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Momentary mood predicts upcoming real-life sedentary behaviour

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Abstract

Humans in the industrialized world spend a large amount of daily time in sedentary behaviour. Since sedentariness negatively impacts a variety of psycho-physiological outcomes the identification of antecedents that lead to sedentary behaviour is an important public health issue. In this context, mood, a central indicator for both psychological well-being and mental health, is severely understudied.

To investigate whether mood dimensions influence subsequent sedentary behaviour, we assessed both constructs at baseline via questionnaires and via Ambulatory Assessment (AA) over 5 days in 92 university employees. We continuously measured sedentary behaviour using accelerometers and assessed mood repeatedly 10 times each day on smartphone diaries. We employed multiple regression analyses to analyze between-subject effects and multilevel modeling to analyze within-subject effects.

Higher momentary ratings of valence ($p < 0.05$) and energetic arousal ($p < 0.01$) predicted lower amounts of subsequent sedentary behaviour, whereas higher ratings of calmness ($p < 0.01$) predicted higher amounts of subsequent sedentary behaviour. The context moderated the effect of energetic arousal and calmness on sedentary behaviour with increased effects in the home compared to the work context. Mood significantly predicted sedentary behaviour on a within-subject but not on a between-subject level.

Preliminary evidence suggests that mood regulates sedentary behaviour in everyday life. Time-sensitive analyses, such as from moment to moment revealed an association between mood and sedentary behaviour (within-subject), whereas analyses between different individuals revealed no associations (between-subject). These preliminary findings may inform multicomponent intervention strategies that target mood, to reduce sedentary behaviour in daily life.

Introduction

Sedentary behaviour negatively impacts a variety of psycho-physiological health outcomes, such as cardiometabolic diseases and depression [1,2]. Technological and social changes in home, environmental and occupational settings have led to an increasingly sedentary lifestyle among different cultures and countries [3]. On average, humans in the industrialized world spend around 9-11 hours/day in sedentary behaviour, i.e., any waking behaviour characterized by an energy expenditure ≤1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture [4]. Thus, from a public health perspective, reducing sedentary behaviour has become a major issue. An important step to address this challenge is to identify antecedents of sedentary behaviour, as they could help tailor effective intervention strategies.

According to the ecological model of sedentary behaviour [5], a wide variety of factors, such as demographic variables, psychological attitudes, social norms, and the environment may influence the choice of behaviour. In a systematic review, Rhodes and colleagues [6] concluded that research on antecedents of sedentary behaviours is still in its infancy. Most of the studies focused on static demographic variables such as age, Body Mass Index (BMI) or ethnicity, whereas in contrast the influence of timely antecedents such as psychological variables like mood has been less explored. Mood is a central indicator for both mental well-being in healthy populations and is altered in many mental disorders (e.g., diminished mood in major depressive disorder or high mood fluctuations in borderline personality disorder) [7]. According to Wilhelm and Schoebi [8], mood can be defined as diffuse affective states that subtly affect our experience, cognition, and behaviour. There is an ongoing discussion about the conceptualization of mood. Some authors tend to argue for a two-dimensional structure with negative and positive affect [9], whereas other authors tend to argue for a three-dimensional model, including basic mood-dimensions such as valence, energetic arousal and calmness. In this context, Wilhelm and Schoebi [8] demonstrated that a two-dimensional model fit their data when taking a between-subjective perspective, whereas a three-dimensional model was superior when taking a within-subject perspective.

Previous studies have started to explore whether mood is associated with sedentary behaviour. In particular, DeMello and colleagues [10] examined the reciprocal relationship between mood states (e.g., vigor, tension, fatigue) and sedentary behaviour in a 1-year longitudinal study. Their results indicated that worsened mood leads to higher levels of sedentary behaviour. Schwerdtfeger and colleagues [11] examined the relationship between affective states and physical behaviour in daily life, with the result that affect is inversely associated with sedentary periods, suggesting that both positive and negative affective states are associated with a decrease in sedentary activities. Moreover, Maher and researchers [12] investigated the extent to which within-subject variability in positive affect and feelings of energy predicted sedentary time. This study did not reveal any association between within-subject variability in affect or energy and sedentary time. In summary, the evidence for the association between mood and sedentary behaviour is inconclusive.

To the best of our knowledge, only two studies, i.e., Schwerdtfeger and colleagues [11] and Maher and colleagues [12] focused on a dynamical within-subject association between mood and sedentary behaviour, whereas DeMello and researchers´ study [10] focused on a longitudinal approach over 1 year. Methodological discrepancies and limitations may be one reason which may explain the divergent findings. In all studies, the operationalization of sedentary behaviour includes only information of participant's motion but not about body postures which is incongruent with the international definition of sedentary behaviour. Thus, there is an intangible risk of misclassifying sitting and standing postures, which may result in an over- or underestimation of sedentary behaviour [13]. Another reason might be the conceptual approach of data collection and data analysis. In particular, DeMello et al. [10] considered and analyzed data over one year with two mood-assessments per participant, while Schwerdtfeger et al. [11] and Maher et al. [12] considered possible dynamical within-subject associations, i.e., several mood-assessments per participant per day. Although the DeMello and colleagues´ [10] study design included the lowest number of a within-subject analysis structure, i.e., two assessments per participant, it did not consider possible dynamical relations. Thus, their study focused primarily on differences between participants, e.g., participants with a poor mood spent more time in sedentary behaviour [10]. In principle, such an approach can be misleading and may contribute to the ongoing problem of the "ecological fallacy" – the perspective that the relationship between variables at one level (between person) can be presumed to exist at another (within-person) level [14]. A well-known example of the difference between the between-subject and within-subject approach is the relationship between blood pressure and physical activity. During physical activity, blood pressure is elevated (i.e., a positive association between physical activity and blood pressure from a within-person perspective); however, individuals with chronic high blood pressure engage in less physical activity (i.e., a negative association from a between-subject perspective) [15]. Since mood varies over time [16], the within-subject approach is indeed sensitive to unravel possible temporal variations such may occur between mood and sedentary behaviour. In general, only within-subject approaches can reveal antecedents.

Taking all this into account, there is a lack of evidence, whether mood is an antecedent of sedentary behaviour among healthy adults. Furthermore, if mood is an antecedent of sedentary behaviour, it is unclear, which methodological approach (between-subject and/or within-subject) may unravel this association. To overcome this limitation and to analyze, whether mood is associated with sedentary behaviour on a between-subject and/or within-subject level, we conducted a study among healthy adults using Ambulatory Assessment (AA). AA is the state-of-the-art methodology for assessing psychological variables such as mood via smartphone-based electronic diaries and objectively captured sedentary behaviour by accelerometers in real-time during participants' everyday life [17,18]. Moreover, prior to the AA assessment, we assessed mood and self-reported sedentary time via paper-pencil questionnaires. We recruited university employees, a population shown to be at high risk for sedentary behaviour [19], thereby aiming to maximize the effects of interest.

While there are only few empirical studies on the association between mood and sedentary behaviour, several theories and conceptual models, e.g., based on psychological hedonism or on a dual-processing perspective allow to derive assumptions on how mood dimensions may influence behaviour [20]. For example, the Dual-Mode Model (DMM) [21] is widely used to explain the relationship between physical behaviour and mood, suggesting that momentary effects of mood on physical behaviour may depend on cognitive processes. Put simply, knowledge on the negative health consequences of sedentary behaviour (e.g., cardiometabolic risk) may lead to decreased mood when being sedentary. Further, the social withdrawal hypothesis [22] allows to derive the assumption that if individuals replace social interactions through time spent in digital media usage, this might result in decreased mood and subsequently increased sedentary behaviour [23].

Based on previous studies [10,11] and theoretical considerations [20–23], we hypothesized that on a between-subject level lower mood ratings of valence, calmness, and energetic arousal would relate to higher amounts of device-based assessment of sedentary behaviour (hypothesis 1a). Additionally, we hypothesized that lower questionnaire-based mood ratings would predict higher amounts of self-reported sedentary time (hypothesis 1b). Moreover, we expected on the within-subject level lower ratings of the mood dimensions valence, calmness, and energetic arousal would lead to higher levels of device-based assessment of sedentary behaviour (hypothesis 2). Furthermore, we conducted exploratory analyses to test whether the association of mood dimensions (valence, energetic arousal, and calmness) and sedentary behaviour varied as a function of the environmental context (at home vs. work).

Materials and Methods

Participants

University employees (n=92) were recruited at two locations. First, between October 2016 and January 2017 at the University of Newcastle, Australia (UoN; n=35), second from May 2017 to August 2017 at the Karlsruhe Institute of Technology, Germany (KIT; n=57). Only participants without restrictions in performing their daily activities (i.e., those without injury or disease) were included in the study. Twelve participants were excluded from this sample for compliance reasons, i.e., <30% responses to e-diary prompts [24] and/or < 3 valid days of minimum ≥ 10h per day accelerometer wear-time [25]. This resulted in a final sample of 80 participants. The Human Research Ethics Committee of the University of Newcastle (H-2016-0347) and the Ethics Committee of the Karlsruhe Institute of Technology (KIT) approved this study. All eligible participants received written and oral information regarding the study procedures before written informed consent was obtained. Participants were free to withdraw from the study at any time.

Study design and procedures

We conducted an AA study over five consecutive days (three weekdays and two weekend days). During this time frame, participants carried three accelerometers (two move-3 and one ECG-move-3, movisens GmbH, Karlsruhe, Germany, movisens.com) and a smartphone (Motorola Moto G, Motorola Mobility LLC, Libertyville, IL, motorla.com) in daily life. Prior to the AA-study, participants received an extensive briefing on the use of the devices and completed a basic survey (including the World Health Organisation-five Well-Being Index (WHO5), the Global Physical Activity Questionnaire (GPAQ), and basic demographic measures).

Participants wore the triaxial accelerometers attached at three distinct positions: hip (move-3), thigh (move-3), and chest (ECG-move3). The participants were instructed to wear the accelerometers continuously during the entire measurement period except during sleep, showering or swimming. The sensors captured movement and body position with a range of ±16 g and a sampling frequency of 64 Hz. Raw acceleration was stored on an internal memory card. Both high-pass filter (0.25 Hz) and low-pass filter (11 Hz) were used to eliminate gravitational components and to exclude artefacts from the acceleration data. Anastasopoulou and colleagues [26] showed that move accelerometers used in this study are appropriate for assessing humans' energy expenditure.

The smartphone prompted the participants via an acoustic, visual, and vibration signal every 40 to 100 minutes within the 7:30 am to 9:30 pm period. The participants had the opportunity to postpone an e-diary prompt for a maximum of 15 minutes. To optimize the assessment of the association between mood and sedentary behaviour, we implemented a mixed-sampling strategy using the software movisensXS (version 0.7.47574; xs.movisens.com). In particular, we developed a sedentary trigger algorithm, i.e., the thigh sensor analyzed and transferred data on body position (sitting/lying or upright) via Bluetooth Low Energy (BLE) to the smartphone in real-time. Each time a participant spent 30 minutes in a sitting/lying position, the e-diary triggered mood ratings. To minimize participant’s burden, we implemented time out triggers, occurring no more than every 40 minutes and at least every 100 minutes. Additionally, to maximize variance, i.e., both sedentary and active phases, we used random triggers at various time points throughout a day. In other words, if a participant would spent zero minutes in a sedentary position between 7:30 am and 9:30 pm, the smartphone would trigger eight prompts per day. In contrast, if a participant spent each minute in a sedentary position between 7:30 am and 9:30 pm, the smartphone would trigger a maximum of 21 prompts per day.

Measures

Sedentary Behaviour. We parameterized sedentary behaviour according to its international accepted definition [4]. In particular, one minute was defined as a sedentary minute if the participant was in a lying/sitting position with an intensity of ≤ 1.5 metabolic equivalents (MET´s). In contrast, a non-sedentary minute was defined as the participant being in a lying/sitting/upright position with an intensity of ≥ 1.51 MET. We calculated the parameters body position and MET in 1-minute intervals using the software DataAnalyzer (version 1.6.12129; movisens.com). Following established procedures, MET was defined as the metabolic rate of a human relative to the basal metabolic rate in relation to his body weight [27]. Body position was defined as the ratio from the vertical thigh to the ventral longitudinal axis of the body. The accelerometer detected either an upright body position (<20°) or a sitting/lying body position (>20°) (movisens.com).

To analyze within-subject effects of mood dimensions on sedentary behaviour, we aggregated sedentary minutes within the time frame of 30 minutes after each e-diary prompt using SPSS (version 25, IBM). To analyze between-subject effects of mood dimensions on sedentary behaviour, we calculated i) the mean sedentary time for each participant (hypothesis 1a), and ii) the self-reported sedentary time from the GPAQ (hypothesis 1b).

Mood. To assess within-subject fluctuations of mood across time, we used a short version of the Multidimensional Mood Questionnaire (MDMQ) presented on electronic smartphone diaries on visual analog scales (0-100) in reversed polarity and mixed order. This six-item short-scale [8] captured three basic mood dimensions: valence, energetic arousal, and calmness, with acceptable psychometric properties (reliability coefficients ranging between 0.65 and 0.76) in our sample. The following items were presented:

Valence was determined by items i) unwell to well, ii) content to discontent; energetic arousal was determined by items i) full energy to without energy, ii) tired to awake; and calmness was determined by items i) relaxed to tense, ii) agitated to calm. The KIT participants were presented the German translation [8]. In addition, the German subsample was asked to report on their current location, e.g., home or work. To analyze between-subject effects of mood, we used the participant's average value of all e-diary mood assessments (hypothesis 1a) and the WHO5-Index score of each participant (hypothesis 1b), respectively. The WHO5 questionnaire includes five items, of which three of them are congruent with the basic mood-dimensions from the MDMQ (for details see [28]). In particular, item two of the WHO5- questionnaire, i.e. “I have felt calm and relaxed”, and the two items of the MDMQ, i.e., agitated/calm and relaxed/tense, both target the mood-dimension calmness. Item three of the WHO5 “I have felt active and vigorous”, and the items tired/awake and full of energy/without energy of the MDMQ, both target the mood-dimension energetic arousal. Finally, item one of the WHO5 “I have felt cheerful and in good spirits”, and the items content/discontent and unwell/well of the MDMQ, both target the mood-dimension valence.

Please insert Figure 1 here

Statistical analyses

We merged the physical behaviour data with the mood ratings by using DataMerger (version 1.6.38.68; movisens.com). To test hypotheses 1a and 1b, i.e., between-subject effect of mood on sedentary behaviour, we conducted two multiple linear regression models. In the first model (hypothesis 1a), participants´ mean of the device-based assessment of sedentary time was our outcome, and we added participants average value of all e-diary mood assessments for the dimensions valence [0-100], energetic arousal [0-100], and calmness [0-100] and the predictors age [years], BMI [kg/m^2], sex, group [KIT vs. UoN]. In the second model (hypothesis 1b), self-reported sedentary behaviour (GPAQ) was our outcome, and we added participants` score of the WHO5-Index [0-100] and further predictors such as age [years], BMI [kg/m^2], sex, group [KIT vs. UoN]. In addition to hypothesis 1a and 1b, we conducted further analyses, whether the WHO5-Index may predict participant´s average of device-based assessments of sedentary time. To test for model assumptions, we checked for linearity, multicollinearity, outliers, and distribution of the residuals, prior to the analyses of our main models

To test hypothesis 2, i.e., within-subject effects of mood on sedentary behaviour, we conducted multilevel analyses [29]. Multilevel analysis has several advantages, such as

(i) the analysis of hierarchically structured data (i.e., multiple mood assessments nested within participants), (ii) separate within- and between-subject effects, and (iii) robustness concerning missing data points. We set up two-level-models and nested repeated measurements (level 1) within participants (level 2). First, intraclass correlation coefficients (ICCs) were estimated. ICCs indicate the amount of variance on the within- vs. between-subject level and they are estimated using unconditional (null-) models. We computed this ICCs for sedentary time segments of 30 minutes after each mood assessment, to estimate the amount of variance on the between vs. within-subject level in our outcome variable sedentary time. Second, we added the predictors time [hours], time-squared [hours^2], valence [0-100], energetic arousal [0-100], calmness [0-100], age [years], sex [male vs. female], group [KIT vs. UoN], day [weekend day vs. weekday] and BMI [kg/m^2] to our models.

To analyze exploratory analyses, we added the context variable [work vs. home] as a further covariate into our model in the German subsample. Moreover, to standardize time and time of the day squared, we subtracted the start time of the study for each day (7:30 am). The predictor time of day (squared) was included in the main model to control for potential nonlinear (quadratic) time-effects. The final model of the within-subject analyses is presented in the equations [1-9] below.

Within-subject analyses [hypothesis 3]

$$\text{level}-1:\ \mathrm{Y(sedentary\ time)}_{ij} = \beta_{0j} + \beta_{1j}\,(\mathrm{valence}_{ij}) + \beta_{2j}\,(\mathrm{energetic\ arousal}_{ij}) + \beta_{3j}\,(\mathrm{calmness}_{ij}) + \beta_{4j}\,(\mathrm{time\ of\ day}_{ij}) + \beta_{5j}\,(\mathrm{time\ of\ day\ squared}_{ij}) + \beta_{6j}\,(\mathrm{weekday}_{ij}) + \beta_{7j}\,(\mathrm{context}_{ij}) + r_{ij} \quad [1]$$

$$\text{level}-2:\ \beta_{0j} = \gamma_{00} + \gamma_{01}(\mathrm{group}) + \gamma_{02}(\mathrm{age}) + \gamma_{03}(\mathrm{BMI}) + \gamma_{04}(\mathrm{sex}) + \mu_{0j} \quad [2]$$

$$\text{level}-2:\ \beta_{1j} = \gamma_{10} \quad [3]$$

$$\text{level}-2:\ \beta_{2j} = \gamma_{20} + \mu_{2j} \quad [4]$$

$$\text{level}-2:\ \beta_{3j} = \gamma_{30} + \mu_{3j} \quad [5]$$

$$\text{level}-2:\ \beta_{4j} = \gamma_{40} \quad [6]$$

$$\text{level}-2:\ \beta_{5j} = \gamma_{50} \quad [7]$$

$$\text{level}-2:\ \beta_{6j} = \gamma_{60} + \mu_{6j} \quad [8]$$

$$\text{level} - 2:\ \beta_{7j} = \gamma_{70} + \mu_{7j} \qquad [9]$$

On level 1, within-subject effects were estimated for participants´ (subscript $_j$) sedentary time after each e-diary entry at any time of measurement (subscript $_i$). Y_{ij} represents the amount of aggregated sedentary time [range from 0-30 minutes], respectively, in person *j* at time *i*. Beta coefficients represent the intercept (β_{00}) and the effects of valence, energetic arousal, calmness, time, time-squared, and day ($\beta_{1j} - \beta_{7j}$) at level 1, and r_{ij} represents the residuals at level 1 [1]. We centered valence, energetic arousal, and calmness on the participant mean. On level 2, between-subject effects were estimated. We included random effects (i.e., individual variation on the sample mean effect γ) for each predictor represented as μ_{ij}. Random slope parameters ($\mu_{1j} - \mu_{7j}$) were kept in the model only if significant (p < .05) variation was observed across participants [2-9]. To compare the effects of each mood dimension, we calculated standardized beta coefficients (stand. BC) following established procedures [30]. Finally, we conducted additional analyses. First, we added participants´ mean ratings of valence, energetic arousal, and calmness across the AA-study period as between-subject predictors into our main model to test whether they predict momentary sedentary time. Second, we conducted a multilevel random-intercept model to test, whether the type of trigger (random vs. triggered) may influence subsequent sedentary behaviour.

Results

In Table 1, the sample characteristics are detailed. Over 5 days, participants were prompted 4,556 times. 77% of all prompts were answered. On a participant level, missing e-diary prompts ranged from 2-60 prompts across the study period. On average, participants answered 44.03 ± 13.15 prompts across the study period (ranging from 10-79 prompts). The amount of sedentary triggered prompts ranged from 0 to 82 across the study period, with an average of 31.7 ± 21 prompts. Because of technical issues, seven participants received only random prompts. Participants reported on a scale ranging from 0 to 100, average mood scores of 63.22 (energetic arousal), 75.88 (valence), and 68.48 (calmness) via e-diary. The WHO-5- Index ranged between 20 and 96 with a mean index-score of 64.65 ± 14.29 points, indicating a well-tempered sample [28]. Context assessments were only available from the German subsample. In particular, 25.7% of 2323 total assessments in the German subsample occurred during work. On average, accelerometers were worn for 15.47 ± 3.47 h/participant/day. Participants spent 8.03 ± 2.71 h/day sedentary. Participants reported via GPAQ a mean sedentary time of 8.14 ± 2.52 h/participant/day. Device-based and self-reported sedentary time correlated significantly on a weak to moderate level (r = .277; p = .013). 93% (ρ_I = 0.07) of the variance in the aggregated sedentary time [ranging from 0-30 minutes] after the mood prompt was due to within-subject fluctuations.

Please insert Table 1 here

Hypothesis 1: Between-subject analyses

In both models, mood did not significantly predict sedentary time (see Table 2). In particular, neither aggregated mood-ratings via e-diary, i.e., valence, energetic arousal, and calmness predicted device-based assessment of sedentary time, nor the WHO5-Index predicted self-reported sedentary time. Moreover, none of the predictor's group, age, BMI, and sex were significantly associated with device-based and self-reported sedentary time in both models. For the first model [hypothesis 1a], the goodness of fit was 0.9% with a lower than small effect size (R^2 = 0.009; f^2 = 0.095), and for the second model [hypothesis 1b] 5.3% with a medium effect size (R^2 = 0.053; f^2 = 0.237). Moreover, additional analyses revealed that the WHO5-Index did not significantly predict (stand. β = -0.156; p = 0.164) participant´s average of device-based measurements of sedentary time.

Please insert Table 2 here

Hypothesis 2: Within-subject analyses

Valence and energetic arousal negatively predicted sedentary time (see Table 3). Contrary, calmness positively predicted sedentary time. In particular, higher ratings (e.g., 90) compared to lower ratings (e.g., 20) of valence were associated with lower amounts of sedentary time of about 2.77 minutes (scale: 0-30 minutes). Higher ratings (e.g., 90) of energetic arousal compared to lower ratings (e.g., 20) were associated with lower amounts of sedentary time of about 4.45 minutes. Put simply, higher values of valence and energetic arousal were associated with lower subsqeuent sedentary time. Contrary, higher ratings of calmness (e.g., 90) compared to lower ratings (e.g., 20) were associated with higher amounts of sedentary time of about 5.54 minutes. Furthermore, age and weekday were significantly related to sedentary time. On average participants aged ≥ 50 years spent 2.37 minutes less in sedentary behaviour compared to participants aged ≤ 30 years. Moreover, on average, participants spent 2.26 minutes less in sedentary behaviour on weekend days compared to workdays. None of the other predictors' group, BMI, sex, time of day and time of day squared were significantly associated with sedentary time. Furthermore, we found significant random effects for energetic arousal, calmness, time of the day, and weekday revealing that effects of these predictors on sedentary time varied between participants. According to Arend and Schäfer´s [31] rules of thumb for minimum detectable effect sizes (MDES), our data allows the detection of small effects (0.12) for within-subject associations and medium to large effects (0.35) for between-subject associations. Additional analyses revealed that participants´ average valence (β = -0.05; p =.433), energetic arousal (β = -0.03; p = .502), and calmness (β = 0.05; p = .268) (aggregated mean ratings across the AA-study period) were not associated with subsequent momentary sedentary time (i.e., sedentary behaviour immediately after the e-diary prompt). Thus, this indicates that momentary mood ratings are a better predictors of subsequent sedentary time for individuals than their average mood. Finally, a robust analyses revealed the type of trigger (random vs. triggered) was associated with subsequent sedentary behaviour. The triggered prompts predicted higher subsequent sedentary behaviour compared to random prompts (β = 4.85; $p \leq .001$). This finding is in line with our expectations that random prompts increases the variance of participants´ physical behaviour and indicated that participants´ did not systematically change their subsequent behaviour through a triggered e-diary assessment.

Please insert Table 3 here

Exploratory context analyses

Figure 2 shows interaction effects. In particular, context moderated the associations between energetic arousal and sedentary time ($\beta = 0.11$; $p \leq .001$), and between calmness and sedentary time ($\beta = -0.05$; p .0034). Translated to practice, higher ratings (e.g., 90) compared to lower ratings (e.g., 20) of energetic arousal were associated with subsequent lower amounts of sedentary time of about 7.69 minutes (scale: 0-30 minutes) in the home context, and of about 0.27 minutes in the work context. Furthermore, higher ratings (e.g., 90) compared to lower ratings (e.g., 20) of calmness were associated with subsequent higher amounts of sedentary time of about 5.75 minutes in the home context, and of about 2.05 minutes in the work context.

Please insert Figure 2 here

Discussion

The study aimed to investigate, whether mood is (i) associated with sedentary behaviour and (ii) whether the association depends on the conceptual approach, i.e., between-subject vs. within-subject level. We found mood was not to be associated with sedentary behaviour on a between-subject level, but was so on a within-subject level. In particular, we found neither in the self-reported data (paper-pencil questionnaires) nor in the between-level aggregated data from the AA-study, an association on a between-subject level. Interestingly within-subject AA data revealed that context (at home vs. work) moderated the effect of mood on sedentary behaviour.

We found that higher ratings of momentary valence and energetic arousal were associated with subsequently lower amounts of sedentary behaviour, whereas higher ratings of momentary calmness were associated with subsequently higher amounts of sedentary behaviour. In line with the present results, a previous finding from Schwerdtfeger et al. [11] shows that increased affect ratings were associated with lower amounts of sedentary behaviour. Contrary to our results, Maher et al. [12] did not find a within-subject association between positive affect and feelings of energy. There might be several possible explanations for this inconclusive state of research. For example, the usage of different assessments of mood and sedentary behaviour, different samples or study designs may influence the results.

Also contrary to our expectations, our study did not find a significant association between mood and sedentary behaviour on a between-subject level, whereas DeMello and colleagues [10] have reported a reciprocal relationship between mood states (e.g., vigor, tense, fatigue) and sedentary behaviour. Further studies are needed to clarify the issue, whether mood is associated with sedentary behaviour on a between-subject level. In a previous work [32], we reported that sedentary behaviour negatively predicted two mood-dimensions (i.e., valence and energetic arousal) on a within-subject level. Thus, the issue of a reciprocal relationship is a crucial question for future research endeavors, which may be of interest to address the question of causality. Even though our data show a chronological order with mood ratings predicting subsequent sedentary behaviour, this chronology constitutes only one aspect of causality [33]. The chronology suggests but does not prove causality because hidden third variables might show similar time-related characteristics. To substantiate a reciprocal causal hypothesis, additional studies with different methods are needed. For example, Dunton [34] suggests to apply computational strategies such as Dynamical Systems Modeling (DSM) for time-varying relations such as between mood and physcial behaviour. Another promising approach may be to use ecological momentary interventions (EMI) or just-in-time adaptive interventions (JITAI´s) to experimentally induce particular mood states in everyday life [35]. For instance, mobile apps to regulate individual's emotions may lead to higher mood-states, and thus may minimize individual's subsequent sedentary behaviour. Moreover, EMI or JITAI can address different contexts of individuals, which might be relevant since our data revealed that in two of three models the effects were moderated through the context. For example, higher ratings of energetic arousal in the home context compared to the work context were associated to subsequently lower amounts of sedentary behaviour.

To the best of our knowledge, regarding the relation between mood and sedentary behaviour, no study has compared whether the results of the conceptual approach (within-level vs. between-level) differs within the same data set. While there is evidence that the conceptual approach may lead to different results [14,15], all previous studies [10–12] used different approaches. However, research from different areas has shown that the conceptual approach differed widely. For instance, Maher and colleagues [36] found that physical behaviour (i.e., physical activity and sedentary behaviour) was associated with satisfaction with life on a within-subject level, but not on a between-subject level. Similar results were found by Zawadzki et al. [37] showing that self-reported anger and objective blood pressure were associated on a within-subject level, but not on a between-subject level. In the same manner, our study adds first evidence that mood is associated with sedentary behaviour on a within-subject level but not on a between-subject level. Social/psychological theories such as the social withdrawal hypothesis might explain the association between mood and sedentary behaviour. Kraut and colleagues [22] reported that greater use of Internet was associated with declines in individuals´ social interaction and increase in depression and loneliness. Thus individuals may remove themselves from social interactions and increase time in computer use, television watching or smartphone usage (mostly in a sedentary position), which may increase the risk for worsened mood and, thus for longer sedentary time [23]. However, because this research field is still at an early stage, we call for further studies to confirm this preliminary finding and to add evidence to the current inconclusive state of research.

Since studies have shown that sedentary behaviour has adverse effects on somatic and mental health [1,2], researchers are interested in tailoring effective intervention strategies to reduce sedentary behaviour in daily life. This is challenging, because sedentary behaviour is a multifaceted behaviour, which is influenced by a complex interaction of individual, socio-cultural and environmental factors [5]. Furthermore, complex interaction of individual, socio-cultural and environmental factors may vary from person to person and within a person from moment to moment. Therefore, multicomponent interventions on both individual and environmental levels may be the most effective strategies. For example, studies have shown that environmental changes such as the implementation of sit-to-stand workstations [38] as well as behavioural support such as self-monitoring [39] can effectively reduce sedentary behaviour. In particular, a recent review and meta-analysis by Compernolle and colleagues [39], revealed that self-monitoring (i.e., keeping records of specified behaviour for example via diary) as a behaviour change technique (BCT) [40] has the potential to effectively reduce sedentary behaviour. Since the process of self-monitoring takes place on an individual level it seems reasonable that studies which focus on a within-subject level provide more in-depth insights than between-subject approaches for the development of tailored intervention strategies. Thus, knowledge about the within-subject fluctuations of individual´s behaviour could be a promising target to change sedentary habits.

In this context, our preliminary finding that momentary mood predicted subsequent sedentary behaviour, may serve as a starting point that regulation of mood could be beneficial as an additional intervention strategy. According to Williams and colleagues integrative framework [20], following three routes may crucial for health behaviour change. First, direct modification of specific affect constructs, e.g., to reduce dread about possible adverse health consequences of “too much sitting”. Second, intervention upon moderators of the affect-behaviour link, e.g., to address habits of sitting through daily work. Third, direct modification of other sources of behavioural influence, e.g. focuses on anticipated affective reactions such as “proud to avoid prolonged sedentary behaviour (≥ 30 min)**”**. However, since the implementation of effective interventions is at an early stage, we call for future research to evolve possibilities of interventions, using e.g. EMI or JITAI´s, to implement strategies for enhancing mood and decreasing sedentary behaviour.

Several aspects of this study need to be acknowledged. First, the accelerometers were not water- or shockproof and therefore could not be worn during all types of physical behaviour (e.g., swimming). Thus, our assessments may not have captured certain physical activities. However, our analyses were focused on the association between mood dimensions and sedentary behaviour, and not on the total amount of physical behaviour, minimizing this limitation. Second, we cannot exclude residual confounders (e.g., everyday life factors that influence sedentary behaviour such as social or environmental conditions or quantity and quality of sleep) [5]. However, our findings were stable within a sample of 80 individuals. Third, our study sample comprises University employees, some of which may be familiar with exercise psychology or particularly interested in the associations of sedentary behaviour and mood. This might have influenced the findings. However, since the participants were employees from various fields and sectors of the university staff, we assume this to be a minor issue. A noteable strength of our study is the custom-developed multi-sensor system with accelerometers at hip, chest, and thigh to enable more precise detection of sedentary behaviour. This system enabled us to quantify sedentary behaviour according to its international definition [4].

Perspective

Our study is one of the first studies that investigated whether mood is an antecedent of sedentary behaviour in daily life and whether different conceptual approaches (between-subject level vs. within-subject level) may lead to different results. Our findings revealed that mood is associated with sedentary behaviour on a within-subject level, but not on a between-subject level, thus indicating a time-varying relationship between mood and sedentary behaviour. Translated into practice, there is preliminary evidence that mood may have an essential function in the regulation of sedentary behaviour. Therefore, regulation of mood may be a promising addition in multicomponent intervention strategies to reduce sedentary behaviour in daily life.

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Figure 1. a) Study design: Basic survey (WHO5; GPAQ) and AA-Study period (Accelerometry; MDMQ) over 5 days. Statistical Analyses: b) Between-subject analyses based on b1) questionnaire data and b2) average values of the AA-study. C) Within-subject analyses with the dynamical relationship between mood and sedentary behaviour.

Figure 2. Multilevel interaction analyses: context moderates associations between mood dimensions and sedentary time. For each of the three models, the y-axis depicts the amount of sedentary time [ranging from 0-30 min]. The x-axis depicts the mood scores [scale: 0-100].

Table 1. Participants characteristics (n =80).

Variable	Mean ± SD[1]	Minimum	Maximum
Female	n= 52; 65 %	---	---
Age [years]	33.88 ± 9.53	22	62
Group (UoN [2])	n= 31; 39 %	---	---
BMI[3] [kg/m^2]	23.55 ± 3.28	17.67	32.49
Answered Mood Assessments [per day][a]	8.33 ± 2.38	2.5	15.8
Valence [0-100][a]	75.88 ± 11.57	35.95	96.35
Calmness [0-100][a]	68.48 ± 13.85	26.49	95.93
Energetic Arousal [0-100][a]	63.22 ± 13.11	30.81	92.55
WHO5-Index [0-100]	64.65 ± 14.29	20	96
Self-reported Sedentary Time [h/day]	8.14 ± 2.52	3	15
Wear Time Accelerometer [h/day][b]	15.47 ± 3.47	8.87	22.84
Sedentary Time Accelerometer [h/day][b]	8.03 ± 2.71	1.55	16.09
Number of prompts per day [c]	10.29 ± 4.07	1	21
Number of random prompts per day [c]	5.05 ± 2.45	0	9
Number of sedentary triggered prompts per day [c]	5.24 ± 4.88	0	21
Context of assessment – Work [%] [d]	39.2 ± 12.47	4.8	69.7

[1] Standard deviation; [2] University of Newcastle; [3] Body-Mass-Index

[a] assessed via e-diary, aggregated within participants

[b] aggregated within participants

[c] aggregated within participants per day

[d] aggregated within participants (context was only assessed in the KIT Group)

Table 2. Multiple regression analyses to predict device-based and self-reported sedentary time.

	***Outcome:* Device-based sedentary time [h/day]**				
		b (SE)[1]	**Stand. BC**	**t-value**	**p-value**
Hypothesis 1a	Intercept	520.54 (175)	---	2.97	.004
	Group[a]	34.79 (41.4)	0.105	0.84	.073
	Age	-2 (2.14)	-0.117	-0.93	.353
	BMI	0.94 (6.38)	0.019	0.15	.884
	Sex[b]	73.85 (40.64)	0.218	1.82	.073
	Valence	2.31 (3.64)	0.164	0.64	.528
	Energetic Arousal	0.06 (2.19)	0.005	0.03	.977
	Calmness	-3.2 (2.75)	-0.272	-	.249
	***Outcome:* Self-reported sedentary time [h/day]**				
		b (SE)[1]	**Stand. BC**	**t-value**	**p-value**
Hypothesis 1b	Intercept	269 (144)	---	1.87	.065
	Group[a]	36.26 (36.58)	0.117	0.99	.325
	Age	-0.68 (1.17)	-0.043	-0.36	.717
	BMI	10.7 (5.66)	0.232	1.89	.062
	Sex[b]	62.7 (36.2)	0.199	1.73	.087
	WHO5-Index	-0.83 (1.17)	-0.079	-0.71	.480

[1] Unstandardized estimates and standard errors

[a]compared to KIT; [b]compared to males

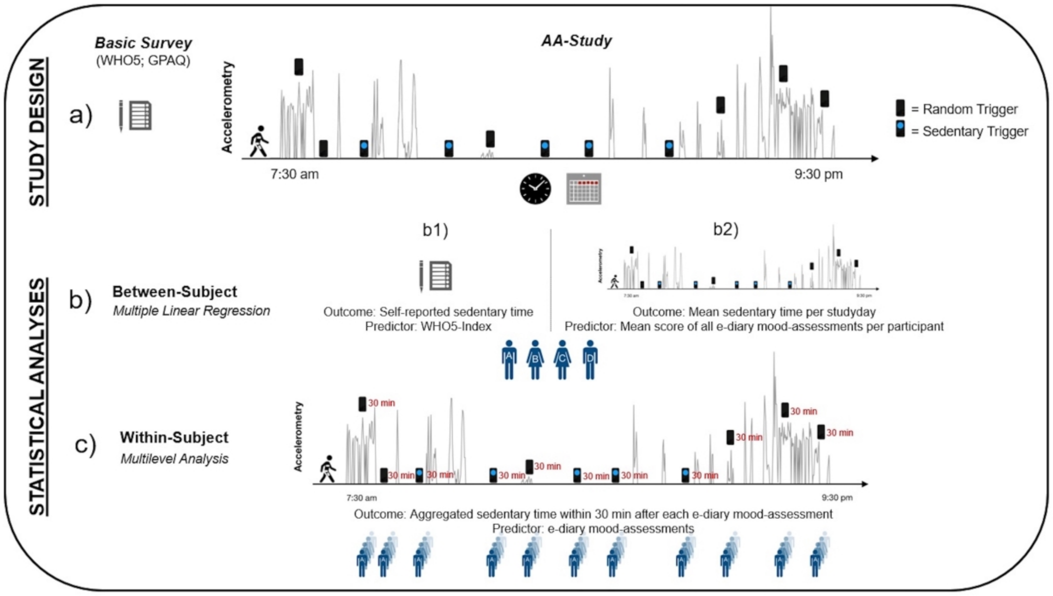
Table 3. Multilevel model analyses to predict sedentary time: Fixed and random effects.

		b (SE)[1]		t-value (df)[3]	95% CI[4]	p-value
Fixed effects	Intercept, β_{00}			8.52 (77)	16.35, 26.33	< .001
	Group[a], β_{01}	0.57 (0.70)	0.03	0.8 (73.1)	-0.83, 1.97	.420
	Age, β_{02}	-0.12 (0.04)	-0.13	-3.3 (70.8)	-0.19, -0.05	.002
	BMI, β_{03}	0.2 (0.11)	0.07	1.9 (68.4)	-0.01, 0.41	.065
	Sex[b], β_{04}	-0.84 (0.68)	-0.05	-1.2 (68)	-2.2, 0.52	.222
	Valence, β_{10}	-0.03 (0.02)	-0.04	-2 (2428)	-0.07, -0.0004	.047
	Energetic Arousal, β_{20}	-0.06 (0.01)	-0.08	-4.4 (80)	-0.08, -0.03	< .001
	Calmness, β_{30}	0.07 (0.02)	0.11	4.4 (107)	0.04, 0.1	< .001
	Time of day, β_{40}	0.09 (0.18)	0.04	0.5 (2791)	-0.26, 0.44	.608
	Time of day squared, β_{50}	-0.01 (0.01)	-0.07	-0.9 (2898)	-0.03, 0.01	.388
	Weekday[c], β_{60}	-2.26 (0.52)	-0.12	-4.4 (72)	-3.29, -1,23	<.001

		b (SE)[1]	Wald Z	95% CI[4]	p-value
Random effects	Intercept, μ_0	1.25 (1.48)	0.85	0.12, 12.6	.396
	Energetic Arousal, μ_2	0.003 (0.002)	2.19	0.001, 0.008	.028
	Calmness, μ_3	0.01 (0.002)	2.45	0.003, 0.01	.014
	Time of day, μ_4	0.03 (0.02)	1.97	0.01, 0.09	.049
	Weekday[c], μ_6	5.36 (1.63)	3.28	2.95, 9.73	.001
	Residual, r	64.95 (1.78)	36.52	61.58, 68.53	<.001

[1] Unstandardized estimates and standard errors; [2] standardized β-coefficient; [3] t-values and degrees of freedom; [4] 95%-Confidence-Interval

[a]compared to KIT; [b]compared to males; [c]compared to weekday



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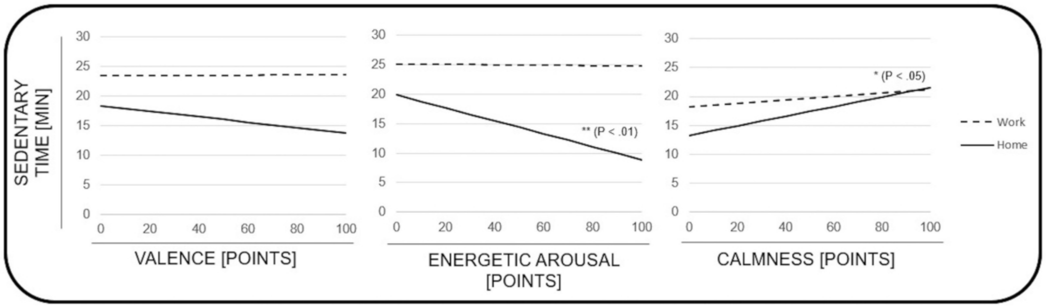

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