Exploring the relationship between sedentary behaviour, depressive symptoms, and evolutionary mismatch: an experience sampling study

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Bachelor Thesis

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June 27, 2023

Abstract

Background: Research has linked sedentary behaviour to negative physical and mental health outcomes. This study particularly focused on depressive symptoms, while additionally making use of the evolutionary mismatch hypothesis, which suggests that our modern lifestyles and environments may conflict with our ancestral adaptations, potentially resulting in various diseases. Consequently, this study aimed to explore the relationship between sedentary behaviour and depressive symptoms using Experience Sampling Methodology (ESM), while further including the potential moderating effect of the level of evolutionary mismatch in individuals' lifestyle.

Methods: An Experience Sampling study was carried out with a group of 47 young adults (M_{Age} = 24.55, SD_{Age} = 3.37, 55% women). Over a period of nine consecutive days, participants used the Ethica app to complete two surveys each day, which measured their total sedentary time and state depressive symptoms. Visualisations of estimated marginal means and linear mixed models were employed to analyse the relationship between sedentary behaviour and depressive symptoms, as well as to examine whether the degree of evolutionary mismatch had a moderating effect.

Results: A positive but statistically non-significant association was found between daily sedentary time and state depressive symptoms. Similarly, the moderation effect of the degree of evolutionary mismatch on the relationship between daily sedentary time and depressive symptoms was insignificant.

Conclusion: Contrary to expectations, the study did not find a significant association between sedentary time and depressive symptoms. Future studies should explore alternative factors that may explain previously established associations between sedentary time and depressive symptoms and should reassess the degree of evolutionary mismatch once the scale has been validated and/or modified.

Keywords: sedentary behaviour, depressive symptoms, evolutionary mismatch, experience sampling methodology

Exploring the relationship between sedentary behaviour, depressive symptoms, and evolutionary mismatch: an experience sampling study

Introduction

Sedentary behaviour is defined as "any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining, or lying posture" (Tremblay et al., 2017). The relevance of prolonged sitting and sedentary behaviours has been quickly enhanced by the growing body of evidence linking it to adverse health markers (Katzmarzyk et al., 2009; Tremblay et al., 2010; Thorp et al., 2011; Chau et al., 2013). Interestingly, the health consequences of prolonged sitting differ from those of lack of physical activity, thus it is important to approach the former independently (Owen et al., 2011). In the current study, sedentary behaviour was operationalized as total sitting time while being awake, accompanying common daily activities such as using the computer for study or work, watching TV or Netflix, using social media, reading, writing, socializing, commuting, etc. This choice was based on a study by Owen et al. (2011), who proposed an ecological model of sedentary behaviours, highlighting that sedentary behaviour should be viewed as co-occurring with various daily activities, and not as an isolated act.

Regarding the prevalence of sedentary behaviour, it is commonly reported that adults exhibit elevated levels of daily sitting time. In a Dutch sample, the average participant spent, while being awake, 61.1% of their non-occupational time – meaning time spent on household chores, leisure, transportation, voluntary work, and education – on sedentary activities, with more than 87% of their leisure time being spent sedentary. Higher levels were noticed in young adult participants, aged 18-34 (Loyen et al., 2019). In a study conducted by Peterson et al. (2018) using objective measures, i.e., an accelerometer, American students aged 18-20 spent on average 68.9% of a day in sedentary behaviours.

When looking at health consequences of prolonged sitting, it is rapidly becoming recognized as a risk factor for various chronic diseases, such as increased risk for cardiovascular disease, metabolic disorders, cancer, and premature death (Biswas et al., 2015; Thorp et al., 2011; Pandey et al., 2016; Lockyer, 2016; Carter et al., 2017). Additionally, research began to discover connections between sedentary behaviours and mental health problems such as stress,

dementia, sleeping issues (Yang et al., 2017; Falck et al., 2017; An et al., 2015), and depression, which was targeted in this paper.

Depression is well-known as a crucial cause of physical and psychosocial diseases and even mortality (Paluska & Schwenk, 2000), affecting an estimated 280 million people worldwide (WHO, 2023). In university students, depression is one of the most common health issues; a systematic review reported a mean prevalence of 30.6% (Ibrahim et al., 2013). Furthermore, in a U.S. sample, the highest prevalence among all age groups, 17%, can be observed in adults aged 18-25 (NIMH, 2020), indicating a concerning issue among younger populations. Depression is linked with socio-occupational impairment and it is highly comorbid with various somatic diseases. However, it can vary greatly in its clinical presentation, from temporary decreased mood states to recurring major depressive disorder (MDD) requiring continuous treatment. This study focused on the former case and examined participants' daily experience of typical depressive symptoms, among which loss of interest or pleasure in daily activities, insomnia or increased tiredness, feelings of worthlessness and guilt, and mental and physical slowness.

As the experience of depressed mood states can predict the onset of MDD, a highly prevalent disorder in young adults, previous studies have investigated sedentary behaviour as a potential predictor of these states. For example, a study conducted by Rebar et al. (2014) on Australian adults revealed that overall sitting time was significantly positively associated with increased severity of depressive symptoms. Teychenne et al.'s (2010) review found that higher levels of sedentary behaviour are indeed associated with the experience of depressive symptoms in healthy adults in most studies. Huang et al. (2020) conducted a meta-analysis of 12 prospective cohort studies investigating the effect of sedentary behaviours on adults' risk of depression, indicating a significantly positive association. However, all these studies were based on self-report measures. Biddle et al. (2021) used objective device measures for the assessment of total and prolonged sitting time and further confirmed a positive association with higher severity of depressive symptoms. Although these studies provide substantial evidence for the relationship between sedentary behaviour and depressive symptoms, short-term repeated-measures studies are necessary, as both constructs can fluctuate highly over time. Furthermore, adopting a broader perspective when analysing human daily behaviours such as sitting could facilitate the identification of additional factors that may influence this relationship.

Evolutionary psychology has proven to be a valuable framework in exploring determinants underlying depressive symptomatology in several studies. According to the evolutionary-mismatch hypothesis, the disparities between the stressors encountered by humans in their ancestral environment and those present in the modern world can lead to the development of diseases. Up until about 10,000 years ago – when they shifted to agriculture – humans followed a nomadic lifestyle as hunter-gatherers, facing distinct stressors compared to those encountered in contemporary environments (Hoogland & Ploeger, 2022). After the shift, humans did not evolve much (Hidaka, 2012), thus being best adapted to the ancestral lifestyles and environments, collectively known as the environment of evolutionary adaptedness (EEA) (Irons, 1998). As a consequence, adaptive mechanisms did not evolve fast enough for people to be able to handle contemporary stressors as effectively (Crawford, 1998), leading to physical and mental health problems. For example, in ancestral environments, sweet tastes were linked to naturally nutritious foods like fruits, yams, and honey, providing beneficial carbohydrates and minerals. However, in modern times, the association of sweetness has shifted to processed sweets lacking nutritional value. This represents a mismatched food source, as our physiological mechanisms have not adapted to handle excessive sugar intake, leading to conditions like diabetes (Li et al., 2018). Further examples of evolutionary mismatches include sleep patterns, insufficient exercise, limited exposure to natural daylight, inadequate access to green environments, reduced social cohesion, and the present information overload (Hoogland & Ploeger, 2022).

Support for the evolutionary mismatch hypothesis and its relation to the experience of depressive symptoms comes from the positive correlation between a modern lifestyle and mental disorders such as depression. Initial evidence comes from exploratory research suggesting higher prevalence of mental disorders in modern societies than in nonindustrial societies. Shifting from a hunter-gatherer lifestyle seems to have increased the incidence of depression in circumpolar peoples (Shepard & Rode, 1996), China (Sun & Ryder, 2016), and India (Chandra et al., 2018). Nonetheless, these findings must be interpreted carefully due to cultural variations in the expression and assessment of depression (Kirmayer et al., 2017). Furthermore, depression was found to be associated with multiple ubiquitous aspects of modern lifestyles, such as elevated processed food intake (Jacka et al., 2010; Hecht et al., 2022; Wu et al., 2023), social media use (Lin et al., 2016; Primack et al., 2017), chronic stress (McGonagle & Kessler, 1990; Tafet &

Bernardini, 2003; Hammen, 2005), insufficient sleep (Roberts et al., 2000; Baglioni et al., 2011), vitamin-D deficiency (Anglin et al., 2013; Milaneschi et al., 2014), physical inactivity (Azevedo Da Silva et al., 2012; Gudmundsson et al., 2015; Hiles et al., 2017), perfectionism (Di Schiena et al., 2012; Smith et al., 2021), and cigarette smoking (Boden et al., 2010; Fluharty et al., 2017). While these correlational studies cannot determine causality, experimental studies manipulating lifestyle factors or studies assessing the effect of healthy lifestyle changes have shown positive effects on the experience of depression. These include interventions such as dietary changes (Jacka et al., 2017; Bourdel-Merchasson et al., 2020), taking a break from social media (Lambert et al., 2022), stress-reducing interventions such as mindfulness (Kuyken et al., 2016; McCartney et al., 2021; Tseng et al., 2023) and yoga (Woolery et al., 2004; Schuver & Lewis, 2016; Cramer et al., 2017), nonpharmacological sleep interventions (Gee et al., 2019), vitamin-D enhancement (Khoraminya et al., 2013; Parker et al., 2017), increasing physical activity levels (Dunn et al., 2005; Kvam et al., 2016; Schuch et al., 2016; Bailey et al., 2018), and smoking cessation (Taylor et al., 2014; Secades-Villa et al., 2017).

Subsequently, this study aimed to assess the degree of evolutionary mismatch in one's lifestyle as a potential moderator of the relationship between sedentary time and depressive symptoms. Each of the potential mismatches in one's lifestyle, both individually and accumulated, contribute to an elevated risk of developing diseases. Although industrialized societies share an overarching modern lifestyle, individual differences in lifestyles and reaction to stressors imply the accumulation of different mismatches for different people (Hoogland & Ploeger, 2022). This in turn leads to distinct severity in potential depressive symptoms. Consequently, it is reasonable to hypothesize that individuals with a high degree of mismatch are likely to be more affected by high amounts of sedentary time in terms of depressive symptoms. Implicitly, an overall lower deviation from the ancestral lifestyle would mitigate the impact that high amounts of sitting time have on the severity of depressive symptoms. This implication could be useful for patient-tailored health interventions that aim at reducing depressive symptoms by tackling individuals' highest mismatches, in cases when sedentary time would be difficult to decrease e.g., due to work commitments.

Prior to addressing a potential moderator of their relationship, sedentary behaviour and depressive symptoms had to be observed over time, thus the experience sampling method (ESM)

was used for data collection. ESM is a structured self-report diary technique that uses mobile devices for collecting experiences, behaviours, and/or physiological parameters, as they occur in daily life (Myin-Germeys & Kuppens, 2022). This technique was chosen because of its advantages over the experimental approach and cross-sectional surveys: real-world data collection instead of a controlled experimental setting, reduced recollection errors or bias, longer-term repeated measures, and the possibility to observe within-person associations of sedentary behaviour and depressive symptoms. All these benefits contribute to an increased reliability and ecological validity when assessing sitting time (Myin-Germeys & Kuppens, 2022). Previous research looking at the relationship between sedentary behaviour and depression was mostly cross-sectional, as previously elaborated. In terms of ESM studies, Snippe et al. (2016) explored this association, however using a clinical sample. Pemberton & Fuller Tyszkiewicz (2016) conducted a systematic review of articles that explore the determinants of depressed mood states in healthy subjects, using ESM, and found that physical activity, sleep, stress, and quality of social interactions are potential risk factors for acute spikes in depressed mood. However, sedentary behaviour has not yet been investigated as a potential predictor of depressed mood states using ESM. A study by Li et al. (2022) that assessed experienced depressive symptoms through ESM only examined the association with physical activity; as previously established, levels of sedentary behaviour and physical activity need to be investigated separately. Thus, this study aimed at filling the gap in ESM literature on sedentary behaviour and the experience of depressive symptoms, while making use of this method's specific advantages.

Based on the literature review, it is expected that sitting time and depressive symptoms are positively associated over time. Furthermore, the role an evolutionarily mismatched lifestyle plays in this relationship was explored. This further adds to the originality of this paper, as the degree of evolutionary mismatch was never investigated as a construct encompassing all potential lifestyle mismatches and how it relates to other health constructs. Based on previously highlighted connections between sedentary behaviour, depressive symptoms, and evolutionary mismatch, it is expected that the degree of evolutionary mismatch positively moderates this relationship. The following research questions were specified:

RQ1: To what extent are daily total sedentary time and the experience of depressive symptoms associated in young adults?
RQ2: To what extent is the degree of evolutionary mismatch moderating the relationship between sedentary time and the experience of depressive symptoms?

Methods

Design

This study is part of a larger research project exploring the relationship between sedentary behaviour and various mental health constructs; thus, the questionnaires included items that are not related to the constructs examined in the present study. An exploratory ESM study design was employed to investigate the relationship between sedentary time, the degree of evolutionary mismatch in an individual's lifestyle, and the experience of depressive symptoms. Typically, ESM studies are observational; in the current study, the amount of sedentary time and the level of experienced depressive symptoms were observed on a daily basis, through the Ethica app, which was a suitable choice for setting up this study as it allowed participants to access the questionnaires anywhere. Moreover, it notified them once a questionnaire became available or to remind them to complete it.

The study was submitted to the Ethics Committee of the University of Twente for ethical approval, which was received on April 5, 2023 (Case number: 230487). Next, the study design was pilot tested for three days by three participants, and additionally by the researchers. Minor changes were applied following the pilot test, then the study was published on the University of Twente SONA System website and advertised for several days before the data collection began on April 24, 2023.

Participants

The participants were recruited by convenience sampling through University of Twente's portal Sona Systems and via social media. Through the university portal, participants studying at the University of Twente were rewarded 1.25 Sona points for successful completion at the end of the study. Inclusion criteria were a proficient level of the English language, access to a smartphone, and between 18 and 35 years old. Van Berkel et al. (2017) reported a median of 19

participants as recommended for an ESM study, while the mean number of participants found when reviewing relevant literature is 53, a relatively high number. Thus, the current study aimed at gathering minimum 19 participants, as due to the longer data collection period a large sample size is not necessarily needed. However, based on van Berkel et al.'s (2017) review, a number closer to 53 subjects was favoured.

The initial data set contained 66 participants, out of which 19 were removed due to having a compliance rate under 60%. The final sample included 47 participants with ages between 19 and 33 years old (M_{Age} = 24.55, SD_{Age} = 3.37), with 26 being female (55%), 20 male (43%), and one choosing the option 'Other". With regards to nationality, 30 of the participants were German (64%), 6 Other EU (13%), 6 Other Non-EU (13%), and 5 Dutch (10%). Furthermore, 23 of the participants were full-time students (49%), 14 were working (30%), 9 were both studying and working (19%), and one was not working, nor studying (2%).

Materials

Baseline Questionnaire

The baseline questionnaire (Appendix B) included questions about demographics, namely gender, age, nationality, and occupation (full-time student, full-time working, student and working, not working, other). Furthermore, it included the PHQ-9 questionnaire to measure participants' *trait depressive symptoms*, and 25 questions about their lifestyle, meant to assess their *degree of evolutionary mismatch*.

The Patient Health Questionnaire (PHQ-9) was originally designed by Spitzer, Williams and Kroenke (2001) to assess the severity of depression, by scoring each of the nine DSM-IV criteria from 0 (not at all) to 3 (nearly every day). An example item is *"feeling tired or having little energy"* and the answer should reflect the past two weeks. The total score then indicates severity, classifying it as none (0-4), mild (5-9), moderate (10-14), moderately severe (15-19), or severe (20-27). One of the original questions (*"Trouble concentrating on things, such as reading the newspaper or watching television?"*) was modified because the examples provided were slightly outdated for the young study population, replacing them instead with "studying or watching Netflix". The original PHQ-9 has an excellent test-retest and internal reliability, with a Cronbach's α of 0.89. The questionnaire also has a sensitivity and specificity of 88% for major

depression, displaying high criterion validity (Williams & Kroenke, 2001). In the current study, the adapted questionnaire indicated good internal consistency, with a McDonald's ω_t of .9.

The evolutionary mismatch questionnaire has been originally developed by researchers in collaboration with students at the University of Amsterdam, which makes it a suitable choice for the young adult population that this study aims to research. They identified 26 potential mismatches in people's modern lifestyles and created one question for each mismatch, for example *"On average how often do you go to sleep between 21:00 and 23:00 and wake up between 6:00 and 8:00?",* referring to deviation from the natural sleep rhythm. Each question has five answer options that differ per question and are scored from 1 to 5, with 1 indicating the lowest degree of mismatch; in the case of the example question, the answer options ranged from 1 (almost never) to 5 (almost every day). In this study, an edited version will be used, which removed the question about sedentary lifestyle, as this construct was measured separately every day through experience sampling. Furthermore, the item "*Do you use hormonal contraceptives (such as contraceptive pills or a hormone IUD)?"* had only three answer options, namely 1 (no), 5 (yes), or 0 (does not apply). Consequently, a participant can score minimum 25 and maximum 125 for the degree of mismatch in their lifestyle. As there are no norms yet available for this questionnaire, the scores will rather be used in testing the variable's moderation effect on the relationship between sitting time and severity of depressive symptoms. The questionnaire's psychometric properties have not been evaluated yet, however the computed McDonald's ω_t for the items measuring the *degree of evolutionary mismatch* was .72, suggesting acceptable internal consistency of the scale.

Daily repeated surveys

The PAST-U questionnaire by Clark et al. (2016) was adapted from the original PAST questionnaire in order to include items that involve students' lifestyle, thus looking at sedentary time during studying, besides sedentary occupational time (Appendix C). Therefore, this was the most suitable scale to use on a young adult sample including both university students and working adults. Its nine items assess sedentary time during various activities and contexts, e.g.: working, studying, travelling, watching television. An example item is *"How long were you sitting at your workplace or working from home in a paid position yesterday (in minutes)?"*. The participants are required to indicate the approximate amount of sedentary time every morning,

with regards to the previous day. Although reporting sitting time in hours might appear easier for participants, minutes were preferred to avoid gross under- or overestimation. The PAST-U questionnaire proved a moderate correlation with another measurement of sedentary behaviour, the activePAL, ICC = 0.64 (95% CI [0.45, 0.77]), and ICC = 0.59 (95% CI [0.33, 0.77]) for students specifically (Clark et al., 2016), thus showing good reliability. For the current study, the reliability of the PAST-U questionnaire was tested using the split-half method by computing Spearman's correlation coefficient, which returned a value of $r_s\,(45) = .58$, $p < .001$, signifying a moderate positive correlation of its items.

The daily afternoon questionnaire included questions assessing five depressive symptoms out of the nine measured by the PHQ-9 (Appendix D), to observe individual variations in mood over the duration of the study, or *state depressive symptoms*. Only five items were chosen to preserve the short duration of the daily questionnaires. For this questionnaire, a VAS scale from 0 (not at all) to 4 (extremely) was used in order to maintain consistency with the scales used in the other daily surveys included in the broader research project. Thus, participants could have a total daily score of minimum 0 and maximum 20. The *state depressive symptoms* construct was tested for reliability using the split-half method, which yielded a Spearman's correlation coefficient of $r_s\,(45) = .42$, $p < .001$, indicating a moderate positive correlation of the five selected items from the PHQ-9.

Procedure

The study was published on the University of Twente SONA System website and advertised for several days before the beginning of data collection. Participants either received a link or scanned a QR code from a promotional poster to register for the study. To obtain the required measurements, the mobile app Ethica was used. Participants were instructed to download the app after signing up for the study and to check that their notifications are turned on. The data collection was set to begin on April 24, thus participants could not access the informed consent and the baseline questionnaire prior to that date, regardless of the time of their registration. ESM studies are usually conducted over periods of one to four weeks (van Berkel et al., 2017), however their requirement for longer participation can be a burden for participants. Thus, the data collection period was set to 9 days, closer to the lower limit. This should in turn help with maintaining a sufficient compliance rate, which was set at 60%. This choice is

substantiated by van Berkel et al. (2017), whose review reported an average response rate of 69.6%, and by the examples discussed by Conner & Lehman (2012), who note that experience sampling that uses participants' own mobile phones to notify them usually yields high compliance rates.

A time-contingent sampling with a fixed time schedule was used to assess participants' daily sitting time and experience of common depressive symptoms. After giving their informed consent (Appendix A), participants received a baseline questionnaire. In case they declined consent, the app would not redirect them further to the baseline questionnaire and their participation would be finished. The baseline questionnaire had to be completed during the first day of participation, with reminders being sent at its release and then two, four, and six hours later in case the subjects did not fill it in yet. The next day, they were only required to fill in the afternoon questionnaire, as the previous day was not included in the data collection period, thus its corresponding sitting time was not relevant. The following days they received two short daily questionnaires, one triggered at 8 a.m. and one at 5 p.m., each available for four hours. The participants could receive in total maximum three notifications per survey, one immediately as it became available, and the following two if they did not complete it two hours later and 30 minutes before the survey would close. The last day only included the morning questionnaire that assessed the sitting time from the previous day, since the last day itself was not considered in the data collection period (Table 1). The fixed time intervals, number of daily questionnaires, their short duration, and the notification templates were all chosen with careful attention to participant burden (Verhagen et al., 2016; van Berkel et al., 2017). The morning questionnaire aimed to measure the sitting time of the previous day in order to obtain more accurate responses. Once finishing each survey, participants were thanked for their contribution to the study.

Table 1

An overview of the study set-up

Date	Questionnaire	Construct	Trigger	Expiration	Reminder
April 24th	Informed consent, baseline questionnaire	Informed consent, degree of evolutionary mismatch, Trait depressive symptoms	8 am	never	Onset, 2 hours, 4 hours, 6 hours
April 25th	Afternoon	State depressive symptoms	5 pm	4 hours	Onset, 2 hours, 3.5 hours
April 26th – May 1st	Morning	Sedentary time	8 am	4 hours	Onset, 2 hours. 3.5 hours
	Afternoon	State depressive symptoms	5 pm		
May 2nd	Morning	Sedentary time	8 am	4 hours	Onset, 2 hours, 3.5 hours

Data Analysis

The ESM data was exported from Ethica and imported to RStudio (version 2023.03.0+386), then prepared for statistical analysis. Participants were excluded if they had a compliance rate under 60%. Rows with reported daily sitting time values exceeding 24 hours were removed, unless doing so would reduce the participant's response rate below 60%. In such cases, the participant was entirely excluded.

Descriptive statistics, namely means (*M*), standard deviations (*SD*), and absolute and relative numbers, were computed for the sample demographics and the four measured variables. For better visualisation, a new variable for total sedentary time in hours was created.

McDonald's Omega was chosen for testing the reliability of the items measuring *trait depressive symptoms* and *degree of evolutionary mismatch* because it provides a more accurate reliability measure for multidimensional constructs*,* representing the internal reliability of all factors in the model. The split-half reliability method was used for testing the repeated measures of *state depressive symptoms* and *total sitting time* and it involved converting the respective data sets into wide format, then creating two variables for the mean values per participant from day 1 to 3 and from day 4 to 7. Further, Spearman's correlation coefficient was computed for assessing internal consistency.

In ESM studies, repeated measures introduce complexities like multilevel data (measurements nested within days, and further nested within participants), time-varying covariates, missing data, within-person differences, and autocorrelated observations (Myin-Germeys & Kuppens, 2022). To address these complexities, linear mixed models (LMMs) with a first-order autoregressive (AR1) structure were used. The AR1 covariance structure accounts for the decreasing correlation between observations over time (Funatogawa & Funatogawa, 2018).

To examine between-subject and between-timepoint differences, EMMs were used to visualise the data. EMMs per participant were computed by running LMMs with *state depressive symptoms* or *total sitting time* as the dependent variable and *ID* as the fixed factor. To calculate EMMs over time, LMMs were run again with the same dependent variables, but with the *day* as the fixed factor. Variations in EMMs for *total sitting time* and *state depressive symptoms* across participants were statistically tested using a one-way ANOVA. The association between *trait depressive symptoms* and *state depressive symptoms* was assessed by computing Spearman's correlation coefficient between *trait depressive symptoms* scores and the EMMs per participant obtained for *state depressive symptoms,* in order to test if the two variables measure distinct constructs as intended.

Further, a LMM with AR1 covariance structure and maximum likelihood estimation was used to investigate *RQ1* by running an analysis with *total sitting time* as the fixed covariate and *state depressive symptoms* as the outcome variable. In order to account for the individual differences in the effect of *total sitting time* on *state depressive symptoms,* a random effect was

added. Regarding *RQ2,* which looks at the *degree of evolutionary mismatch* as a potential moderator, a moderation analysis was performed by adding this variable and the interaction effect of *total sitting time* and *degree of evolutionary mismatch* as fixed covariates to the LMM used for *RQ1*. The moderation analysis was tested at a significance level of 0.05.

Results

Association between Daily Total Sitting Time and State Depressive Symptoms (*RQ1*)

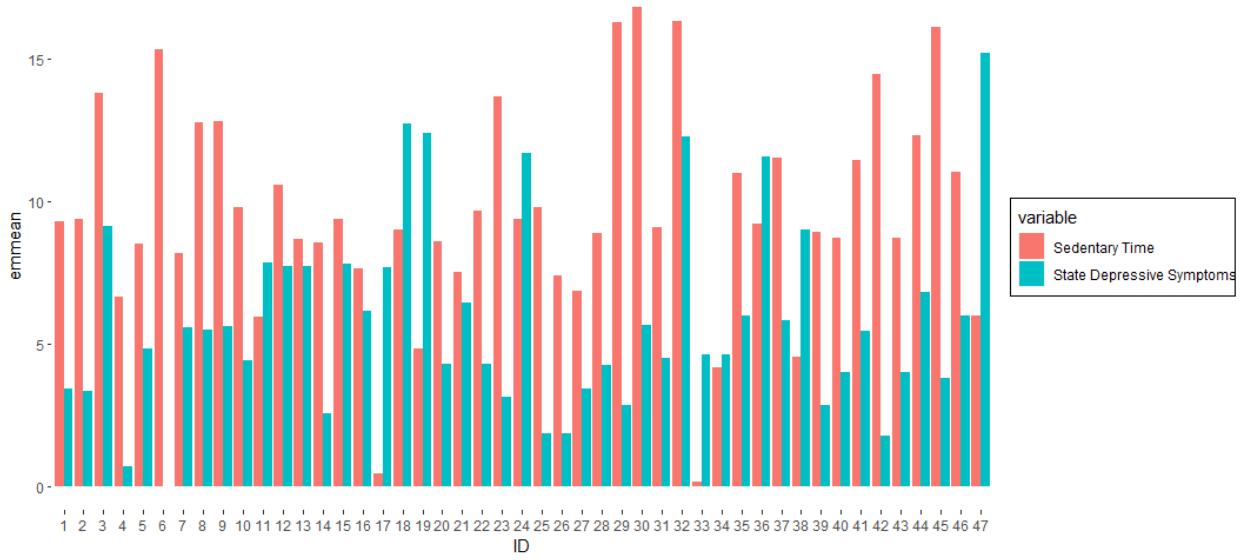
The median amount of sedentary time was 9.2 hours ($IQR_{totalSB} = 5$). There was significant variation in the EMMs of daily *total sitting time* across participants (F (46, 203) = 2940, $p < .001$) as can be seen in Figure 1. In Figure 2 the EMMs of *total sitting time* were plotted over time along with the EMMs of *state depressive symptoms.* The *total sitting time* increased from day 1 to 5 and then decreased until the last day, but nonetheless an overall increasing tendency was observed.

Scores for *trait depressive symptoms* ranged from 0 to 21, the median score being 7 ($IQR_{traitDS} = 7$). Scores for *state depressive symptoms* ranged from 0 to 18, the median score being 5 ($IQR_{stateDS} = 6$). Significant variation can be observed in the EMMs of *state depressive symptoms* across participants (F (46, 231) = 3011.9, $p < .001$), which can be visualized in Figure 1. Over time, a decreasing tendency was observed, as *state depressive symptoms* increased from day 1 to day 2, decreased on day 3, then again slightly increased on day 4, after which there was a steady decrease until the last day. Moreover, the scores for *trait depressive symptoms* and *state depressive symptoms* were found to be significantly positively correlated, r (45) = .68, $p < .001$.

The results of the LMM showed a positive but non-significant effect of *total sitting time* on *state depressive symptoms* ($b = 0.09$, SE = 0.06, 95% CI [0.03, 0.15]). Based on the observed trajectories of the two variables, it can be concluded that they do not covary over time, as sedentary time mostly increases, while depressive symptoms show a steady decrease.
There was also very little variation in within-person associations, meaning that the effect was minimal for all participants.

Figure 1

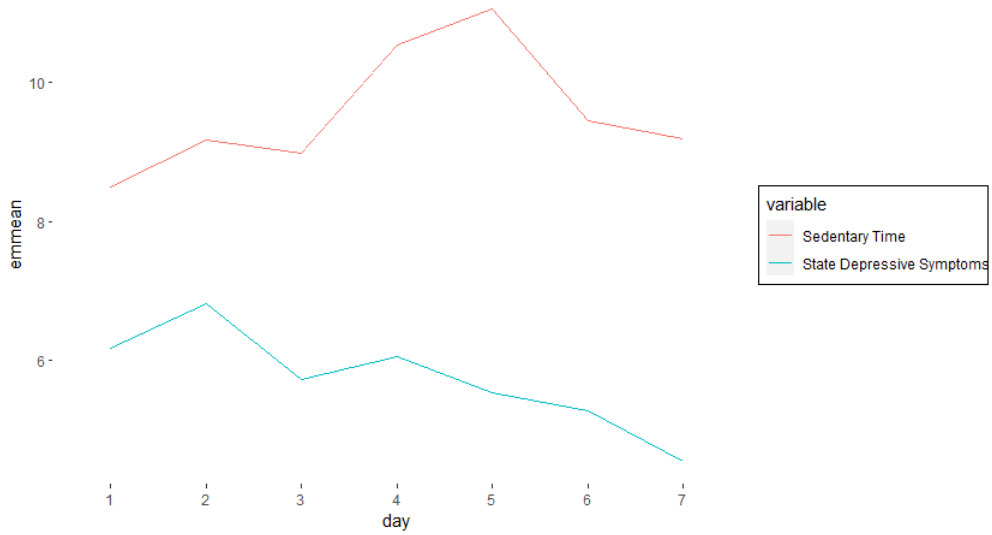
Estimated Marginal Means of Total Sitting Time and State Depressive Symptoms across Participants



Note. Values for State Depressive Symptoms could range between 0 to 20. Sedentary Time is reported in hours.

Figure 2

Estimated Marginal Means of Total Sitting Time and State Depressive Symptoms over Time



Note. Values for State Depressive Symptoms could range from 0 to 20. Sedentary Time is reported in hours.

Association between Daily Total Sitting Time and State Depressive Symptoms, moderated by the Degree of Evolutionary Mismatch (*RQ2*)

Scores for the *degree of evolutionary mismatch* ranged from 57 to 88, the median score being 70 ($IQR_{totalEM} = 8$). This indicates moderate scores as compared to the potential total score of 125. Furthermore, the questions that yielded high median scores, above 3, are displayed in Table 2.

Table 2

Evolutionary Mismatch questions with high median scores

Question	Median score
On average how often do you go to sleep between 21:00 and 23:00 and wake up between 6:00 and 8:00?	4
On average how long per day are you outside?	4
On average how many times a week are you in nature (park, forest, dunes, etc.)?	4
How large is the town you live in?	5
How often do you feel like you lack time?	4
How important is it for you to strive for perfection?	4
'I prefer to do things on my own.' Do you agree with this statement?	4
'I spend more time on social media than I like.' Do you agree with this statement?	4

In order to test whether the *degree of evolutionary mismatch* moderates the relationship between *total sitting time* and *state depressive symptoms,* the previous LMM was updated to include an interaction effect. The interaction effect of the *degree of evolutionary mismatch* and

total sitting time was not significant (b = 0.01, SE = 0.01 , t (175) = 1.21, p = .22). The results of the moderation analysis are displayed in Table 3.

Table 3

An Overview of the Moderation Analysis Results

Parameter	Estimate	Std. Error	*df*	*t*	*p*	95% CI	
						Lower Bound	Upper Bound
Intercept	-5.77	7.26	175	-0.79	0.42	-13.03	1.49
totalSB_hours	-0.78	0.71	175	-1.1	0.27	-1.49	-0.07
totalEM	0.15	0.1	45	1.5	0.14	0.05	0.25
totalSB_hours:totalEM	0.01	0.01	175	1.21	0.22	0	0.02

Note. totalSB_hours = total sedentary time in hours; totalEM = degree of evolutionary mismatch.

Discussion

This study aimed to explore the association between sedentary behaviour and the experience of depressive symptoms in young adults over time, while also assessing the role of evolutionary mismatch in this relationship. A positive association was observed between sedentary time and depressive symptoms, however, contrary to expectations, the effect was insignificant. Therefore, participants who sat more did not necessarily experience more severe depressive symptoms. Moreover, the degree of evolutionary mismatch did not moderate this association, therefore participants with a higher degree of mismatch did not experience more severe depressive symptoms when sitting a lot.

The first research question examined the association between the daily amount of time spent sedentarily and the experience of depressive symptoms. Although sedentary time has shown a positive association with depressive symptoms, the effect was minimal and insignificant. In other words, participants who sat more did not experience a meaningful increase in severity of depressive symptoms, thus sedentary behaviour does not seem to be linked to experienced depressive symptoms. Previous cross-sectional studies suggested a positive

association between the two constructs (Teychenne et al., 2010; Rebar et al., 2014; Huang et al., 2020; Biddle et al., 2021), while the assessment of this association over time contradicted these findings. This indicates that alternative factors probably mediate this association, while sedentary time independently does not relate much to depressive symptoms over time. This brings good news for younger populations, as factors like the activity performed or the surroundings while sitting may link to depressive symptoms, and not the amount of sitting alone, which might be difficult to reduce for some people. Alternatively, depressive symptoms were assessed as both state-like and trait-like, but the high significant correlation between the measurements indicates that, at least for the current sample, they measured the same underlying construct. The sample is generally experiencing mild to moderate trait depressive symptoms, with five subjects indicating moderately severe or severe symptoms. This is not unexpected since the sample consisted of young adults, who, according to literature (Ibrahim et al., 2013; NIMH, 2020), do indeed experience more depression. This needs to be taken into account when looking at the steady decrease of state depressive symptoms over time, as participants already experiencing these trait-like symptoms may have reported lower state scores due to increased self-awareness from the previous days. Consequently, measuring depressive symptoms through ESM was not particularly useful in this study and may have contributed to the unexpected lack of association.

The second research question examined the potential moderating effect of the degree of evolutionary mismatch in one's lifestyle on the association between sedentary time and depressive symptoms. Contrary to initial expectations, the degree of mismatch did not yield a statistically significant impact on this association. Given the lack of significance of the main effect of sedentary time on depressive symptoms, moderation was indeed unlikely. Therefore, individuals with a higher degree of mismatch did not exhibit more severe depressive symptoms when engaging in prolonged sitting. Furthermore, a positive but statistically insignificant effect of the degree of evolutionary mismatch on the experience of depressive symptoms was observed. This suggests that the absence of moderation may be attributed to the fact that the sample generally exhibited moderate scores relative to the maximum score, indicating relatively healthy lifestyles. Moreover, as each individual item represents a potential mismatch, the sample's median scores for each question were explored; participants were most mismatched in terms of deviation from natural sleep rhythm, lack of being outside, lack of contact with nature, urbanization, lack of time, perfectionism, individualism, and social media overuse. The sample's

scores on other items were relatively low, and out of these highest scoring mismatches only perfectionism (Di Schiena et al., 2012; Smith et al., 2021) and social media overuse (Lin et al., 2016; Primack et al., 2017) were found to be correlated with depression in previous studies. Thus, assessing the overall degree of mismatch may not accurately capture its relationship to depressive symptoms due to the construct's multidimensionality. In other words, it assesses multiple highly distinct lifestyle indicators that differ greatly in their potential health outcomes. In this case, each mismatch influences the severity of depressive symptoms to a different extent. The presence of lower item scores may counterbalance higher item scores, resulting in a low or moderate degree of evolutionary mismatch with minor consequences in terms of depressive symptoms.

Interestingly, the decreasing tendency in state depressive symptoms over time may be also explained by the fact that four days of the data collection week were weekend or holiday days. Higher values can be observed only during the three working days of the week (Tuesday, Wednesday, and Friday). Decreases can be observed during King's Day, and further during the whole weekend and the next Monday, which was a national German holiday and thus again free. This holiday must be taken into account due to the predominantly German sample. Since in these contexts young people usually gather with friends and celebrate, it can have a mood enhancing effect which in turn explains the lower scores on the four days and the overall decreasing trend in state depressive symptoms.

Strengths and Limitations

The current study possesses two notable strengths that warrant emphasis: the utilization of experience sampling methodology to investigate sedentary time and depressive symptoms, and the novelty of investigating the degree of evolutionary mismatch as a construct. This study sought to integrate evolutionary psychology, particularly the evolutionary mismatch hypothesis, as an explanatory framework. This aims at bridging anthropology and psychology to present a comprehensive perspective on what is perceived by people to be customary and natural behaviours within modernized societies and their evolution into unhealthy practices.

Notwithstanding its strengths, the study's limitations should also be acknowledged. Firstly, there were some surprising reports of daily sedentary time exceeding 24 hours or displaying unusually high values (e.g., 22 hours). This may be due to a misunderstanding of the

items or the given instructions, which led to overlap between reported amounts; for instance, the amount of sedentary time spent eating and drinking may overlap with the amount spent for socializing with friends or family. Secondly, the adoption of the split-half method for reliability testing, where higher correlations denote better scale reliability, is less suitable for longitudinal data, as greater fluctuations between halves are anticipated, thus the obtained values may not be particularly useful. Furthermore, the sample was predominantly German, thus the overall low scores on evolutionary mismatch could be explained by Germans usually engaging in healthy lifestyles, as Germany is one of the very few European countries showing a compression of morbidity rates (Welsh et al., 2021). A more ethnically diverse sample might have yielded quite different results.

Another limitation pertains to the discrepancy in scoring between the PHQ-9 items used to measure trait and state depressive symptoms. The modification implies a higher potential score for this variable, therefore higher scores for state depressive symptoms differ from higher scores for trait depressive symptoms. However, higher scores still indicate a participant burdened by more severe depressive symptoms as the state depressive symptoms scale proved moderate reliability. Additionally, the adaptation of one of the questions of the PHQ-9 to fit better with younger populations was not validated and may have not been interpreted by participants as intended. Thus, it is important to mention that it may have slightly influenced the participants' answers and scores on that question in this study. Moreover, due to the relative novelty and lack of research on the degree of evolutionary mismatch as a construct, the questionnaire assessing it lacks validation and normative data to aid in the interpretation of the scores, thus it could only be used in testing associations. All these aforementioned limitations most likely also contributed to the high variability and many outliers in mean scores on most variables.

Implications and Directions for Future Research

Based on the issues identified post-analysis and other limitations of this study, future research can build upon the findings and try to incorporate the following suggestions for improvement. Firstly, the measurement instruments used should be refined. The questionnaire used to assess the degree of evolutionary mismatch should be used after validation to ensure the utilization of a robust and reliable instrument with available norms. Given the multidimensionality of the construct, the development of new measurement tools that account for

the various mismatches and their potential health outcomes is needed instead of an all-encompassing scale. After accordingly refining the construct, a more profound understanding of the role that it plays in the investigation of common unhealthy behaviours could aid in finding solutions that are more aligned with humans' evolved psychological mechanisms, resulting in better outcomes. Secondly, prior to introducing the PAST-U items to participants, it is imperative that the provided information clarifies the need for distinguishing between potentially overlapping activities when reporting sedentary time. Thirdly, future research should employ objective measures for daily behaviours, such as an accelerometer, along to self-report measures such as the PAST-U, in order to obtain highly accurate measurements.

Given that sedentary behaviour alone did not appear to associate with depressive symptoms in this study, future research should investigate mediating factors that may contribute to the associations found by previous cross-sectional studies. It may be that the surroundings people sit in associate with depressive symptoms. Then, for example, changes in office design might be easier to implement than trying to reduce sitting time in cases when one's work commitments do not allow it. In addition, the duration of the data collection should be longer or chosen more carefully to account for variations in mood, as in the current study most of the assessed days were holidays or weekend. A more ethnically diverse sample is also advised to allow for better exploration of various lifestyles and for the generalizability of the findings.

Conclusion

To conclude, this study explored the association between sedentary behaviour and depressive symptoms in young adults, as well as the potential moderating role of the degree of evolutionary mismatch. Although a positive association was observed between sedentary time and depressive symptoms over time, the effect was minimal and insignificant. The degree of evolutionary mismatch did not moderate this association, indicating that individuals with higher mismatch scores did not experience more severe depressive symptoms when engaging in prolonged sitting. Overall, the outcomes of this study bring positive news for younger populations, as they indicate that prolonged sitting alone does not significantly associate to the occurrence or exacerbation of depressive symptoms over time. Nonetheless, the many adverse

health consequences of sedentary behaviour must not be disregarded, therefore reducing sitting time and engaging in less sedentary activities as much as possible is highly advised.

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Appendix A

Informed Consent

Dear participant,

you are asked to participate in a study conducted by Theodora Buzulica, Hannah C. Schäfer, and Luisa Wiggeshoff from the psychology department of the University of Twente. The study is part of an undergraduate project, and we thank you for taking the time to participate in our study! You may participate in this study if you are 18 to 35 years old, and proficient in English. Please read the information below about the details of our study.

Purpose
The purpose of this study is to investigate the relationship between daily sitting time and emotional eating, mood states and feelings of social anxiety. By participating in this study, you will help us contribute to the scientific knowledge about sitting and its relationship to mental health.

Procedure
The study will be conducted over a period of nine days. On the first day of the study (April 24th), you will be asked to complete a baseline questionnaire, which will take about ten minutes to fill out. Starting the following day (April 25th), you will receive one afternoon survey at 5:00pm. From April 26th on, you will receive two daily questionnaires: one morning survey at 8:00am, and one afternoon survey at 5:00pm. On the last day, May 2nd, you will receive the morning survey only.
Each survey should take no longer than 3 and 1 minute(s), respectively, and can be completed within 4 hours. For example, the first questionnaire can be answered from 8:00am until 12pm. All surveys will be completed via the Ethica App. Please make sure that permanent notifications for Ethica are enabled on your device.

Participant Rights
Your participation in this study is completely voluntary. If you wish to withdraw from this study, you may do so at any time without giving a reason. To withdraw from participation after the study, please inform the researchers via email within 10 days of your participation.

Risks or Discomforts
Participation in this study should not pose any risks. One possible consequence is an increased awareness of your daily feelings, behaviors, and/or emotions. If you are sensitive to these issues, or if you are suspected of having or have been diagnosed with a mood and/or anxiety disorder, or an eating disorder, please consider your participation in this study carefully.

Confidentiality
Your responses will be kept confidential: All personal data will be anonymized and will not be published and/or shared with third parties. The data will only be used for this study, and will be kept in locked files. Only research personnel will have access to these files.

The study has been approved by the ethics committee of the University of Twente. If you have any questions or concerns before, during or after your participation, please do not hesitate to contact the researchers:

t.buzulica@student.utwente.nl (Theodora Buzulica)
h.c.schafer@student.utwente.nl (Hannah Schäfer)
l.wiggeshoff@student.utwente.nl (Luisa Wiggeshoff)
(g.schaap@utwente.nl) (Gerko Schaap, supervisor)

After having read the information above, do you agree with the following statements and at the same time confirm that you are participating in this study and that your data will be used for research as described?

I understand that my participation is voluntary and that I am free to withdraw my participation, without explaining, until 10 days after participation.

I understand that any information given by me may be used in future reports or presentations by the researcher/s, but that my data will not be identifiable.

I understand that anonymized data will be kept according to university guidelines for up to 10 years after the end of the study.

I agree to take part in the study.

Appendix B

Baseline Questionnaire

Demographics

- How do you identify?
  - Female
  - Male
  - Other
  - Prefer not to say
- What is your age? (In numbers)
- What is your nationality?
  - Dutch
  - German
  - Other-EU
  - Other Non-EU
- What is your current occupation? Please consider what applies most to you.
  - Full-time student
  - Full-time working
  - Student and working
  - Not working
  - Other

Trait Depressive Symptoms – PHQ-9

We would also like to know a bit about your **mood** over **the past 2 weeks**. Please indicate how often you have been bothered by the following problems:

Little interest or pleasure in doing things.

1. Not at all
2. Several days
3. More than half the days
4. Nearly every day

Feeling down, depressed, or hopeless.

1. Not at all
2. Several days
3. More than half the days
4. Nearly every day

Trouble falling asleep or sleeping too much.

1. Not at all
2. Several days
3. More than half the days
4. Nearly every day

Feeling tired or having little energy.

1. Not at all
2. Several days
3. More than half the days
4. Nearly every day

Poor appetite or overeating.

1. Not at all
2. Several days
3. More than half the days
4. Nearly every day

Feeling bad about yourself or that you are a failure or have let yourself or your family down.

1. Not at all
2. Several days
3. More than half the days
4. Nearly every day

Trouble concentrating on things, such as studying or watching Netflix.

1. Not at all

2. Several days
3. More than half the days
4. Nearly every day

Moving or speaking so slowly that other people could have noticed. Or the opposite being so fidgety or restless that you have been moving around a lot more than usual.

1. Not at all
2. Several days
3. More than half the days
4. Nearly every day

Thoughts that you would be better off dead, or of hurting yourself.

1. Not at all
2. Several days
3. More than half the days
4. Nearly every day

Degree of Evolutionary Mismatch

Lastly, we would like to know more about your **lifestyle**. Please answer the questions with **the last three months** in mind.

On average how often do you go to sleep between 21:00 and 23:00 and wake up between 6:00 and 8:00?

o (almost) never (5)

o 1-2 times per week (4)

o 3-4 times per week (3)

o 5-6 times per week (2)

o (almost) every day (1)

On average how many hours do you spend actively moving (including sports, biking, walking, cleaning, doing groceries, gardening, etc.)?

- o less than an hour per day (5)
- o 1-2 hours per day (4)
- o 2-3 hours per day (3)
- o 3-4 hours per day (2)
- o more than 4 hours per day (1)

On average how long per day are you outside?

- o less than an hour per day (5)
- o 1-2 hours per day (4)
- o 2-3 hours per day (3)
- o 3-4 hours per day (2)
- o more than 4 hours per day (1)

On average how many times a week are you in a nature (park, forest, dunes, etc.)?

- o (almost) never (5)
- o 1-2 times per week (4)
- o 3-4 times per week (3)
- o 5-6 times per week (2)
- o (almost) every day (1)

How large is the town you live in?

- o less than 1000 inhabitants (1)
- o 1000-20.000 inhabitants (2)
- o 20.000-50.000 inhabitants (3)
- o 50.000-100.000 inhabitants (4)

- o more than 100.000 inhabitants (5)

On average how often do you have a social activity for fun (such as diner with other people, going to the cinema with other people, going to a party, bar, club, etc.)?

- o (almost) never (5)
- o 1-2 times per week (4)
- o 3-4 times per week (3)
- o 5-6 times per week (2)
- o more than 6 times per week (1)

How often do you worry, for example about your financial situation, housing, study results, deadlines, politics, climate change, etc.?

- o (almost) never (1)
- o monthly (2)
- o weekly (3)
- o multiple times per week (4)
- o (almost) every day (5)

How often do you feel like you lack time?

- o (almost) never (1)
- o monthly (2)
- o weekly (3)
- o multiple times per week (4)
- o (almost) every day (5)

How often do you feel freedom/autonomy to do what you want to do?

- o (almost) never (5)
- o monthly (4)

- o weekly (3)
- o multiple times per week (2)
- o (almost) every day (1)

From how many people do you receive regular emotional support (including parents, siblings, grandparents, neighbors, teachers, friends, etc.)?

- o from no one (5)
- o from one person (4)
- o from two persons (3)
- o from three persons (2)
- o from four or more persons (1)

As a child (0-12 years), from how many people did you receive regular emotional support (including parents, siblings, grandparents, neighbors, teachers, friends, etc.)?

- o from no one (5)
- o from one person (4)
- o from two persons (3)
- o from three persons (2)
- o from four or more persons (1)

How important is it for you to have many material possessions?

- o not important at all (1)
- o slightly important (2)
- o neutral (3)
- o important (4)
- o very important (5)

How important is it for you to strive for perfection?

o not important at all (1)

o slightly important (2)

o neutral (3)

o important (4)

o very important (5)

'I prefer to do things on my own.' Do you agree with this statement?

o strongly agree (5)

o agree (4)

o neutral (3)

o disagree (2)

o strongly disagree (1)

'I spend more time on social media than I like.' Do you agree with this statement?

o strongly agree (5)

o agree (4)

o neutral (3)

o disagree (2)

o strongly disagree (1)

On average how often are you engaged with music (such as dancing, singing, making music, listening to music with full concentration, etc.)?

o (almost) never (5)

o 1-2 times per week (4)

o 3-4 times per week (3)

o 5-6 times per week (2)

o more than 6 times per week (1)

How important is religion and/or spirituality for you?

o not important at all (1)

o slightly important (2)

o neutral (3)

o important (4)

o very important (5)

On average how often do you eat ultra-processed foods (such as fast food, packaged cookies, cakes, ice-cream, salty snacks, frozen meals, sausage, pizza, instant noodles, ready-made sauces, soft drinks, etc.)?

o (almost) never (1)

o 1-2 times per day (2)

o 3-4 times per day (3)

o 5-6 times per day (4)

o more than 6 times per day (5)

On average how often do you eat fiber-rich food (such as fruit, vegetables, whole grain bread, legumes, nuts, seeds, etc.)?

o (almost) never (5)

o 1-2 times per day (4)

o 3-4 times per day (3)

o 5-6 times per day (2)

o more than 6 times per day (1)

On average how many cigarettes do you smoke in a day?

o I (almost) never smoke (1)

- o less than 5 cigarettes per day (2)
- o 5-10 cigarettes per day (3)
- o 10-20 cigarettes per day (4)
- o more than 20 cigarettes per day (5)

On average how many glasses of alcohol do you drink a week?

- o I (almost) never drink (1)
- o less than 6 glasses per week (2)
- o 6-10 glasses per week (3)
- o 11-15 glasses per week (4)
- o more than 15 glasses per week (5)

On average how many times do you use drugs (such as weed, magic mushrooms, XTC, LSD, cocaine, etc.)?

- o (almost) never (1)
- o 1-2 times per month (2)
- o 3-4 times per month (3)
- o 5-6 times per month (4)
- o more than 6 times per month (5)

On average how often do you use medication, including painkillers (paracetamol, aspirin, ibuprofen, etc.), sedatives and/or soporifics (benzodiazepines, valerian, melatonin, beta-blockers, etc.), medication against allergies, antidepressants, stimulants (Ritalin, Concerta, amphetamines, pemoline, etc.)?

- o (almost) never (1)
- o 1-2 times per week (2)
- o 3-4 times per week (3)
- o 5-6 times per week (4)

o (almost) every day (5)

Do you use hormonal contraceptives (such as contraceptive pills or a hormone IUD)?

o yes (5)

o no (1)

o does not apply (1)

How often do you feel stressed?

o (almost) never (1)

o monthly (2)

o weekly (3)

o multiple times per week (4)

o (almost) every day (5)

On average how often do you have physical complaints, such as headache, stomach ache, back-, neck-, or shoulder pain, an allergy and/or asthma attack, a skin rash or outbreak?

o (almost) never (1)

o 1-2 times per week (2)

o 3-4 times per week (3)

o 5-6 times per week (4)

o (almost) every day (5)

Appendix C

Morning Questionnaire – PAST-U

Good morning, we hope you had a great start of the day!

The following questions aim to assess your sitting time **of the past 24 hours**. Please consider the amounts of time spent sitting while being **awake**. Please report the amounts in **minutes**.

For example, if you've watched television while sitting on the couch for 1 hour, please fill out **'60'**.

Please note: you can enter the minutes directly using the mobile phone keypad, you do not have to use the arrows.

1. **How long** were you sitting while **studying** yesterday? (include the time in minutes at university, during lectures, tutorials, meetings, group discussions, self-study, study from home, etc.)
2. **How long** were you sitting at your **workplace** or **working from home** in a paid position yesterday (in minutes)?
3. Please estimate the **total** time that you spent **sitting** to **travel** from one place to another. Please **include sitting and waiting** for transport in minutes. Do **not** include any time you were standing up while travelling or waiting.
4. Please estimate the **total time** you spent sitting or lying down to **watch TV** or DVDs or **play games**on the TV, such as PlayStation/Xbox yesterday (in minutes). This includes if you watch TV in bed.
5. Please estimate the **total time** yesterday that you spent sitting or lying down and **using the computer**. (For example, include time spent playing games on you Iphone/Ipad/tablet, using the internet or activities that **were not for studying or working purposes**, like Facebook, Twitter, Skype, YouTube, online-shopping, etc. Please indicate the time in minutes.)
6. Please estimate the total time yesterday that you spent sitting or lying down while **reading during your leisure time**. Include reading in bed but do not include time spent reading for paid work or for study. Please estimate the time in minutes.
7. Please estimate the total time yesterday that you spent sitting down for **eating and drinking**, including meals and snack breaks, in minutes.
8. Please estimate the total time yesterday that you spent sitting down to **socialize with friends or family**, regardless of location (at university, at home or in a public place), in minutes. Include time on the telephone.

9. We are interested in any other sitting or lying down that you may have done that you have not already told us. For example this could include; **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 in minutes, **NOT** including time that you have told us about in the previous answers.

Appendix D

Afternoon Questionnaire

Good afternoon! 👏

Now, we would like you to indicate to what extent the following statements apply to you.

1 = Never, 5 = Extremely

1. I felt little interest or pleasure in doing things today.
2. I felt down, depressed, or hopeless today.
3. Last night I had trouble falling or staying asleep, or sleeping too much.
4. I felt tired or I had little energy today.
5. I had trouble concentrating on things, such as studying or watching Netflix today.