The association between Sedentary Time, Physical Activity and Mood: An Experience Sampling Study

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Abstract

The following Bachelor's Thesis addresses the association between daily sedentary time and a person's mood using prior physical activity as a moderator variable. It was conducted following a call in previous research for the use of the experience sampling method (ESM) and for a focus on physical activity as a possible moderator.

The study's sample consisted of 34 students (M_{age} = 22.4, SD_{age} = 2.2, 76.5 % female, 97,1 % university students). An experience sampling method was employed that let participants receive and fill out 5 questionnaires in total with the application 'Ethica' on their smartphones. Two of those questionnaires were one-time on day one (demographics and trait mood) and the other three (state mood, physical activity, and mood) were daily starting from day two to day 8. On day 9 only a questionnaire about sedentary time was sent. These questionnaires inquired about the students' amount of sedentary time and moderate-to-vigorous physical activity (MVPA) in the preceding hours and their current mood among the dimensions of *positive affect* and *negative affect*. An *overall mood* variable, consisting of these two dimensions was created after the data collection.

The major findings were as follows: (1) Students who spent more time being sedentary reported significantly diminished scores of *overall mood* (B = -0.0021, F (1, 189) = 4.679, $p < .05$), (2) *Physical activity* was not found as a moderator. However, *physical activity* was directly associated with reports of less *negative affect* (B = -0.013, F (1, 264) = 4.674, $p < .05$), and (3) More time spent being physically active was associated with an improvement in *overall mood* (B = 0.026, F (1, 274), $p < .05$).

It is noteworthy that the association between *physical activity* and *mood* did not manifest in the way it was expected in the form of a moderator for *sedentary time*. Rather it was directly associated with a lowering of *negative affect* and consequently of *overall mood*. Moreover, *sedentary time* did show a significant association with an amalgamated *overall mood* score, but not with its constituents *positive affect* and *negative affect*. The results support previous assumptions that sedentary behavior and physical activity are two distinct factors in the area of mood instead of just being the absence of each other. Future research should make use of more reliable measure of sedentary time such as accelerometers, consider the day of the week as a possible confounder for students' scores on all three variables, and examine the precise intensity of *physical activity* that would be needed for improvements in mood.

Keywords: Sedentary Behavior, Physical Activity, Mood, Experience Sampling

Introduction

There have been changes in the past decades through which it has become ever more common to be in a sitting position most of the time (Church et al, 2011). Dunstan, Healy, Sugiyama, and Owen (2010) point out that sitting is "engineered into our lives" (p. 2), listing watching TV, playing video games, browsing the internet, and increasing car ownership as examples. Moreover, Dunstan et al. (2010) name computers and labour saving devices at work, precluding standing up for certain tasks, as reasons for a greater share of sitting throughout a person's daily life. This is accompanied by a decline in the amount of physical activity that people engage in. At work, during transport, and at home people are less physically active (Brownson, Boehmer, & Luke, 2005).

For many people the Covid-19 pandemic then has brought about even more time to spend sitting. Employers switch to home office for the continued operation of their businesses and students stay away from their lecture halls to be taught via internet-based conference meetings. Commutes to work cease to exist and most cultural institutions are closed to curtail the spread of the infection. So, there is less reason to be out and about and more to sit at home.

Even before the COVID pandemic exacerbated it, this large-scale societal change in occupational and general activity level has brought about a field of research concerned with the health-related consequences of sitting. Among the field of research on sitting behavior, also called sedentary behavior (S.B) is a growing focus on its relationship with mental health (Giurgiu et al., 2020; Hoare, Milton, Foster, & Allender, 2016). To examine one of these relationships between S.B. and mental health this thesis aims to explore the association between daily sitting time and self-reported mood as one indicator of mental health. Hoare et al. (2016) in their systematic literature review suggest for future research to examine whether physical activity moderates the association between S.B. and mood.

Sedentary Behavior

A definition of S.B. is provided by Tremblay et al. (2017). In their conference proceedings they used "any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents while in a sitting, reclining or lying posture" (p. 2) as definition to classify behavior as sedentary. Put more simply, S.B. refers to such behaviors as sitting in front of a computer at work or in front of the TV at home, watching a show. On the other hand, a sitting activity with a higher physical engagement, like riding a bike, would not classify as S.B. under this definition. This means that someone might be physically very active in their free time (e.g. jog every day) and still sit too much when at their job. Persons with such an activity pattern are often referred to as 'active couch potatoes' (Dunstan et al., 2010)

Owen et al. (2011) and Tremblay et al (2017) emphasize that S.B. as a health risk differs from a lack of physical activity. Apart from the somatic consequences of S.B., e.g. regarding mortality, chronic

diseases, and obesity (Biddle et al., 2019), the impact on mental health has been reported to include depression, psychological distress, anxiety, and mood disturbances (Giurgiu et al., 2019).

Physical activity

Being physically active has been identified as an important factor for a person's health, both bodily and mental. In their meta-review Warburton and Bredin (2017) suggested that it is not even necessary to reach a certain threshold of exercising. "Simply moving more" (p. 4) should already yield health benefits. As examples of light, moderate, and vigorous exercise Piercy et al. (2018) mention light household chores, brisk walking, and jogging. Furthermore, they point towards different indicators of mental health that can be improved through physical activity, such as better quality of life, reduced anxiety, and a lower risk of depression Piercy et al. (2018). In the context of mental health promotion, Giurgiu et al. (2019) called the replacement of S.B. with physical activity a 'major health priority' (p. 10). Specifically, this thesis focuses on participants' mood and how it is associated with S.B. and moderate-to-vigorous physical activity.

Mood

Mood is an often examined indicator in this discussion on mental health in the context of the relationship between S.B. and physical activity (Chan et al, 2019; Endrighi, Steptoe, & Hamer 2016; Giurgiu et al., 2019; Giurgiu et al., 2020a; Giurgiu et al., 2020b). In their systematic review, Chan et al. (2019) termed mood an important factor in constituting mental health. Being physically active is assumed to increase positive and decrease negative affect. Physical activity is then proposed as a 'cost-effective way to improve quality of life and combat mood problems' (Chan et al., 2019, pp. 17-18).

To conceptualize mood, Watson, Clark, and Tellegen (1988) suggested a two-factor model. In this framework, mood consists of positive and negative affect. Positive affect refers to the 'extent to which a person feels enthusiastic, active, and alert' while Negative affect points toward 'subjective distress and unpleasurable engagement' (Watson et al., 1988, p. 1). According to them, examples of positive affects are 'excited', 'inspired', and 'attentive' and for negative affects 'irritable', 'upset', and 'jittery' (Watson et al., 1988, p. 5).

Chan et al. (2019) highlight a limitation that their found results were mostly from experimental studies leading to a lower ecological validity of the findings. For future research the authors suggested using experience sampling to track mood changes throughout daily activity.

Experience Sampling Method

The experience sampling method (ESM) is described by Myin-Germeys et al. (2018) as a 'structured self-report diary technique' (p. 1). The idea is to decrease recall bias and capture behavior and internal processes as they occur throughout the day of the participants in order to get more ecologically valid results than from experimental studies. An example would be participants receiving a prompt on their smartphone that lets them fill out a short questionnaire (van Berkel, Ferreira, & Kostakos, 2017). This method can include both self-reports on behavior and internal processes, but can also be accompanied by objective measuring tools like a heart monitor, accelerometer or inclinometer. In the context of this thesis, the experience sampling questionnaire will focus on the following behavioral and mental health characteristics: the participant's recent length of S.B., if and how long they have engaged in physical activity recently, and finally their current (as of filling out the questionnaire) mood.

Myin-Germeys et al. (2018) point toward ESM as being well-suited for research in the field of mental health. One of the advantages of using this method is curtailing possible recall bias compared to other methods that ask participants to remember further back in time than just a few hours or a day ago. Capturing 'actual experience as it occurs in everyday environments' (p. 1) is another reason to use the experience sampling approach, meaning it lacks (in a positive sense) the control of experimental studies. The idea behind this is for the results to offer a more ecologically valid picture. Its longitudinal nature offers the potential to examine the variability and 'temporal associations' (p. 3) between the behaviors and internal phenomena under study. Lastly, the authors also point to the empowerment of the persons participating in the experience sampling study. They are being treated as the expert on their own experience. In the case of this study, it is university students that are to be asked regarding their daily sitting time, physical activity and mood.

University Students

The target group for this thesis is university students. According to Castro, Bennie, Vergeer, Bosselut, and Biddle (2020) this group is especially likely to exceed healthy levels of time spent sedentary. In this context, Patterson et al. (2018) stated that in and above the range of 6 - 8 hours/day the risk for all-cause mortality is the strongest.

The common activities of students, like attending lectures, writing assignments or studying are suspected to drive the increased sitting time in this population. This is reflected in the reported average sedentary time for students of 7.29 hours/day in contrast to 5.86 hours/day among young adults in general (Castro et al., 2020). An elevated amount of sedentary time such as this would then put students at a greater risk of the aforementioned mental health risks, such as depression and anxiety Romero-Blanco et al. (2020).

Zhai and Du (2020) also pointed toward worsening psychological consequences for students due to the disruption of academic routine by the Covid-19 pandemic, such as anxiety, depression, substance abuse, difficulty sleeping, and stress eating. Hence, mental health has been termed an important factor for achieving academic success with a typical onset of many mental disorders between 18 and 24 years old (Eisenberg, Golberstein, & Hunt, 2009).

At the time of this study's data collection (April - May 2021), the Covid-19 pandemic was still ongoing and due to limitations on public gatherings universities mostly did not offer on-campus lectures. Daily academic routine had for the most part shifted toward virtual lectures and internet-based meetings. Romero-Blanco et al. (2020) examined the effect of the lockdown on university students' levels of S.B. and physical activity. They found that both physical activity and time spent sedentary increased and concluded that even if students use the time they now have to spare to be more physically active, they still could suffer the health consequences from an increased level of S.B. Romero-Blanco et al. (2020) then suspect that students started to exercise more during lockdown to counteract their perceived increase in sedentary time.

Furthermore, Copeland et al. (2021) examined the effect of Covid-19 on the mood of college students and found "modest but persistent" (p. 7) changes across their sample. According to their findings the students' mood was negatively impacted by the consequences of the pandemic on academic routine. They conjecture that it might be the uncertainty, isolation, economic and health effects that contribute to a diminishing mood in students.

This thesis aims to focus further on the mood of university students and its association with their sedentary behavior and physical activity during the lockdown.

Research Question and Hypotheses

The present thesis's goal is to contribute to the literature on S.B., physical activity and mood by using the approach of experience sampling to longitudinally examine the link between S.B. as the independent variable, mood as dependent variable, and physical activity as moderator variable. Physical activity was included as a moderator to explore the assumption of both Hoare et al. (2016) and Romero-Blanco et al. (2020) that a person might suffer the negative consequences through S.B. even if they engage in a large amount of physical activity. The findings of Patterson et al. (2018) point toward physical activity attenuating the effect of S.B. on somatic outcomes. This thesis's research question aims to examine whether it also attenuates its association with a mental construct such as mood. In order to support the assumption of Hoare et al. (2016) and Romero-Blanco et al. (2020) the results would have to show that physical activity does not attenuate the expected negative association between S.B. and mood, neither as a moderator nor on its own.

The research questions are, for a population of Dutch university students, whether self-reported mood is significantly associated with self-reported overall sitting time in the preceding period and whether physical activity during the preceding sitting period moderates the effect. The two questions that are of interest here are how strong the association between physical activity and mood is and whether the former acts more as moderator or a direct influence on mood. The hypotheses are as follows:

H_1: "Overall sitting time is positively associated with state negative affect."

Being one of the two dimensions of mood this hypothesis represents one part of the most basic premise of this study, that a person that sits more should have more thoughts and emotions that fall under negative affect.

H_2: "Overall sitting time is negatively associated with state positive affect".

Similar to the first, this hypothesis represents the second half of this study's conceptualization of mood. It likewise follows previous literature's basic findings that certain affect-related positive thoughts and emotions should be diminished if a person spends more time sitting. The last hypothesis is concerned with physical activity, which has been suggested to moderate the association between S.B. and mood.

H_3: "Physical activity of moderate to vigorous intensity lessens the effect of sedentary behavior on both dimensions of affect and overall mood."

Methods

Participants

For this study, University students who were at least 18 years old, are proficient in English and own a smartphone were invited to participate. The final sample (*n = 34)* consisted of 33 University students and 1 student of higher education. 26 (76.5 %) were female and 8 (23.5 %) were male. 3 (8.8 %) were Dutch, 30 (88.2 %) were German, and 1 (2.9 %) indicated "other" as their nationality. Participants' mean age was 22.4 (SD = 2.2). Recruitment was conducted via convenience sampling through the university's research subject pool SONA as well as convenience snowball sampling of students known to the researchers. This was done either by approaching them personally or texting them, inviting them to participate and asking them to tell other students of the study if possible. The study was approved by the Ethics Committee of the Faculty of Behavioral, Management, and Social Sciences (BMS) at the University of Twente (requestnr. 210263). Participation was voluntary and students were offered to earn study credits with it. Before starting, students were required to fill out an active informed consent form to be able to become part of the study.

Materials

For the data collection the program 'Ethica' was used. It is an experience sampling research tool that enables researchers to create questionnaires that are then sent to participants. The items inquiring about the participants' demographic information consisted of 4 items. The first one asked about the participants' age. The second inquired about their occupation, offering (1) student (university), (2) student (higher education), and (3) other as possible answers. This item was not relevant to the analysis itself but serves as an exclusion criteria. The third item was about the participants' gender with (1) female, (2) male, (3) other, and (4) prefer not to say for possible answers. The fourth question asked the participants whether their nationality is (1) German, (2) Dutch, or (3) other. The demographic questionnaire items can be found in Appendix B.

Items on sedentary behavior were taken from the PAST-U questionnaire (Past-day Adults' Sedentary Time-University) which contains 9 items. Clark, Pavey, Lim, Gomersall, and Brown (2015) reported an acceptable validity with university populations including students. They used the ActivPAL as a criterion to test the PAST-U's validity and found a correlation of r = .57, which exceeds their reported cut-off point of .5. This is in line with the performance of the original version of the PAST, for which an acceptable reliability (intraclass correlation coefficient: .5) and a good criterion validity (r = .57, against the ActivPAL) was reported.

In order to not overburden participants during the daily questionnaires and keep compliance rates as high as possible it was shortened to 6 items. The two items about sedentary behavior for study and work were merged into one item. The item about sitting in transport was dropped since due to the corona pandemic the daily commute to campus for students is not there. The item inquiring about the use of computers and electronic devices was also not included. An example of an item is the following: "How many minutes were you sitting while studying/working yesterday? (include the time at university, during lectures, tutorials, meetings, group discussions, self-study, study from home etc.)." The final list of items on participants' sedentary time can be found in Appendix F.

Concerning the participants' physical activity, a single self-constructed item was used: "In the last 4 hours, approximately how many minutes did you engage in moderate-to-vigorous physical activity? (e.g. walking briskly, bicycling, running or jogging, jumping ropes, lifting weights, etc.)". It was an open question requiring participants to type in their estimated time of physical activity. The item excluded light physical activity because of its wide reaching nature; counting such things as standing already as physical activity. Moreover, it was intended to make estimating time easier for participants and obtain a sharper defined result to focus only on moderate-to-vigorous activity. The focus on the last 4 hours serves the purpose of diminishing recall bias and making it easier for participants to estimate the length of their physical activity as precisely as possible. Examples of moderate-to-vigorous physical activity that are

presented to participants are taken from Warburton and Bredin (2017) and Piercy et al. (2018). For the purposes of data collection physical activity is operationalized via length in minutes and a compound item inquiring about moderate-to-vigorous physical activity. The questionnaire item can be found in Appendix E.

Regarding the construct of mood, this study distinguished between its trait and state form. Trait mood is concerned with a more or less stable characteristic of a person. This means that someone should have a tendency to fall into a certain area for both positive and negative affect throughout their lifetime. On the other hand, state mood describes the short-term mood of a person at the moment of assessment. This can concur with the trait assessment or deviate from it. To summarize in layman's terms, a generally cheery person can have a bad day and a generally grumpy person can experience a pleasant day once in a while.

To measure mood the international and short version of the Positive Affect Negative Affect Schedule (I-PANAS-SF) was used. Thompson (2007) reported a test-retest reliability coefficient (within 8 weeks) of .84 ($p < .01$) for both negative and positive affect constructs. For convergent validity (validity through comparison with other measures of the same construct), the correlation of positive affect with a subjective well-being scale (Diener, 1984) and a subjective happiness scale (Lyubomirsky and Lepper, 1999) has been reported at $r = .33$, $p < .01$ and $r = .39$, $p < .01$ respectively. For the negative affect construct the correlations are $r = -.33$, $p < .01$ and $r = -.051$, $p < .01$ respectively. This means there is a weak, but significant correlation between the I-PANAS-SF and the subjective well-being scale, while there is a weak to moderate negative correlation between the I-PANAS-SF and the subjective happiness scale.

The full 10-item scale of the I-PANAS-SF contains items such as 'active' and 'inspired' for the positive affect side of mood and 'upset' and 'nervous' for negative affect. It is used for the initial data collection on trait mood on the day of registration in its full length. However, for the sake of brevity, during the daily prompted questionnaires on state mood a shortened version of 6 items was utilized. The items chosen for positive affect were: (1) active, (2) attentive, and (3) determined. Those for negative affect were: (1) upset, (2) nervous, and (3) afraid. among both scales those that have the highest factor loading regarding their dedicated construct (Thompson, 2007). Moreover, the items inquiring about these constructs were worded differently depending on whether they were concerned with a trait or a state. A trait item is indicated by the formulation of how the participant "normally" feels, while a state item asks how they feel "right now". The items on trait mood can be found in Appendix C, the items on state mood in appendix D.

Procedure

Participants downloaded the Ethica application through a link via their smartphone's app store and registered for the study. Two times a day participants were asked to report on their current mood and length of physical activity preceding the filling out of the questionnaire. Once a day they indicated how much time they had spent sedentary on the day before. This frequency was chosen in order to not overburden participants and keep compliance rate as high as possible. Data collection started on the 9th of April, 2021 and ended on the 9th of May, 2021. The data collection for a single participant extended over 9 days. The first day the participant receives information about the study's aims and methods, contact information of the researchers, as well as a form of active informed consent required to fill out to be part of the study (Appendix A). On the same day they receive a prompt to fill out a questionnaire on their demographics (age, occupation, nationality, and gender) and their trait mood. Starting on day 2 until day 8 participants received two prompts a day randomly within a set time frame; one between 10:00 and 13:00 and one between 17:00 and 20:00. This random prompting is suggested by van Roekel, Keijsers, and Chung (2019) in order to reach the participants in a possibly natural context, without them having been able to see it coming and change their behavior because of it. Both prompts led to questionnaires about their state mood and physical activity within the last 4 hours. The first questionnaire of the day also contained items that asked to estimate how much time participants have spent sedentary on the previous day within specific contexts. These items started appearing only on the third day since sitting time on day one (day of registration) is not important for this study. On day 9 there was only one prompt leading to the final question about sedentary behavior for day 8. The items within the state mood questionnaire appeared in random order.

After receiving a prompt, a participant had 1½ hours to complete the survey with a reminder halfway through; otherwise the data point will be handled as missing. However, the participant was then still able to continue the study normally. However, if a participant falls under a threshold of 50 % completed questionnaires his/her data was excluded from the set. A single questionnaire took about 5 minutes to complete. Table 1 shows the timeframes for the prompts and the dedicated questionnaires they lead to.

Table 1

Timetable for prompts and content of questionnaires

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9
Immediately after registering: Demographics, trait mood	11:00-13:00 State mood & physical activity	11:00-13:00 Sedentary time, state mood, & physical activity	11:00-13:00 Sedentary time, state mood, & physical activity	11:00-13:00 Sedentary time, state mood, & physical activity	11:00-13:00 Sedentary time, state mood, & physical activity	11:00-13:00 Sedentary time, state mood, & physical activity	11:00-13:00 Sedentary time, state mood, & physical activity	11:00-13:00 Sedentary time
	17:00-20:00 State mood & physical activity	17:00-20:00 State mood & physical activity	17:00-20:00 State mood & physical activity	17:00-20:00 State mood & physical activity	17:00-20:00 State mood & physical activity	17:00-20:00 State mood & physical activity	17:00-20:00 State mood & physical activity	

Data Analysis

The program used for the analysis was 'SPSS Statistics 25'. After the data collection was completed the data was downloaded from Ethica and imported to SPSS to be prepared. Each "Activity" in Ethica yields its own dataset that corresponds to the blocks of questionnaires shown in Figure 1. Hence, 5 different datasets were drawn from the application: (1) day of registration, (2) morning of day 2, (3) morning of day 3 - 8, (4) evening of day 2 - 8, and (5) morning of day 9. Every dataset was merged into one except for the one regarding the day of registration, which contained demographic and trait data. Next, where necessary the variables were changed from string into numeric variables and given identical names for SPSS to be able to merge the entries together. Data from participants with a compliance rate of under 50 % were removed from the data set according to the value given by Conner and Lehman (2012).

Furthermore, the data set was searched for systematic errors of participants. This resulted in re-writing some replies given for the amount of sedentary time and physical activity. As an example, some participants started off the study by giving '1' or '2' as their time being sedentary or physically active, but then with subsequent surveys started answering with '60' or '120' (or other multiples of 60, indicating that they likely meant hours instead of minutes in the beginning). In cases like this it was assumed that the participant misread (or did not see) the instructions that came with the survey item and instructed them to write the answer in minutes. Subsequently, answers like this were changed to fit into the expected format: '1' became '60', '2' became '120', and so on.

Four new variables were created termed "state positive affect", "state negative affect", "state mood", and "state sedentary time". Each of those represents the sum score of a variable for any given time point. State positive affect for example is the sum of all 3 scores a participant gave on the Likert-scales concerning positive affect at that timepoint; likewise State negative affect. State mood is an amalgamated score out of these that is calculated by subtracting the negative affect score from the positive affect score. It is to be used in additional exploratory analysis of the data. The variable trait mood was included as part of a shared data collection but was subsequently not used in this thesis's analysis, because it was not relevant for the research question and hypotheses.

State sedentary time is calculated by adding all six measures of sedentary time at that timepoint to come up with a total time.

Then, for the descriptive statistics "occupation", "gender", and "nationality" a simple list of frequency and share is computed. For "age" a sample-wide average and standard deviation is calculated to account for the nested nature of the data, a new variable called "timepoints" was added to group every participant's entries together in chronological order. There were overall sixteen different timepoints at which a participant entered data into the app. However, the first on day 1 only registered demographic and trait data and the last on day 9 only the sedentary time of day 8. Hence, the first one is not included in the

analysis and the last one taken to belong to the day before, making for 14 timepoints overall. So, timepoint 1 represents the morning of day 2 and timepoint 14 stands for the evening of day 8. The trait mood data assessed on day 1 was part of a shared data collection and was ultimately not included in the analysis of this thesis.

Furthermore, in order to have a more concise score for mood an amalgamated value of both positive and negative affect was calculated. This was done by subtracting each participant's negative affect from their positive affect score. This leads to a score between +12 and -12. Through using this method of merging the two mood dimensions a score is created that indicates the balance between positive and negative affect within a single participant. A value of +12 would then mean someone who always scored the maximum for positive affect and always the minimum for negative affect. This would describe someone who only ever is in a good mood and never has bad days. Conversely, a score of -12 describes someone that always indicated maximum negative affect and minimum positive affect. A person like this would always be in a bad mood and never experiences positive affect. Hence, a participant whose average scores for positive and negative affect are the same would score 0 on this overall mood scale regardless of intensity on both sides.

To answer the hypotheses a linear mixed model was utilized. This is to account for the nested and longitudinal nature of the data and to account for missing data. Within the SPSS menu of this model the user-ID was chosen as subjects and timepoints for repeated measures. For covariance structure "AR (1)" was chosen. After that, mood (3 models: positive affect, negative affect, overall mood) was taken to be the dependent variable and timepoint as factor in order to answer hypotheses 1 and 2 as well as to explore overall mood (consisting of positive and negative affect) as a dependent variable. For hypothesis 3 the process is repeated but physical activity is added as a covariate and interaction effect with total sedentary time. From the output the unstandardized estimate (*B*), stating the mean response for each factor (in this case timepoints), are used for analysis. A significance level of .05 was chosen for the interpretation of the result. These are not person-mean centered so that they show between-person differences.

Results

Descriptive statistics

Three participants were excluded for having filled out seven or less questionnaires. This corresponds to being below 50 % compliance rate (rounded up). One participant was excluded for very likely not taking the study seriously by giving the maximum score for every single state measurement (both positive and negative affect) and, when asked about the amount of moderate-to-vigorous physical activity, answering with '-1'. After cleaning up the data set, 34 participants remained in the sample. The

overall compliance rate across all participants was 81.9 %. Table 2 shows a summary of the demographic statistics for this study's sample.

Table 2

Summary of demographic statistics

	Frequency	Percent
Occupation		
University student	33	97.1
Student in higher education	1	2.9
Gender		
Female	26	76.5
Male	8	23.5
Nationality		
Dutch	3	8.8
German	30	88.2
Other	1	2.9

Note. n = 34

Mood per Participant

For this study, mood was conceptualized as consisting of two dimensions called positive affect and negative affect. Each dimension was assessed with three survey items respectively that were to be answered on a 5-point Likert scale. This leads to the scale for each of these dimensions to range between 3 and 15, with increasing scores indicating more subjective experience of the respective mood dimension. Figure 1 shows per participant their averaged value for both affect dimensions throughout the 14 assessment time points. Figure 1 shows that every participant on average indicated a higher positive than negative affect.

Figure 1

Mean state positive and negative affect per participant

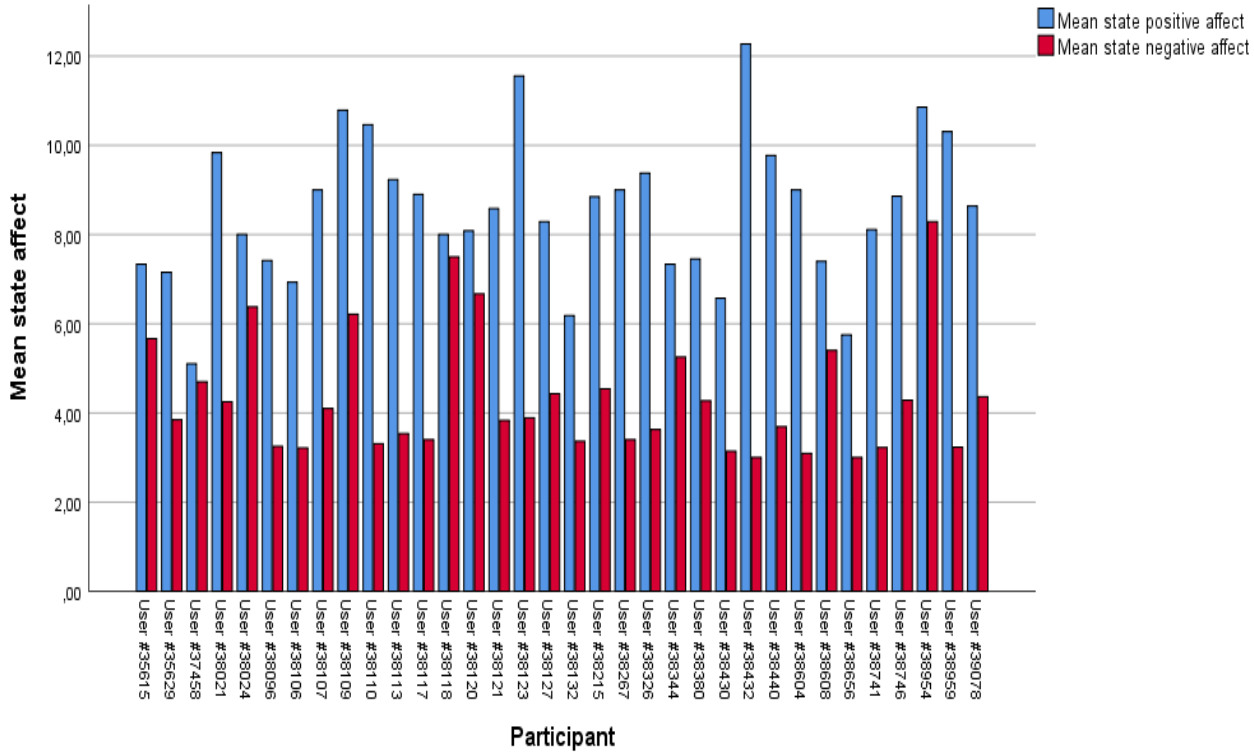
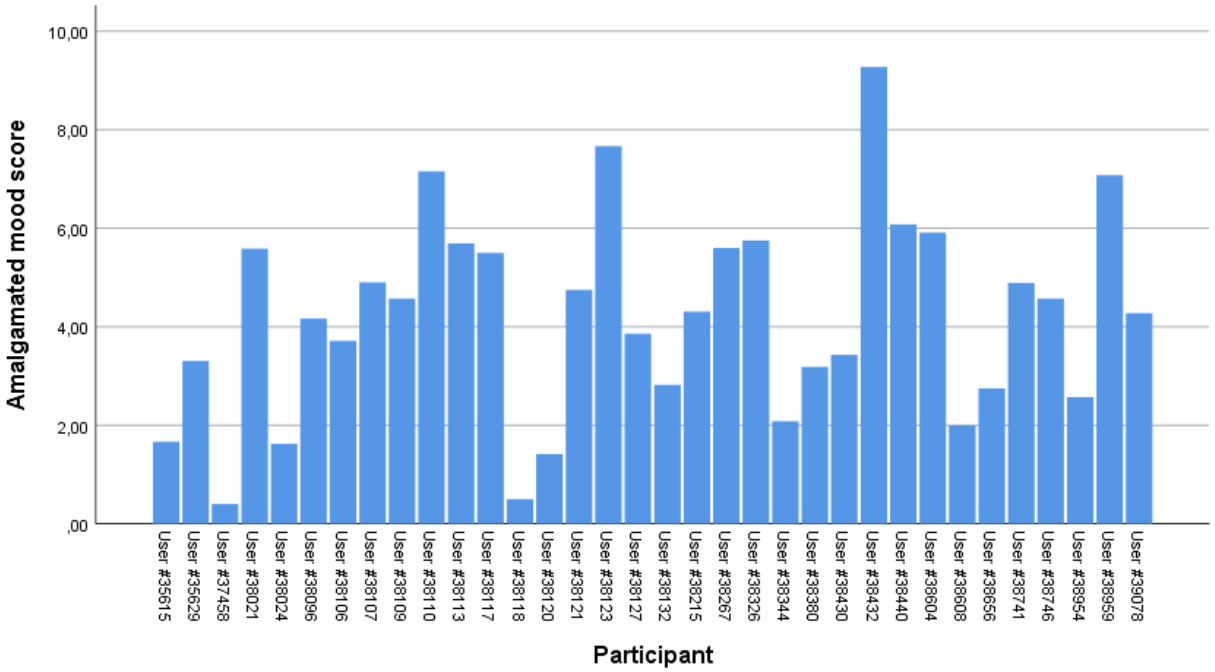


Figure 2 shows the overall mood score for each participant that was calculated by subtracting their negative affect score from their positive affect score.

Figure 2

Amalgamated mood score per participant



To clarify both Figure 1 and 2 the participants #38118 and #38432 make for good examples. The former's positive and negative affect are very close to each other so their overall mood score is close to zero. The latter scores exceptionally high on positive and at the same time very low on negative affect. This leads to their overall mood score to be strikingly high. It is also noteworthy that each participant reports a higher level of positive than negative affect leading to every overall mood score to be positive.

Apart from looking at each individual participant the data can also be shown over time. This encompasses the estimated marginal means of every participant's value for a certain variable for a certain time point. Figure 3 shows the mean values for both positive affect, negative affect, and overall mood for all 14 time points. Of course, every participant partook throughout a different time period, so the figure shows the mean of all the participants' mood at their respective first to 14th questionnaire. Hence, the timepoints are not connected to certain days of the week.

Moreover, one of the most basic inquiries of this study was whether a greater time spent sedentary is associated with a worse mood. In this context, it is interesting to compare the data from Figure 3 with those in Figure 4, which shows the mean of the overall sitting time for all participants at those same time point.

Figure 3

Mean positive and affect and overall mood over time

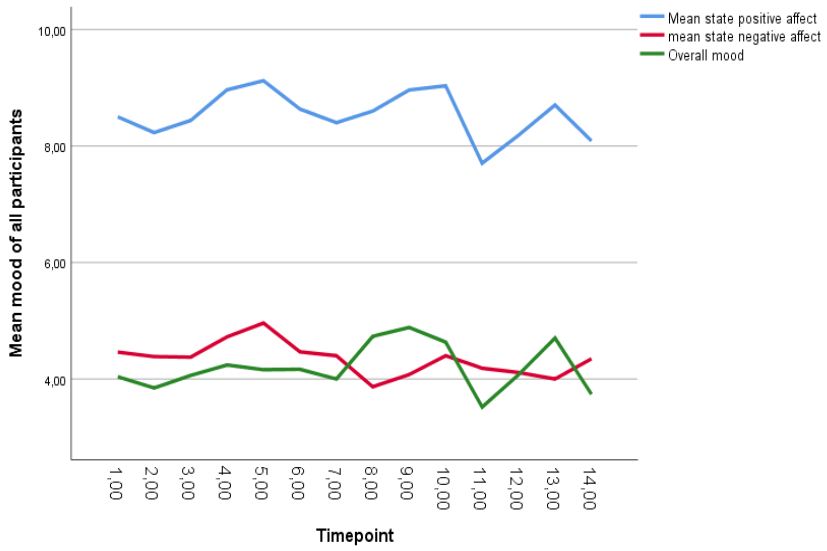
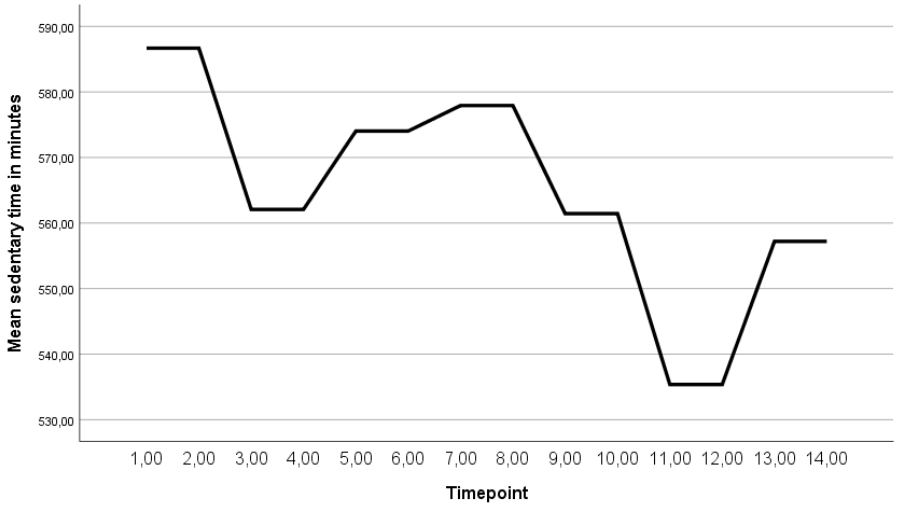


Figure 4

Mean sedentary time at different time points



What is most noteworthy is the sharp decline in positive affect between the 10th and 11th time point. Since the overall mood value is an amalgamated score made up of both positive and negative affect,

and negative affect stays relatively stable during that same time period, the overall mood likewise declines. The remarkable observation here is, as can be seen in Figure 4, that the mean sedentary time of the sample's participants registers a similarly strong drop at the same time point. However, this points toward an association between sedentary time and positive affect that is partly against expectation. At times a rise in sedentary time corresponds to a drop in positive affect (time points 2 - 3). At other times a drop in sedentary time comes likewise with a decline in positive affect (time points 8 - 11)

Compared to this, the mean state negative affect seems to be less fluctuating overall and at times seems to go against the expectation of being increased by a higher sedentary time and decreased by lower sedentary time This seems to partly support and partly be contrary to this study's hypotheses regarding sedentary time and a person's two mood dimensions.

Figure 5 shows the mean moderate-to-vigorous physical activity per participant. It can be seen that there is a quite large variance in the data, ranging from a report of 0 minutes of MVPA to more than 2 hours a day on average.

Figure 5

Mean amount of physical activity per participant

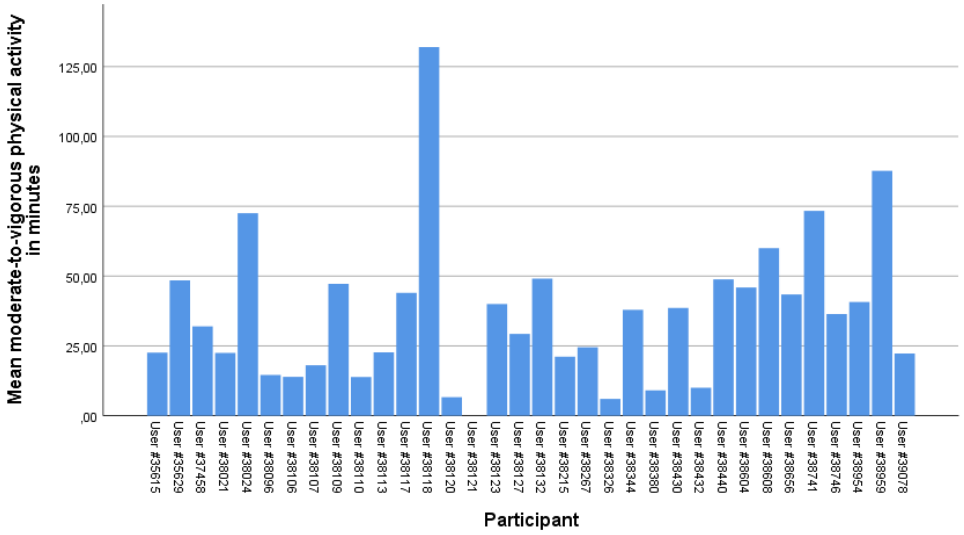
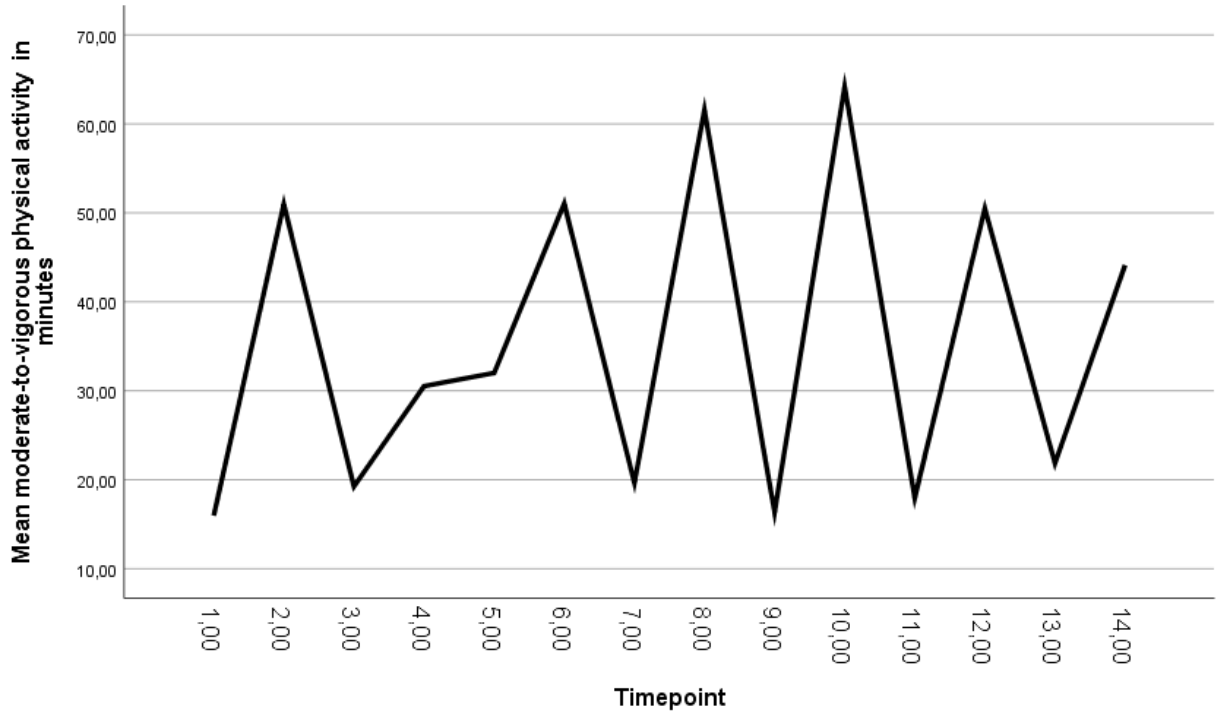


Figure 6 shows the mean amount of moderate-to-vigorous physical activity of all participants over time. The strong and relatively consistent fluctuation might be attributable to the times of day that the questionnaires were sent out. Each day has had one around midday and one in the early evening, asking about the hours that preceded it. Thus, the odd numbered timepoints are all earlier in the day and the even numbered ones are in the evening. This might explain why these two groups of time points so

consistently yield markedly different amounts of physical activity. It might be that the more intense spectrum of physical activity, like MVPA, is more likely to be done later in the day rather than early in the morning.

Figure 6

Mean physical activity over time



Inferential statistics

Hypothesis 1

This hypothesis was as follows: 'Overall sitting time is positively associated with state negative affect.' It was expected that a person that sits more throughout the day should report higher amounts of negative affect than a person that sits less.

Running a linear mixed model with total sedentary time as independent variable and negative affect as dependent variable shows a small and positive but non-significant slope coefficient, $B = 0.0008$, $t(230) = 1.274$, $p = .204$.

This suggests that variance in state negative affect is not explained by the total time that participants spent sedentary on that day. Hence, from the collected data of students it seems that the amount a person sits is not associated with having a stronger negative affect. Hypothesis 1 is thus not supported by the data and should be rejected.

Hypothesis 2

This hypothesis states that 'overall sitting time is negatively associated with state positive affect'. Regressing positive affect on total sedentary time via a linear mixed model yields an expectedly negative, albeit small and narrowly non-significant association between the two, B = -0.0015, t(208) = -1.956, p = .052, 95 % confidence interval [-0.003035, 0.000012]. Hence, no support has been found for the hypothesis that a greater amount of overall sitting time is associated with lower reports of positive affect. Hypothesis 2 should be rejected.

Exploratory regression on an amalgamated mood variable

The regressions of both positive and negative affect respectively have suggested that there is no statistically significant association between how much a person sits throughout the day and their corresponding two mood dimensions. To explore the data more a third regression was run using total sedentary time and amalgamated mood.

The model showed a small negative effect of sedentary time on overall mood. Moreover, this time the effect was found to be significant, B = -0.0021, t(188) = -2.163, p = .032. The result of this model indicates that with every additional minute that a student spends being sedentary their overall mood should decrease by 0.002 units on a scale that ranges from +12 to -12. Hence, for example sitting for 2 hours would then be associated with a decline of 0.24 points on overall mood.

With the two mood dimensions put together like this the results rise to statistical significance. Even though there was no initial hypothesis connected to this overall mood variable it does lend support to the general idea of the study that too much sitting is associated with the worsening of a person's mood.

Hypothesis 3

This hypothesis states that 'physical activity of moderate to vigorous intensity lessens the effect of sedentary behavior on both dimensions of affect'. For this hypothesis the variable of moderate-to-vigorous physical activity is added to the models as a moderator. Then, regressing positive affect on MVPA and sedentary time it shows small and non-significant effects for sedentary time (B = -0.0011, t(239) = -1.212, p = .227) and amount of physical activity (B = 0.0117, t(266) = 1.552, p = .122) on positive affect as well as the interaction effect between the two (B = -0.000003, t(264) = -.248, p = .804).

This indicates that neither the amount of sitting time, nor the time spent being physically active on their own have an effect on the students' positive affect. Furthermore, the expected moderating effect of physical activity on the association between sitting time and positive affect could not be established. It is in the hypothesized direction but it is remarkably small and does not rise to statistical significance.

Repeating the same process with negative affect as dependent variable yields the following results: The effect of sedentary time is negligibly small and non-significant, B = -0.000034, $t(249)$ = -.046, p = .963. However, it should be noted here, that this is the first time in the inferential statistics an association of sedentary time with an affect dimension goes against expected direction and points towards sedentary time being associated with less negative affect; even though it, too, is non-significant. MVPA's effect is also small and expectedly negative, but was shown to be significant, B = -0.0129, $t(264)$ = -2.162, p = .032. This points toward physical activity on its own being beneficent by being associated with a lower negative affect. According to this model, each minute that is spent being moderately to vigorously active decreases negative affect by approximately .013 points on a scale that ranges from 3 to 15. So, one hour of moderate-to-vigorous physical activity should diminish negative affect by 0.78 points and thus improve the overall mood score by the same amount. The interaction effect between sedentary time and MVPA is not in the expected direction. However, similar to the main effect of sedentary time it is strikingly small and non-significant, B = 0.0002, $t(261)$ = 1.899, p = .059.

To again explore the data more, another regression was run with the amalgamated variable for overall mood by combining participants' results for positive and negative affect. In this model the association of sedentary time was shown to be in the expected negative direction. But, it is very small and non-significant, B = -0.0009, $t(222)$ = -.764, p = .446. The association between MVPA and mood, however, was shown to be positive and significant, B = 0.0264, $t(274)$ = 2.502, p = .013. The interaction effect again was very small and non-significant, B = -0.000027, $t(273)$ = -1.441, p = .151.

Again, moderate to vigorous physical activity on its own, rather than as a moderator seems to be associated with better overall mood, indicating an approximate .026 increase for overall mood per minute of activity on a scale ranging from -12 to +12. Table 3 shows a summary of every model's statistics discussed so far.

Table 3

Summary of model statistics

		Estimate (B)	F-value	t-value	p-value	95 % confidence interval
Model						
	Sedentary time and negative affect (DV)	0.0008	1.623	1.274	.204	-0.0004, 0.002
	Sedentary time and positive affect (DV)	-0.0015	3.825	-1.956	.052	-0.003, 0.00001
	Sedentary time and overall mood (DV)	-0.0021	4.679	-2.163	.032	-0.004, -0.0002
Sedentary time, physical activity, and negative affect (DV)	Sedentary time	-0.00003	0.002	-0.046	.963	-0.001, 0.001
	Physical activity	-0.013	4.674	-2.162	.032	-0.02, -0.001
	Interaction effect	0.00002	3.608	1.899	.059	-0.0000007, 0.00004
Sedentary time, physical activity, and positive affect (DV)	Sedentary time	-0.001	1.468	-1.212	.227	-0.003, 0.0007
	Physical activity	0.01	2.407	1.552	.122	-0.003, 0.03
	Interaction effect	-0.000003	0.061	-0.248	.804	-0.00003, 0.00002
Sedentary time, physical activity, and overall mood (DV)	Sedentary time	-0.0009	0.584	-.0764	.446	-0.003, 0.001
	Physical activity	0.026	6.259	2.502	.013	0.006, 0.05
	Interaction effect	-0.000027	2.077	-1.441	.151	-0.00006, 0.00001

Discussion

Main findings

The aim of this study was to examine whether the length of time a person spends sitting throughout the day is associated with a worsening of that person's mood. Moreover, the amount of physical activity of moderate-to-vigorous intensity was examined as a possible moderator of this expected association. The main findings to these notions were that (1) total sedentary time was found to be negatively associated with overall mood, (2) physical activity was negatively associated with negative affect, (3) physical activity was negatively associated with overall mood, and (4) no significant moderating effect of physical activity on sedentary time's association with any of the three mood constructs was found. By these findings all three hypotheses have to be rejected. No significant association between sedentary time and positive or negative affect could be established nor any moderating effect of physical activity. However, the exploratory analysis of participants' sedentary time and overall mood score yielded a significant association. So, even though the specific hypotheses have been rejected, this exploratory analysis lends support to the basic assumption of this thesis's research question that there might be an association between students' total sedentary time and their self-reported mood. The fact that the overall mood score yielded a significant association, but not its constituents positive and negative affect, might point towards conceptualization of mood as one crucial factor for whether an association is found.

Comparison with previous findings

Sedentary Behavior

Putting these findings in the context of previous findings shows that they partially agree and disagree with it. Concerning the association between sedentary time and affect there were differing results. Aggio et al. (2017) found no significant association between sitting time and both affective states in a sample of mostly (70 %) university students. This concurs with this thesis's finding of no association between sedentary time and the dimensions of positive and negative affect. However, it should be pointed out that Aggio et al. (2017) used a different conceptualization of mood by focussing on well-being, vigor and calm for positive affect and "anger", "depression" and "anxiety" for negative affect. There is some overlap between those and this thesis's wording of questionnaire items. For example, all three of this study's positive affect items ("active", "attentive", and "determined") seem to mostly correspond to the "vigor" subscale used before, while the items for negative affect ("upset", "afraid", and "nervous") seem to be similar to the "anger" and "anxiety" subscale.

On the other hand, the findings were partly not in line with those of Giurgiu et al. (2019) that suggested an improvement in a person's mood when they engaged in less sedentary behavior. Like Aggio et al. (2017) they used a different conceptualization by examining "valence", "energetic arousal", and "calmness". This focus on different facets of mood might explain why the association between sedentary time with positive and negative affect that was reported previously could not be found here, but a significant negative association with the overall mood score could be reported. Though, it is possible, if, for example, this study also took measures to examine "energetic arousal" that similar results to those of Giurgiu et al. (2019) would be found. It is a measure for level of energy that puts no valence into the scores, while the items used in the present study already carry in themselves a certain emotional direction (e.g. anger generally being considered a 'bad' thing). So, these differing results might not actually contradict but complement each other.

Elavsky, Kishida, and Mogle (2016) reported sedentary time to be related to a lowering of positive affect. They especially point out that being sedentary in a previous moment has a negative effect on positive affect the following moment. However, they could not establish the same for negative affect. Again, the finding of this thesis that sedentary time and negative affect do not seem to be related accords with this. However, the previously found negative association between sedentary time and positive affect could not be established here.

The formerly mentioned conjecture that conceptualization of mood is one reason for different findings mirrors the assumption made by Elavky, Kishida, and Mogle (2016) that it might be an "artifact of using different measures of affect" (p. 4). These different ways of examining a person's mood can manifest, for example, by using a scale of 0 - 100 for the mood dimensions, like Elavky, Kishida, and Mogle (2016) did or by utilizing a five-point Likert scale, like Aggio et al. (2017) or this thesis. The greater sensibility for smaller changes of a 0 - 100 scale might account for reported findings that could not be established by a Likert scale that only has 5 gradations.

Summarizing, although this study's results partly disagree with previous literature regarding certain components of mood, it does seem to agree with the overall notion of there being an association between spending time sedentary and having a worse mood than before.

Physical Activity

Kanning and Schlicht (2010), using an ESM approach, reported a significant positive association between a person's level of physical activity and their mood. The findings of this thesis are in line with that. Moreover, it is noteworthy that physical activity does not seem to have it's helpful effect in improving a person's mood in the way that it was expected. No moderating effect of physical activity on the association between sedentary time and mood was found. Instead, concurring with Aggio et al. (2017),

the findings suggest that physical activity might improve mood by lowering its negative affect component. This finding seems to support the notion of sedentary behavior and physical activity being two distinct factors. Among others, Hoare et al. (2016) and Biddle et al. (2019) suggested treating sedentary behavior and physical activity as distinct phenomena and not just one as the absence of the other. In the context of this study, this would in turn suggest that both of them have their own associations with mood and its dimensions without needing the other. The lack of a moderating influence of physical activity on sedentary time paired with significant associations between respectively sedentary time and physical activity with mood seems to support this notion of distinct health factors. Although this differentiation might seem inconsequential for the end result (better mood), it is in line with what Romero-Blanco et al. (2020) suspected in their study. In it, they suggest that students might even suffer from the negative consequences of sedentary behaviour even if they use their new-found free time during the quarantine to be more physically active. This conception would then mean that sedentary time on its own has a worsening effect on mood and physical activity likewise on its own has an improving effect. Engaging in more moderate to vigorous physical activity does make for a better end result of a better mood, but any negative effect of sedentary time still stands uninfluenced by it. To achieve the highest possible improvement of one's mood (at least regarding the variables under study), one would then have to engage in more activity *and* try to minimize their time sitting independent of each other; a conclusion shared by Biddle et al. (2019).

On a more minor result, it is interesting to note that the increase of positive affect by being physically active that was found by Chan et al (2019) could not be established here; only the decrease of negative affect.

Strengths and limitations

Strengths of this study are its ecological validity compared to experimental studies, the narrow focus on moderate-to-vigorous physical activity instead of physical activity in general, and the use of widely encompassing items to capture participants' total sedentary time. Moreover, the use of ESM followed a specific call in previous literature (Chan et al. 2019) for the use of ESM to examine mood changes in daily life and allowed for a temporal dimension to be included in the participants' assessment. Furthermore, the target group of university and higher education students offered a sample of a generally highly sedentary population.

There are several limitations to this study. The first is that self-reports were utilized for gathering data about participants' times being sedentary and physically active instead of more objective measures such as an inclinometer and accelerometer. It might be that reports from the participants' memories were not as accurate as expected. Even though the Experience Sampling Method is designed to minimize recall

bias, still participants have to try and remember how much time in the last few hours they sat or engaged in physical activity. Even such a short time might skew the participants' estimation. The time spans before receiving a prompt have been kept as short as possible while still offering a reasonable period for participants to engage in different activities. Another possibility to minimize recall bias would be to instruct participants to keep a diary in order to note time spans of activities as soon as they are finished. Furthermore, for the sake of brevity the questionnaire for asking participants' mood had to be shortened from 10 to 3 items in order not to overburden them and keep compliance rates as high as possible. There is a possibility that this might have condensed the conceptualization of mood that was introduced by Watson et al. (1988) too strongly. However, in the context of an experience sampling study it is not advisable to use any questionnaire on mood in its full length because of time constraints. To alleviate this limitation as much as possible the items with the highest factor loadings regarding their respective mood dimension were chosen to represent them as accurately as possible. Also, similarly condensed operationalizations have been used by ESM studies in the past. Moreover, there were only two assessments per day regarding participants' current mood and recent physical activity and one concerned with their total sedentary time. Lastly, the day of the week was not considered in how it might affect the students' sedentary time, physical activity, or self-reported mood.

Recommendations

Future research might benefit from using more reliable measures to examine participants' sedentary time such as accelerometers. Furthermore, it might be helpful to consider the days of the week for an additional confounding factor possibly having an influence on how much a person is sitting, being physically active and their mood. Moreover, future studies might aim to narrow down a more exact notion of how intensive physical activity, as a distinct factor rather than a moderator, should be to improve mood by focussing on only one part of the spectrum (light, moderate, or vigorous).

Conclusion

To summarize this study, the results appear to agree with what Warburton and Bredin (2017) suggested in their review of systematic reviews. One excellent (not to mention evidence-based) slogan to give someone who wants to better their mental health is to simply stand up and move more. In this area of mood it is even doubly applicable, for it serves both suggestions made before. Stand up to cut off sedentariness's negative influence on your mood and start jogging (or another at least moderate physical activity that fits you) to even improve it!

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Appendix A: Information page on the study and active informed consent form

Dear participant,

Thank you for taking part in our study!

Here is some practical information for you to know about this study:

For you to participate, you need to be at least 18 years old and have a proficient understanding of the English language.

During the study:

1) We are interested in the relationship between sitting behaviour and mood. Also, we are going to look into possible influences on this relationship, such as your activity and thoughts at the time. For that, you will fill out multiple questionnaires.

2) On the day of signing up, so on day one, you will complete a demographic questionnaire, as well as two questionnaires, one on your mood and one on your thoughts. Together, this will take approximately 10 minutes. Starting from the next day, so on day two, you will fill out two short questionnaires a day that will take about 3 minutes to complete. You will receive a notification on your phone when it is time to complete the survey. These notifications will appear randomly within the time frames of 10:00 - 13:00 and 17:00 - 20:00. You will receive a reminder after 30 minutes. One hour after receiving the prompt, the questionnaire will be no longer available. If you miss a measurement, don't worry but please continue with the study and try to be consistent :)

3) From day three to day eight, you will fill out a somewhat longer questionnaire of 8 minutes once a day together with your morning prompt that measures your sitting behaviour from the day before. On day nine in the morning, you will fill out the last questionnaire on your sitting behaviour for day eight.

The data gathered will be used solely for the purpose of this study. Ethica will generate participant IDs upon registering, meaning that the data will be anonymised. Your name and email address is stored on the Ethica database. You have access to your own data via your online account as well as have the right to delete your data at any time. This means that your name and email address are stored separately from your survey answers. The researchers only have access to the content of your surveys as well as your participant ID. You can withdraw from the study at any time, without providing a reason for doing so.

This study has been reviewed and approved by the Ethics Committee. No risks can be expected from taking part in this study. You may become increasingly aware of your mood, thoughts and behaviour which could potentially lead to discomfort in some people.

For further information, or in case of any questions, the researchers involved can be contacted via email.

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If you have any questions about your rights as a research participant, or wish to obtain information, ask questions or discuss any concerns about this study with someone other than the researchers, please contact the Secretary of the Ethics Committee of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-bms@utwente.nl

Hereby, I declare that I am 18 years or older. I have read and understood the information provided, or it has been read to me. I consent voluntarily to participate 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.

(a) I consent
(b) I do not consent (In this case, the study will end at this point)

Appendix B: Demographic questionnaire

(1) How old are you?

(2) What is your occupation?
    (a) Student (University)
    (b) Student (Higher education)
    (c) Other

(3) What is your gender?
    (a) Female
    (b) Male
    (c) Other
    (d) Prefer not to say

(4) What is your nationality?
    (a) German
    (b) Dutch
    (c) Other

Appendix C: Questionnaire on trait mood

5 items on positive affect with the stem: 'Thinking about yourself and how you normally feel, to what extent do you generally feel...'?

(1) Attentive
(2) Active
(3) Alert
(4) Inspired
(5) determined

5 items on negative affect with the stem: 'Thinking about yourself and how you normally feel, to what extent do you generally feel...'?

(1) Hostile
(2) Upset
(3) Nervous
(4) Ashamed
(5) Afraid

Both of these sets are to be answered by indicating degree on a 5-point Likert-scale.

A. Very slightly or not at all
B. A little
C. Moderately
D. Quite a bit
E. Extremely

Appendix D: Questionnaire on state mood

3 items on positive affect with the stem: 'Right now, to what extent do you feel...?'

(1) Active
(2) Attentive
(3) Determined

3 items on negative affect with the stem: 'Right now, to what extent do you feel...?'

(1) Upset
(2) Afraid
(3) Nervous

Both of these sets are to be answered by indicating degree on a 5-point Likert-scale.

A. Very slightly or not at all
B. A little
C. Moderately
D. Quite a bit
E. Extremely

Appendix E: Item on physical activity

In the last 4 hours, approximately how many minutes did you engage in moderate-to-vigorous physical activity? (e.g. walking briskly, bicycling, running or jogging, jumping ropes, lifting weights, etc.)

Appendix F: Questionnaire on sedentary time

The following explanation precedes the 6 items on sedentary time:

First, we would like to know about your sitting time of yesterday. Please indicate per question, how much time in minutes you have spent sitting during each activity. (please do not write out "minutes/min")

(1h = 60)

(2,5h = 150)

(1) How many minutes were you sitting while studying/working yesterday? (include the time at university, during lectures, tutorials, meetings, group discussions, self-study, study from home etc.)
(2) How many minutes were you sitting or lying down while watching TV or playing video games yesterday? (e.g. watching TV in bed, playing computer games or playstation, playing games on your iphone/ipad/talet, using the internet or activities that were not for studying or working purposes, like facebook, twitter, skype, youtube, online-shopping etc.)
(3) Thinking again of yesterday, how many minutes were you 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)
(4) How many minutes did you spend yesterday sitting down for eating and drinking. (including meals and snack breaks)
(5) Please estimate the total in minutes of 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 on the telephone)
(6) We are interested in any other sitting or lying down that you may have done that you have not already told us. (e.g. hobbies such as doing art and craft, playing board games; listening to music or for religious purposes. Again thinking of yesterday, please estimate the total time that you spent sitting or lying down NOT including time that you have told us about in the previous answers)