some behaviours may not strictly be either active or passive. For example, socializing may be very relaxing for some persons, whereas it can be very taxing for others, also depending on the topic of the conversation. Hence, the validity of this measure may be limited.

Related to this, a dichotomous measure may not capture all necessary nuances of mental activity. For example, writing an exam and doing crafts were both considered mentally active, though the exam is most likely more demanding. Furthermore, the dichotomous measure hindered the interpretation of the construction and interpretation of the Linear Mixed Models, as linear predictions are not optimal for distinct categories. Hence, a continuous measure of mental activity would have been more appropriate to capture details and facilitate the analysis. One option would be to use one of the various physiological measures of mental workload (e.g. blood pressure or skin conductance), which are unobtrusive and can be used by participants without disturbing their daily routine (Charles & Nixon, 2019), just like ESM. Hence, ESM and physiological measures may be combined in one study, similar to the use of ESM in combination with an accelerometer to measure physical activity and bouts of sitting. These combinations may offer more objective and wholistic data about the sedentary behaviour, mental activity, and state fatigue of students and other groups in the population.

Thirdly, fatigue was measured on a unidimensional item with questionable reliability. Using more items that distinguish between mental and physical fatigue may aid the exploration of the relationships presented in the present study. As a last limitation, fatigue is a construct that may be influenced by a multitude of factors (Shen, et al., 2006). Even though this study did take into account the cognitive workload and sedentary time of the participants, factors such as stress, a messed up sleeping schedule, or emotional troubles may still influence fatigue.

A clear strength of this study was the experience sampling method. It enabled direct insights into everyday sedentary behaviour and its relationship mental activity and fatigue. These

flexible and often changing mental states and activities could be captured in the present study, in contrast to cross-sectional studies. Furthermore, not only observational data, but the actual experience of the participant was recorded without being intrusive or too demanding. Even though this data richness did not lead to clear outcomes in the analysis, it does show that the relationship between sedentary time, mental activity, and fatigue in everyday live may be less straight-forward and linear than experiments and observations may have suggested. Additionally, this was one of the first studies to investigate the relationships between these three variables and among students, a risk group prone to elevated levels of sedentary time and fatigue. The results underline the necessity to conduct further research on this group to identify the potential health risks resulting from prolonged sedentary time and how to support their energy levels. Overall, this experience sampling study offers detailed data about in-vivo experiences of students and may serve as an inspiration for future studies in both the area of sedentary behaviour and the investigation of mental states.

Future Research

Based on the results of the present study and by taking into account the limitations discovered during the process, various recommendations for future studies can be given. First of all, the results suggest that a mediation model may be more accurate to describe the relationships between sedentary time, mental activity, and fatigue. Hence, the separate links between these variables should be investigated more closely, especially the relationship between sedentary behaviour and mental activity. Furthermore, it is still unclear how the different dimensions of fatigue may be related to different levels of mental activity and sedentary behaviour.

A possible study design would be similar to the one used in the present study, using experience sampling to get in-vivo insights. Sedentary behaviour may be assessed either by more frequent self-report or by wearing and accelerometer to decrease the burden on participants. This would offer the opportunity to control not only for complete sedentary time per day, but also for frequency and length of bouts and physical activity of participants (Giurgiu, et al., 2018). Mental activity may also be either assessed either by self-report or an unobtrusive physiological measure. If a self-report measure is employed, a scale should be used to determine mental activity and items have to be operationalized carefully to ensure validity. Fatigue on the other hand should be treated as a two-dimensional construct, differentiating between mental and physical fatigue. With these adjustments, a Mixed Linear Model using a mediation framework

may yield further insights. Overall, these changes should offer a better theoretical framework for studying the relationship between sedentary time, mental activity, and fatigue.

Conclusion

Even though we may all be tired of sitting, this study cannot fully explain whether sedentary time is actually the main factor that is increasing our fatigue. Overall, this study supports the assumption that sedentary time increases fatigue in university students. The type of activity performed while being sedentary seems to have an important impact on the relationship of sedentary time and fatigue, though further research is needed to determine the directions and workings of these relationships, as they are less clear and straight forward as previously expected. In future research, all variables should be measured on a frequent base and in a fashion that accurately represents the underlying constructs to aid a detailed understanding of the underlying framework. More precisely, fatigue should be measured on at least two dimensions, whereas mental activity should be treated as a continuum. Furthermore, the fit of a mediation model should be explored. A combination of ESM and physiological measures seems promising to yield reliable and valid results. Overall, the elevated levels of sedentary time and fatigue in the sample are a clear indication that physical and mental health among university students is at risk, threatening their well-being and academic performance. Hence, a bigger focused should be put on this risk group for future research, informing health interventions for future generations now and after the pandemic.

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Appendix A

Information Sheet and Informed Consent Form

Information Sheet

Hello and thank you for signing up as a participant in our study!

We are three third year Psychology students from the University of Twente. For this study, we want to explore the relationship between sedentary behaviour and states of psychological well-being. Sedentary behaviour refers to any waking behaviour that requires little energy, such as sitting or laying down. Earlier research has shown that there is a correlation between sedentary behaviour and certain mental health risks. As we as students are sitting quite a lot, especially during the Covid-19 pandemic, we want to further explore this relationship between this behaviour and mental health.

Over the course of the next eight days, you will fill in questionnaires about your sedentary behaviour and three mental health dimensions that we are interested in - fatigue, emotional exhaustion, and motivation. In total, you will answer one questionnaire on the first day and four questionnaires on every remaining day. Filling in the questionnaires should not take more than 20 minutes in total per day.

On the first study day, you will fill in one questionnaire in which we want to assess more general information. The following questionnaires will then focus on your sedentary behaviour and mental states during different times of the day. We will send you notifications to you when it is time to fill in the questionnaire. The measurements will be at some point in the morning, in the noon, in the afternoon and in the evening. The questionnaires will be available to you for about half an hour after you receive the notifications.To summarize, completing the study will take eight days in total with one longer questionnaire on the first day, and four short questionnaires per day for the remaining 7 days.

Keep in mind that at any point of the study, you are free to opt out of the study without having to provide an explanation. Your participation is completely voluntary.

Apart from the fact that participation will take a certain amount of time each day, there are no inconveniences or risks tied to this study.

The study will take place via an app named “Ethica”, so make sure to have a smartphone or tablet with you most of the day. You can install it here: Ethica - Apps on Google Play. The study registration code is 1737. You can also follow this link https://ethicadata.com/study/1737/ or scan the QR-code. By working with Ethica, all your information will be anonymized and it will not be possible to trace data back to you.

By participating in this study you are contributing to important psychological research into the well being of students - thank you for that!

If you have any remaining questions, feel free to contact this email address: j.wingbermuehle@student.utwente.nl.

Kind regards,

Judith, Simona and Jini

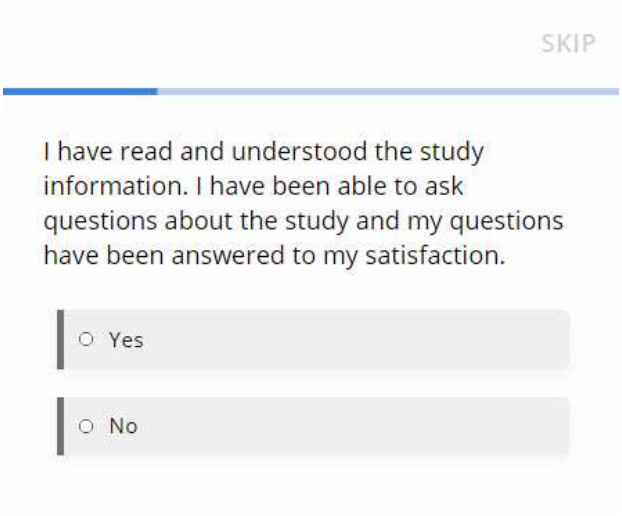
Informed Consent Form

I have read and understood the study information. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	Yes ◯	No ◯
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	Yes ◯	No ◯
I understand that taking part in the study involved a longer starting questionnaire, 4 short daily assessments of my behaviour and my mental state using the Ethica application (app or browser). I understand that I fill in these questionnaires without the researcher being present. Further, I was informed that all data will be anonymized and cannot be traced back to me.	Yes ◯	No ◯
I understand that information I provide will be used for a Bachelor thesis and that processes results may appear in published reports.	Yes ◯	No ◯
I understand that data collected about me will not be shared beyond the study team.	Yes ◯	No ◯
I hereby declare that I have been fully informed about my participation in the described study. By ticking the box, I actively consent to participating in this study and the processing of my data.	Yes ◯	No ◯

Thank you for your answers 😊 If you are eligible to participate in this study, please proceed by answering the baseline questionnaire that is presented to you in the study overview.

Figure 1.

Screenshot of the first informed consent question in Ethica



Appendix B

Items of the FAS

Item	Never	Sometimes	Regularly	Often	Always
Usually, I am bothered by fatigue.	O	O	O	O	O
Usually, I get tired very quickly.	O	O	O	O	O
Usually, I don't do much during the day.	O	O	O	O	O
Usually, I have enough energy for everyday life.	O	O	O	O	O
Usually, I feel physically exhausted.	O	O	O	O	O
Usually, I have problems starting things.	O	O	O	O	O
Usually, I have problems thinking clearly.	O	O	O	O	O
Usually, I feel no desire to do anything.	O	O	O	O	O
Usually, I feel mentally exhausted.	O	O	O	O	O
When I am doing something, I usually can concentrate quite well.	O	O	O	O	O

Appendix C

Daily Measures

Sedentary Behaviour Time

How many hours did you approximately spend sitting or laying down in the last 24 hours?

- Field to add number manually

Assessment of Mental Activity

What did you **mainly** do while sitting or laying down since the last measure (while being awake)?

only one answer possible

- Sozialising
- Watching TV/Netflix/YouTube/etc.
- Reading
- Working on a laptop/computer
- Playing computer or video games
- Listening to music
- Playing a musical instrument
- Doing crafts or arts
- Travelling in a motorized vehicle (such as car, bus, train)
- Being on social media
- Other
- I did not sit or lay down

State Fatigue

How fatigued to you currently feel?

1. Not at all
2. Barely
3. A little
4. Somewhat
5. Moderately
6. A good deal
7. Quite a bit
8. To a great extend
9. Strongly
10. Extremely