Pretest-Posttest and Daily Diary Study: Observing the Effects of Virtual Reality "Walk in Nature" Intervention on Subjective Vitality, Energy, Stress, and Daily Activities in Students

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Abstract

Background. Previous research employing virtual reality (VR)-based interventions concentrated solely on enhancing subjective vitality through the relaxing effects of being present in nature. Bareišytė (2021) introduced a novel approach to increasing subjective vitality by combining revitalising and physical activities in the VR-based "Walk in Nature" intervention. Nevertheless, no prior research moved beyond the traditional pretest-posttest measurements to observe the real-life effects of the VR-based interventions. **Objective.** The present study explored the differences in students' subjective vitality, stress, energy, and daily activities between one week before and one week after the "Walk in Nature" intervention with the pretest-posttest and daily diary methods. **Method.** A one-group pretest-posttest within-subjects observational design with the daily diary method was employed among 34 higher-education students in Enschede (*M*age = 21.85, *SD*age = 2.08, 52.9% female, 47.1% male). The visual inspection, paired-samples t-test, and (generalised) linear mixed modelling analyses were applied to explore the differences in the pre-and post-intervention days. **Results.** The findings revealed no significant differences in vitality energy, and stress. On the other hand, a significant change was observed in the engagement in daily activities, including household chores, travel, physical exercises, and university-related activities after the intervention. **Conclusion and Discussion**. Future research should focus on determining the real-life intervention effect using single-case experiments with an increased number of measurements of the variables during the day to further explore daily fluctuations. In addition, more sessions of the "Walk in Nature" intervention are needed to provide longer-term effects.

Keywords: subjective vitality, stress, energy, daily activities, virtual reality intervention, daily life, daily diary

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In recent decades, researchers have devoted significant attention to the concept of subjective vitality, defined by Arslan et al. (2022) as "the state of energy, feeling alive, and non-fatigue and exhaustion" (p. 1043). Subjective vitality represents positive experiences of energy, such as high enthusiasm, determination, and alertness (Arslan et al., 2022; Ryan & Frederick, 1997; Ugur et al., 2019). In contrast, low subjective vitality levels may manifest in unpleasant emotional states (e.g. anxiety, tension, anger, or edginess), external locus of control (Ryan & Deci, 2000; Ryan & Frederick, 1997), and fatigue, i.e. perceived experience of lack of energy (Buchner et al., 2022; Rose et al., 2017; Smolders et al., 2013; Weigelt et al., 2021). Vitality encompasses both physical capacities for performing actions and subjective experiences, such as motivation, purpose, and self-efficacy (Lavrusheva, 2020; Martela et al., 2016; Ryan & Frederick, 1997).

Individuals with enhanced vitality are inclined to be involved in enjoyable and motivating activities (Deci & Ryan, 2000), which are associated with increased energy (Ryan et al., 2010). To illustrate, Wizior (2020) found that engagement in positive social interactions heightened the sense of vitality in university students, while Couto et al. (2017) and Kukić et al. (2022) established that improved vitality levels have been related to increased physical activity. Additionally, the study by Wensik (2022) determined the connection between different types of daily activities and subjective experience of fatigue. The findings revealed that household chores and social interactions diminished the experience of fatigue while eating/drinking and strenuous relaxation increased fatigue, but no significant association was found for other activities (Wensik, 2022). Thus, existing research highlights the relationship of engagement in certain activities with vitality and energy.

Furthermore, improved subjective vitality has been related to various positive outcomes. For instance, an association of vitality with healthy lifestyle adherence and enhanced physical health has been established (Ryan and Frederick, 1997). Namely, subjective vitality predicted long-term abstinence from tobacco use (Niemiec et al., 2010) and increased consumption of fruits and vegetables (Conner et al., 2017). Additionally, vitality has been associated with enhanced sleep

quality, reduction in physical discomfort and body aches (Myers et al., 1999), and diminished risk of coronary heart disease (Kubzansky & Thurston, 2007). Decreased subjective vitality, in contrast, may lead to declines in functional ability, increased disability, and greater mortality risk (Avlund, 2010).

Subjective vitality has also been linked to enhanced general well-being, including improved coping abilities with different stressors, such as difficult life events and environmental disasters (Kubzansky & Thurston, 2007). Miksza et al. (2019) and Satici (2020) investigated the relationship between vitality and stress, revealing that lower stress predicted increased vitality among university students. In addition, research has established an association between vitality and improved self-confidence (Chen & Sengupta, 2014), mood (Partonen & Lönnqvist, 2000), happiness (Akin, 2012), and satisfaction with life (Baruch et al., 2014). Overall, subjective vitality has been related to numerous physical and mental health benefits.

Enhancing Subjective Vitality in Students

Due to the elevated stress and stress-related consequences that higher education students experience (Matud et al., 2020; Oyeniyi et al., 2016), they may particularly benefit from enhanced subjective vitality. In the Netherlands, the percentage of students facing high stress amounted to 57% in 2019 (ISO, 2019). In 2021, this number increased (62%), which can be explained by the shift to online learning, disruption of academic routines, and other consequences of the COVID-19 pandemic (Gadi et al., 2022; RIVM, 2022). Elevated stress in students may also emerge from the issues they encounter in the university context, such as adaptation to a new environment, accommodation issues, family-related conflicts, sleep and eating disturbances, or financial concerns (Freire et al., 2020; Karyotaki et al., 2020; Pascoe et al., 2020). Possible consequences of high stress include the following: depressive symptoms, social isolation (Dahlin et al., 2005; Megivern et al., 2003; Newcomb-Anjo, 2016), burnout (Dahlin et al., 2005), and suicidal thoughts (Tyssen et al., 2001).

Individuals with enhanced vitality experience improved energy (Myers et al., 1999; Buchner et al., 2022) and efficiently cope with stress (Kubzansky & Thurston, 2007). Considering the increased stress levels faced by students, they are more susceptible to experiencing a lack of energy (Lang et al., 2022; Wang et al., 2021), which may, in turn, lead to poorer academic success (Smith,

2018), increased risk of somatic disease, or destructive health behaviours (e.g. smoking) (Rose et al., 2017). Based on the established relationships between vitality with stress (Miksza et al., 2019; Satici, 2020) and fatigue (energy) (Buchner et al., 2022; Smolders et al., 2013; Weigelt et al., 2021), enhancing vitality in students may also diminish experienced stress and fatigue levels. One of the known approaches to improving subjective vitality is through the use of virtual reality(VR)-based interventions.

Virtual Reality

Benoit et al. (2015) define VR as "a computer-simulated environment that can provide the sensation of physical presence in places representing real or imagined worlds" (p. 558). By overlaying virtual elements onto the physical environment, VR enriches real-world experiences (D'Cunha et al., 2019; García-Betances et al., 2015). In other words, VR provides a sense of transporting a user to different locations and/or assigning them another physical form without mental exertion (Adhyaru & Kemp, 2022). By integrating auditory stimulation (e.g. through headphones or speakers) and interaction with the simulated environment (using a keyboard or gaming controllers) in VR, a high immersion level, i.e. "the degree to which the range of sensory channel is engaged by the virtual simulation" (p. 95; Kim & Biocca, 2018), can be achieved (Hudson et al., 2016; Mandal, 2013).

Furthermore, VR provides a stronger sense of presence in the virtual environment compared to other technologies (Meehan et al., 2002), which establishes more believable experiences with cognitive and emotional impact (Diemer et al., 2015; Price & Anderson, 2007; Seth et al., 2012). For instance, users with flying phobia experienced greater fear during VR-based exposure therapy when their presence was heightened (Price et al., 2011). In addition, enhanced presence promotes motivation and engagement (Witmer & Singer 1998), which may benefit the effectiveness of psychological interventions (Freeman et al., 2017). Nevertheless, it is worth noting that VR equipment is relatively heavy and can cause headaches and neck discomfort when used for prolonged periods (Verma et al., 2021). Moreover, exposure to VR may lead to symptoms such as motion sickness and dry eyes, which can influence the overall experience (Chen et al., 2015; Ohyama et al., 2007). Thus,

while VR can provide increased presence and immersion, it is important to acknowledge its limitations when using it in psychological research.

Virtual Reality and Subjective Vitality

Previous studies implementing VR-based interventions to enhance subjective vitality focused on the benefits of presence in nature environments. Namely, Reese et al. (2022a) found that vitality, stress, and restoration improved after one session of VR-based nature exposure, regardless of the presence of human-developed structures (e.g. buildings or bridges). In the study by Mattila et al. (2020), vitality, mood, and perceived restoration improved after five minutes of being exposed to the VR-simulated forest. Additionally, Reese et al. (2022b) compared the effects of walking in a simulated VR forest as opposed to a physical urban forest environment. The results indicated that subjective vitality, stress, affect, and restoration improved after both VR-based and physical intervention, with no significant differences between these conditions. These findings suggest that VR-based nature is 1) effective in enhancing subjective vitality even with limited exposure time, 2) can improve other factors, such as stress, and 3) appears to be a fair and effective alternative to physical nature environments.

Previous studies primarily focused on enhancing subjective vitality through passive means. Participants were asked to enjoy the VR-simulated nature in a sitting or standing position or to take a self-paced walk in a forest, which promoted a relaxing and attention-restoring effect (Mattila et al., 2020; Reese et al., 2022a; Reese et al., 2022b). Building upon previous research conducted without the use of VR, which illustrated that an individual's vitality was strongly associated with how physically active they were (Couto et al., 2017; Kukić et al., 2022), combining physical activities with restoring activities in the VR environments could provide additional benefits.

"Walk in Nature" Intervention

The approach of including both revitalising and physical activities in VR was incorporated by Bareišytė (2021). She developed the "Walk in Nature" intervention, which comprised four components: 1) a walk in the virtual forest, 2) a breathing activity called the "breathing tree," 3) a physical exercise "butterfly task," and 4) a "social yoga." The first task familiarised participants with

the environment and involved a short walk in a VR nature which was found to improve vitality, mood, and stress (Mattila et al., 2020). The “breathing tree” focused on improving psychological well-being through breathing techniques, known to decrease stress and provide energy (Zaccaro et al., 2018). The “butterfly task” targeted physical well-being, aligning with literature supporting the effectiveness of VR-based physical exercises in promoting relaxation (Plante et al., 2006). Finally, the "social yoga” involved both psychological and physical components, incorporating yoga and mindfulness, which can reduce stress and improve energy and vitality (Büssing et al., 2012; Khoury et al., 2015).

The intervention was initially employed by Bareišytė (2021) among university students, yielding improvement in subjective vitality, tension, and stress. However, no changes in energy level were found. In a later study by Ahire (2022), the effectiveness of the “Walk in Nature” intervention was examined in another sample of international university students. A respiratory biofeedback sensor to increase engagement in the “breathing tree” exercise and measure physiological changes of stress was added to the original VR intervention. The study established that, after experiencing the intervention, students experienced a heightened sense of subjective vitality and diminished acculturative and perceived academic stress (Ahire, 2022). Overall, both studies demonstrated that combining both physical and restoring components in the VR-based intervention can be an effective strategy for improving subjective vitality and stress (Ahire, 2022; Bareišytė, 2021).

In fact, existing research confirms the effectiveness of VR-based interventions in enhancing vitality, but their impact and relevance for daily life remain unclear. Previous studies relied on the pretest-posttest measurements, where measures were employed shortly before and after the intervention (e.g. Ahire, 2022; Bareišytė, 2021; Reese et al., 2022b). While this is a reliable method for determining the effectiveness of an intervention (Dimitrov & Rumrill, 2003; Pollack et al., 2022), it provides limited insight into its real-life effects. To establish VR-based interventions as effective tools for enhancing vitality, evaluating them within the context of daily experiences is essential (Kazdin, 2023).

Ecological Momentary Assessment

To study vitality, stress, and energy in natural environments, ecological momentary assessment (EMA) can be used in combination with a traditional pretest-posttest method. EMA is a systematic daily approach employed to assess (near-)real-time experiences, such as thoughts, feelings, and behaviour in daily life (Van Berkel et al., 2017). It can be administered one or several times a day as a self-report (e.g. in a daily diary) (Van Berkel et al., 2017) or objective measures (e.g. physiological data collected through wearables) (Weale et al., 2023). Compared to the pretest-posttest method, EMA enables individuals to report more accurate estimates of their feelings or behaviours without being influenced by recall bias (Fredrickson, 2000; Trull & Ebner-Priemer, 2009). In addition, EMA assessment is used to establish changes in experiences over time in response to certain events, such as participation in psychological interventions (Rogers, 2021). However, one of the main limitations of EMA is the high attrition rate (Siedlecki, 2020; Wray et al., 2014), which is why the combination of pretest-posttest and EMA methods can yield more robust and reliable outcomes.

Furthermore, the EMA method may not only provide insights into variations in vitality, stress, and energy but also into the daily behaviour of students. Namely, employing the daily diary technique enables individuals to report activities that they engage in during the day (Van Berkel et al., 2017). While prior research evaluating VR interventions primarily focused on the effects on internal states, excluding behavioural assessments (Morina et al., 2015), the established relationship in research between vitality, energy, and daily activities (Wensik, 2022; Wizior, 2020) suggests that by increasing vitality level, engagement in daily activities may also change. For instance, after the intervention, individuals may be more involved in activities that provide them with an increased sense of energy. Thus, comparing behaviours performed before and after the “Walk in Nature” intervention and the energy provided by them may present new insights regarding the intervention’s influence on the daily lives of students (Morina et al., 2015).

The Present Study

The current study aims to investigate changes in students' daily lives in the periods before and after the "Walk in Nature" intervention in stress, energy, subjective vitality, and daily activities.

Additionally, as the "Walk in Nature" is considered a novel intervention, its usability will be evaluated. Based on the objective, the following research questions (RQ) were formulated:

RQ1: Do subjective vitality, stress, and energy levels of students significantly differ one week before and one week after participating in the “Walk in Nature” intervention?

RQ2: Which changes in the daily lives of students related to vitality, stress, energy, and daily activities can be observed in the post-intervention period compared to the pre-intervention period?

RQ1 relates to the pretest-posttest study, whereas RQ2 concerns the daily diary study. For both research questions, it is hypothesised that, after the intervention, students’ subjective vitality and energy significantly increase, and stress levels significantly decrease compared to the levels before the intervention. Additionally, RQ2 aims to explore activities performed one week before and one week after the intervention and the energy students receive from them.

Methods

Design

A one-group pretest-posttest within-subjects observational design with the ecological momentary assessment (EMA), namely, the daily diary method, was applied. The study consisted of three main parts: pretest-posttest, participation in and evaluation of the VR “Walk in Nature” intervention, and EMA (pre- and post-intervention daily diary). To address non-compliance in EMA measurements (Siedlecki, 2020; Wray et al., 2014) and enhance statistical power for determining pre- and post-intervention differences, this study employed the pretest-posttest measurements (Pasnak, 2018). Additionally, the EMA data were collected over a two-week period to improve compliance and obtain a representative sample (Stone et al., 199; Rogers, 2021). Finally, due to the lack of available reliable and validated categorisations of daily behaviours, in the current study, daily activities were measured based on the study by Wensik (2022).

Participants

Participants for the study were recruited via convenience and snowball sampling. In total, N = 41 individuals took part in the study, with the final sample comprising N = 34 students (52.9% female, 47.1% male; M_{age} = 21.85, SD_{age} = 2.08). Thus, the response rate amounted to 82.93%.

Inclusion criteria required participants to possess a good command of English, be enrolled as a university or HBO student, and have access to a smartphone with the Apple Store or Google Play Store. Participants were excluded if they had a history of motion sickness, active nausea, vomiting, or epilepsy when using VR, if they had limitations in hearing, sight (sensitivities to rapidly changing light), or body movement that could obstruct the VR experience, or if they had lepidopterophobia (fear of butterflies).

The study included participants of different nationalities, with most of them being Latvian (17.6%) and Dutch (17.6%). Most students were also pursuing a bachelor's degree (61.8%). For a complete overview of the demographic characteristics, refer to Table 1.

Table 1

Demographic Data of the Sample

	n (%)	*M (SD)*
Gender		
Female	18 (52.9)	
Male	16 (47.1)	
Age		21.85 (2.08)
Nationality		
Latvian	6 (17.6)	
Dutch	6 (17.6)	
German	5 (14.7)	
Ukrainian	4 (11.8)	
Russian	3 (8.8)	
Moldovan	2 (5.9)	
Lithuanian	2 (5.9)	
Other	6 (17.6)	
Education		
University of Applied Sciences	2 (5.9)	
University Bachelor	21 (61.8)	
University Master	11 (32.4)	

Materials

The web-based software Qualtrics served as the platform for completing the pretest-posttest surveys and the VR-associated measurements, whereas Twente Intervention and Interaction Machine (TIIM) mobile phone application were used to complete the daily diary measurements by participants. The VR intervention was implemented in the XR Lab on the campus of the University of Twente. In the room (15,18m^2), the Oculus Rift (VR set) comprising the head-mounted display (HMD) and the controller set was provided. The HMD enabled participants to explore the VR-simulated nature from different angles, and the controllers facilitated the interaction with the VR. The wire from HMD was connected to the Alienware PC with the Dell Monitor and let participants freely move around the room. The Unity software installed on the PC was utilised for starting the intervention. Finally, a comfortable couch in the room served as a seating space for participants to complete the VR-associated measurements after their participation.

Measurement Instruments

Subjective Vitality

For the pretest-posttest one-time measurements, subjective vitality was measured with the Subjective Vitality Scale (SVS), which is a self-report instrument developed by Ryan and Frederick (1997). The scale consists of seven items, scored on a Likert scale from 1 (not at all) to 7 (very true). The total scores range from 6 to 36, with higher scores implying a greater vitality level. A scale score is calculated by averaging all item scores. The cut-off scores for the scale to differentiate between levels of vitality were not provided by the developers. Following the recommendation by Bostic et al. (2000), item 2 was excluded from the questionnaire.

The SVS has two versions: the state-level version, which reflects the current state of vitality, and the individual difference-level version, which relates to the ongoing characteristic of vitality (Ryan & Frederick, 1997). In the current study, the former was employed. In addition, the scale was modified to measure how participants felt during the past week (Appendix A). An example of an item was: “I looked forward to each new day.” Bostic et al. (2000) found that the construct validity of SVS was good, and all items demonstrated high factor loadings (loadings > .60). Additionally, Delgado-

Lobete et al. (2020) established excellent internal consistency of the 6-point SVS scale (Cronbach's α = .84–.86). In the current study, the internal consistency was good both for the pretest (Cronbach's α = .78) and posttest measurements (Cronbach's α = .76).

For the daily diary, two SVS items, namely "right now I feel alive and vital" (item 1) and "I feel very energetic at this moment" (item 2), and the scale's answer format were used (Appendix B). The other items were excluded to increase feasibility and engagement. Minimising the number of items can decrease the time spent on the diary and thus reduce the response burden (Bize & Plotnikoff, 2009; Rolstad et al., 2011). The daily score for vitality was calculated by summing up the item scores. The internal consistency of the scale and the test-retest reliability for the two-week period were good (Cronbach's α = .78, the daily coefficients ranging from a = .77 to a = .94; ICC =.78).

Stress

The Perceived Stress Scale (PSS) developed by Cohen et al. (1983) was employed for one-time pretest-posttest stress measurements. The PSS items examine the extent to which individuals perceived their lives to be unpredictable, overwhelming, and uncontrollable in the past month. There are three versions: a 14-item version, a 10-item version, and a 4-item version (Cohen et al., 1983). The present study incorporated the 10-item version due to its enhanced psychometric properties (Lee, 2012). The items were altered to measure stress experienced in the past week (Appendix C). An example of an item was: "In the last week, how often have you felt that you were on top of things?".

The response format on PSS is a four-point Likert scale with scores from 0 (never) to 4 (very often), and the total scores range from 0 to 40 (Cohen et al., 1983). The severity of stress is estimated in clusters: scores in the range 0–13 represent low stress, 14–26 indicate moderate stress, and 27–40 suggest high stress (Rijal et al., 2023). Items 4, 5, 7 and 8 are negatively worded and thus must be reversed. Remor (2006) found that the internal consistency of the PSS was good (Cronbach's α = .82). In the current study, the internal consistency was also good for the pretest (Cronbach's α = .79) and posttest (Cronbach's α = .82) measurements.

In the diary, stress was assessed with the following two modified items from the PSS: "I currently feel that I am able to control the important things in my life" (item 1, reverse-scored) and "I

feel nervous and stressed right now" (item 2) (Appendix D). The total daily score was calculated by summing up the item scores, and the answer format was the seven-point Likert scale from 1 (not at all) to 7 (very true). The internal consistency and the test-retest reliability for the two weeks were acceptable (Cronbach's α = .65, the daily coefficients ranging from *a* = .24 to *a* = .72; ICC = .65).

Fatigue (Energy)

For one-time pretest-posttest energy measurements, the Fatigue Assessment Scale (FAS) was used. The FAS is administered as a self-report questionnaire for assessing mental and physical symptoms of chronic fatigue (Michielsen et al., 2003). Due to the lack of validated instruments measuring energy level, in the current study, FAS was employed for assessing the energy of the participants. The items of the FAS were adjusted to measure energy experienced over one week (Appendix E). The following represents an example of an item: "I was bothered by fatigue."

In total, FAS contains 10 items, where items 4 and 10 are reversed-scored. To answer each item, a five-point Likert scale from 1 (never) to 5 (always) is used. The minimum obtained score is 10, and the maximum is 50 (Michielsen et al., 2003). Different score ranges represent fatigue levels: 10–22 for normal or "healthy" fatigue, 22–34 for mild-to-moderate fatigue, and 35–50 for severe fatigue (De Vries et al., 2004; Hendricks et al., 2018). Horisberger et al. (2019) found that the internal consistency of the FAS was excellent (Cronbach's α = .93). In the present study, the internal consistency was good for the pretest (Cronbach's α = .74) and posttest (Cronbach's α = .81).

Energy and Daily Activities

In the daily diary, the energy of participants was measured using the "energy diary." Individuals were asked with open questions to report activities they engaged in during the day based on the ten categories: "passive relaxation," "physical activity," "sleeping over the day," "university," "work," "household," "eating/drinking," "self-care," "travelling," and "social activities" (Appendix F). They were given examples of activities for each category as references. Participants manually entered activities for each category into a text field limited to 700 characters. If they did not perform activities falling under a specific category, they were asked to enter "not applicable."

For each category, participants indicated how much energy activities in that category provided them. They could answer the item with one of the following answer categories: “little energy” (1), “some energy” (1), “a lot of energy” (1), “they took my energy” (-1), “they did not provide nor take my energy” (0) and “not applicable” (treated as a missing value) (Appendix G). The total daily energy level was calculated by summing up the scores (provided in the brackets) obtained for each type of activity.

The ten activity categories were derived from the study by Wensink (2022) and included in the current research with several adjustments. First, based on the expectation that students may pursue part-time jobs alongside their studies, the “work/school” category was divided into two distinct categories, i.e. “work” and “university.” Second, the activity categories “strenuous relaxation,” “on the go,” and “sleeping/resting” were renamed to “physical activity,” “travelling,” and “sleeping over the day” for enhanced clarity.

Virtual Reality-Associated Measurements

Immersive Tendencies Questionnaire (ITQ). The ITQ was created by Witmer and Singer (1998) to measure the degree to which users are able to immerse themselves in different environments. The ITQ consists of 18 items, and the responses are measured on a Likert scale from 1 (never) to 7 (often) (Appendix H). To illustrate, one of the items in the questionnaire is: “how well do you concentrate on enjoyable activities?” the ITQ includes several subscales: “focus,” “involvement,” “emotions,” and “game.” The total score is calculated by summing all item scores, and the score for each subscale is derived by averaging the subscale-specific items. Finally, the internal consistency of the total ITQ scale was evaluated as good by Witmer and Singer (1998) (Cronbach’s α = .78.). In the current study, the internal consistency was acceptable (Cronbach’s α = .66).

Presence Questionnaire (PQ). The PQ was also developed by Witmer and Singer (1998) to measure the subjective experience of being in VR. It comprises 24 items which are divided into seven subscales: “realism,” “possibility to act,” “quality of interface” (all items are reverse-scored), “possibility to examine,” “self-evaluation of performance” “sounds,” and “haptic” (Appendix I). Each item is answered on a Likert scale from 1 to 7 (different descriptive labels apply to different items).

“How involved were you in the virtual environment experience?” was an example of the item from PQ. The sum of the individual item scores is used to create the total score, and the average of the items that make up each subscale is used to get the score for that subscale. Witmer and Singer (1998) evaluated the internal consistency of PQ as good (Cronbach’s α = .84). The similar outcome was observed in the present study (Cronbach’s α = .86).

System Usability Scale (SUS). The SUS is a self-report instrument for assessing usability, designed by Brooke (1996). It represents a scale with ten items, which can be answered with a Likert scale from 1 (strongly disagree) to 7 (strongly agree) (Appendix J). The following statement represents an example of the SUS item: “I felt very confident using the system.” To compute the SUS score, the scores from each item must be combined. Each item's score contribution represents a number from 0 to 4. For items 1, 3, 5, 7, and 9, 1 must be subtracted from the position on the scale to determine the contribution. For items 2, 4, 6, 8, and 10, the position on the scale must be subtracted from 5 to establish the contribution. The sum of these scores must be multiplied by 2.5 to obtain the total SUS value (Brooke, 1996). The higher the score, the superior the usability of the utilised technology. Lewis and Sauro (2009) found that the internal consistency of the SUS was excellent (Cronbach’s α = .91). In the current study, the reliability remained good (Cronbach’s α = .83).

Intervention

The “Walk in Nature” intervention consisted of four parts. The introductory part allowed participants to get used to the VR surroundings. Participants observed and walked in the open forest with trees and flowers, accompanied by the sounds of nature (see Figure K1 in Appendix K). During the first task, the "breathing tree," users observed a sticky-looking tree, which reflected their lungs (see Figure K2 in Appendix K). The expansion and contraction of the tree, along with its colour changing from grey to green, corresponded to users’ inhalation and exhalation of air. The pre-recorded voice instructed them on their breathing pace. In the next task, the "butterfly task," participants interacted with the VR environment by touching butterflies with the controllers and pressing the trigger button. The environment included a greenery-clad arch with butterflies positioned

at different heights (see Figure K3 in Appendix K). When participants touched the butterflies, they flew away into the open nature space. The task was finished when all butterflies had been released.

Finally, in "social yoga," participants stood on a virtual mat in an open space and followed the instructions from the breathing bubble on the screen and the pre-recorded voice (see Figure K4 in Appendix K). While maintaining the breathing pace suggested by the voice, participants repeated yoga exercises after the animated instructor together with the two animated participants. After completing the yoga movements, the users were guided through a brief mindfulness task, where they closed their eyes, focused on their breath, and set a positive intention for the day.

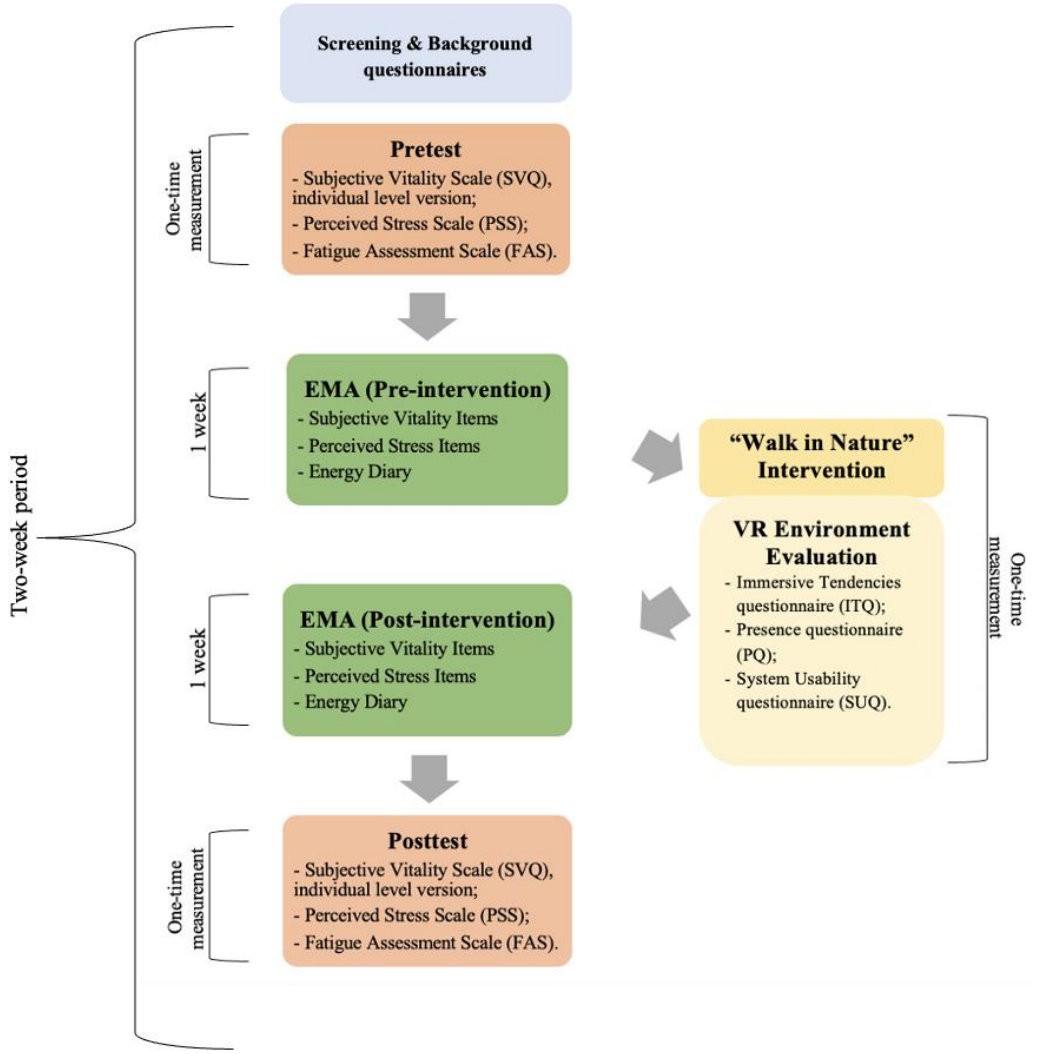
Procedure

The study was approved by the Ethics Committee of the Behavioural, Management and Social Sciences faculty of the University of Twente on 17.02.2023 (request number 230028). The data were collected from 28.02.2023 until 27.04.2023. Prior to participating, students were informed that taking part in the study would earn them 1.5 credits in the test subject pool system (SONA) and provide the opportunity to with a 10-euro prize.

The full overview of the study procedure is presented in Figure 1. Initially, students completed the intake survey, which included informed consent (Appendix L). Individuals who met the inclusion criteria by answering screening questions proceeded to answer background items (email address, gender, age, nationality, and the degree pursued at the moment of filling in the survey) and the pretest questionnaires (see Appendix M for screening and background items). Then, they were invited via email to download the TIIM application and join the study using the QR code. A scheduled time slot was arranged for each participant to experience the VR intervention. Then, over two weeks, students were completing the diary items daily, which were accessible from 8 p.m. to 12 a.m. Notifications from the TIIM app were sent at 8 p.m. daily.

Figure 1

Study Design and Procedure



On the eighth day of the data collection, participants experienced the VR intervention. They were introduced to the VR display and instructed about its use and possible motion sickness. Subsequently, they put on the VR headset and took the controllers. Then, the "Walk in Nature" intervention was activated, and participants completed each task one by one. The researcher did not interact with the participants during that process.

After completing the exercises, participants were asked to take off the HMD. They were invited to sit on a couch and fill in the VR-associated survey. Then, they left the room and continued

filling in the daily diary. At the end of the two-week data collection period, all students were thanked for their participation via email and asked to complete the posttest survey.

Data Analysis

The data were analysed employing the statistical software IBM SPSS (Version 27). To ensure anonymity, participants' email addresses were substituted with the assigned numbers (1 to 34). Incomplete or ineligible responses (N = 7) were excluded. The patterns of missing data were analysed by exploring the number of participants with missing data for each measurement point. Then, descriptive statistics and frequencies were computed for the background data, pretest-posttest data, VR-associated measurements, and daily diary data. A more detailed exploration of answers for all ten activity categories was conducted for a randomly selected participant. Due to time constraints and the diverse nature of responses, qualitative coding of the data was not performed. Finally, based on the mean scores, the ten activity categories were categorised into higher-order categories such as energy-givers (0.3 to 1), energy-drainers (-1 to -0.3), or energy-neutral activities (-0.2 to 0.2).

The normality assumption of the PQ, ITQ, SUS, and pretest and posttest SVS, PSS, and FAS scales as well as the distribution of residuals for vitality, stress, and energy over the two weeks was evaluated with the QQ-plots and Shapiro-Wilk test, using $p > 0.5$ as an indicator. Then, employing a one-sample t-test, the PQ and ITQ questionnaire and subscale scores were compared to the mean scores of the norm groups, and the SUS score was compared to the reference group. The one-sample Wilcoxon Signed Rank test was not considered as the median of the norm/reference groups could not be obtained. Additionally, the average SUS score of participants was interpreted according to the proprietary scale developed by Bangor et al. (2009) (Appendix N).

To answer RQ1, the paired samples t-test and the Wilcoxon signed-rank test were performed. To answer RQ2, first, visual analyses were conducted to examine fluctuations in vitality, stress, and energy at the group level and individual level (with two randomly selected participants for each variable) over the fourteen-day period. Additionally, a Chi-squared test was performed to compare the obtained differences in performed activities between the pre-and post-intervention periods. Then, the (generalised) linear mixed model analysis was conducted using the maximum likelihood method. The

dummy variable differentiating between the first and second weeks was treated as a fixed effect, the variable representing a measurement day was a repeated factor, and vitality, stress, or energy was the dependent variable. The first-order autoregressive structure with heterogeneous variances was chosen as the repeated covariance type, considering the assumption that the correlation between daily measurements may change over time. Since the dummy variable was treated as a fixed effect, the assumptions of linearity and sphericity were not assessed. The chosen inferential analyses allow the inclusion of participants with missing data without the need to exclude any cases (Peters et al., 2012), therefore, the analyses included individuals with missing data.

Results

Missing Data

The screening of the missing data revealed that there were no missing values for the pretest-posttest and the VR-associated measurements. Nevertheless, during the EMA assessment phase, the number of participants with missing data varied per day. Namely, the lowest incidence of missing data was recorded on day ten, with 4 participants (11.8%) not completing the diary measurements. In contrast, the highest incidence was observed on day three, when 12 participants (35.3%) did not finish the diary. On the other days, the number of individuals missing the EMA measurements ranged from 5 (14.7%) to 11 (32.4%). According to Stone & Shiffman (2002) and Jones et al. (2018), non-compliance in the EMA studies is largely systematic, which suggests that the data in the current study were missing not at random (MNAR).

Baseline Characteristics

Table 2 depicts the baseline data for subjective vitality, stress, and energy/fatigue for the pretest and the pre-intervention week average measurements. Overall, most individuals had moderate levels of stress, energy/fatigue, and vitality before participating in the intervention.

Table 2

Baseline Data of the Participants (N=34)

	n (%)	*M (SD)*	Min	Max
Pretest				
SVS		4.14 (0.93)	2.17	6.00
PSS		17.24 (5.74)	5.00	28.00
Low stress	9 (26.5)			
Moderate stress	23 (67.6)			
High stress	2 (5.9)			
FAS		27.35 (6.34)	15.00	41.00
Normal (“healthy”) fatigue	6 (17.6)			
Mild-to-moderate fatigue	23 (67.6)			
Severe fatigue	5 (14.8)			
Daily diary				
Subjective vitality		8.11 (0.21)	2.00	14.00
Stress		6.40 (0.16)	2.00	13.00
Energy		2.29 (0.16)	-4.00	7.00

Note. SVS = subjective vitality scale. PSS = perceived stress scale. FAS = fatigue assessment scale.

Virtual Reality-Associated Outcomes

The distribution of the data for immersive tendencies and presence did not deviate from normality ($W = .50$, $p > .05$ and $W = .49$, $p > .05$, respectively), as indicated by the Shapiro-Wilk test. The outcomes of the one-sample t-tests revealed that participants' average scores for presence and immersive tendencies were significantly elevated compared to the norm groups’ scores. Additionally, the current sample displayed significantly higher scores on most subscales of immersive tendencies, as well as the “haptic” and “sounds” subscales of presence. Hence, participants in the current study, on average, demonstrated a greater ability to immerse themselves into different mediated environments and experienced heightened presence during the “Walk in Nature” intervention, including enhanced touch and auditory senses.

Nevertheless, participants' average scores for the immersive tendencies' subscale "focus" and presence-related subscales "possibility to examine" and "possibility to act" were significantly lower compared to the scores of the norm group. These results suggest that participants' ability to ignore the disturbing effects of the environment was decreased, and the possibilities to explore the VR environment and perform actions were limited in the current study.

Following the obtained average score for system usability and its position on the scheme created by Bangor et al. (2009), the ease and clarity of the intervention's use were evaluated as very poor and non-acceptable (Appendix N). The analysis of the Shapiro-Wilk test ($W = .93$, $p > .04$) and the Q-Q plot indicated that the data were positively skewed (Appendix O). Compared to the findings from the previous study by Ahire (2022), the usability of the "Walk in Nature" intervention in the current study was evaluated as significantly inferior, as indicated by the one-sample t-test. For the overview of average system usability, immersive tendencies, and presence scores and outcomes of the one-sample t-tests, refer to Table 3.

Table 3

Immersive Tendencies and Presence in the Sample (N = 34) and the Norm or Reference Groups

Scales and subscales	Sample	Norm group by Robillard et al. (2002) (*N* = 94)		Norm group by Robillard et al. (2003) (*N* = 13)		Reference group by Ahire (2022) (*N* = 18)	
	M (SD)	*M (SD)*	*t*-test	*M (SD)*	*t*-test	*M (SD)*	*t*-test
Immersive Tendencies Questionnaire							
Focus	22.38 (4.11)	24.81 (7.54)	-3.44*				
Involvement	21.15 (4.38)	15.33 (8.67)	7.75**				
Emotions	16.76 (4.46)	14.25 (6.70)	3.29*				
Game	10.03 (3.93)	6.56 (4.95)	5.16**				
Total	70.32 (11.16)	64.11 (13.11)	3.25*				
Presence Questionnaire							
Haptic	8.32 (2.73)			5.8 (3.5)	5.40**		
Sounds	15.12 (3.16)			13.3 (5.5)	3.54*		
Self-evaluation of performance	11.76 (1.96)			11.5 (2.1)	0.79		
Possibility to examine	14.59 (2.63)			15.7 (2.1)	-2.47*		
Quality of interface	15.24 (3.19)			16.2 (3.0)	-1.76		
Possibility to act	20.12 (4.11)			22.2 (4.6)	-2.96*		
Realism	30.41 (6.31)			28.9 (5.5)	1.40		
Total	115.56 (15.98)			93.7 (11.2)	7.98**		
System Usability Scale	25.66 (15.25)					87.08 (13.48)	-23.47**

Note. *$p < .05$, **$p < .001$

RQ1: Pretest-Posttest

The Shapiro-Wilk test did not provide evidence for the non-normality of the pretest scores on subjective vitality ($W = .98$, $p > .05$), stress ($W = .98$, $p > .05$), and fatigue ($W = .96$, $p > .05$). The data were also normally distributed for the posttest measurement of vitality ($W = .98$, $p > .05$) and stress ($W = .97$, $p > .05$). Nevertheless, the posttest fatigue scores were positively skewed ($W = .92$, $p = .022$), which was confirmed during the inspection of the Q-Q plot (Appendix P).

The outcomes of the paired samples t-test indicated that the levels of vitality were somewhat increased one week after the intervention compared to the one week before the intervention, but the difference was not statistically significant ($M = 4.23$, $SD = 0.92$ compared to $M = 4.14$, $SD = 0.93$, $t(33) = -.57$, $p = .573$). Additionally, stress levels were higher in the pretest than in the posttest ($M = 17.24$, $SD = 5.74$ compared to $M = 15.79$, $SD = 5.75$); nevertheless, no significant difference was established ($t(33) = 1.40$, $p = .173$). Finally, the outcome of the Wilcoxon signed rank test demonstrated that fatigue levels before the intervention were insignificantly increased compared to the post-intervention measurements ($M = 27.36$, $SD = 6.34$ compared to $M = 26.09$, $SD = 6.53$, $z = -.90$, $p = .371$). While the observed pretest-posttest differences in vitality, stress, and fatigue aligned with the hypothesised direction, these differences lacked statistical significance.

RQ2: Daily Diary

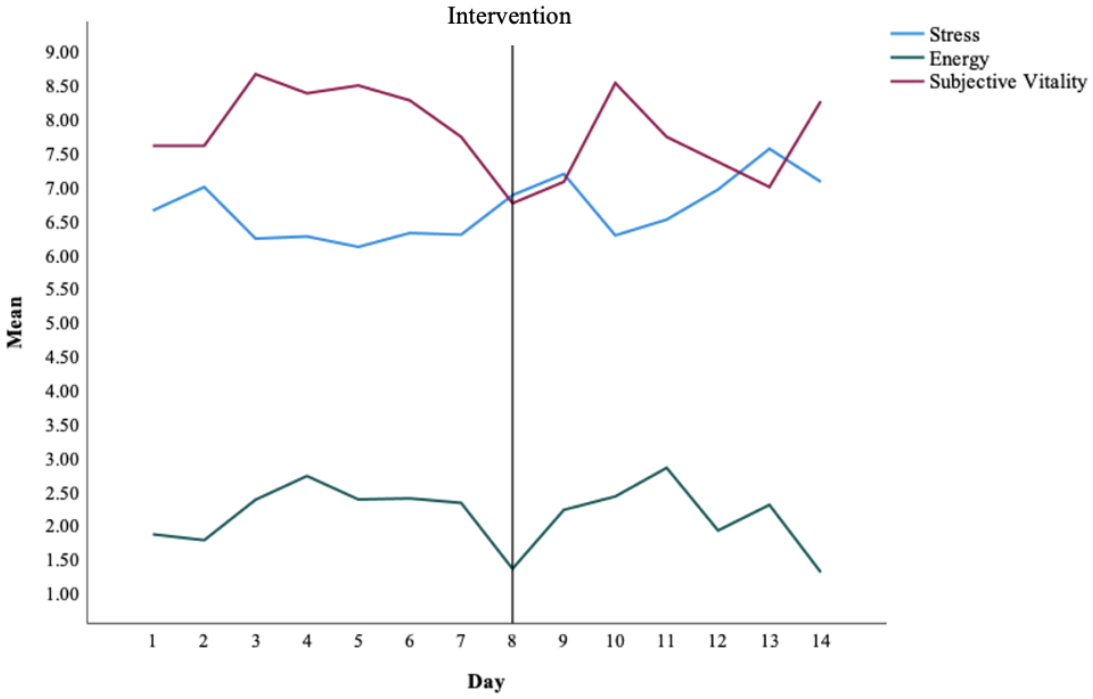
Stress, Subjective Vitality, and Energy

The visual analyses of the daily mean scores of the sample revealed the level of subjective vitality, stress, and energy varied from day to day, not being consistently stable over the two-week measurement period. The overview of the mean scores for each variable is illustrated in Figure 2. The average scores for subjective vitality varied from $M = 7.11$ ($SD = 3.14$) on the intervention day to $M = 8.83$ ($SD = 3.54$) on day ten. Thus, the vitality level on the intervention day was noticeably low compared to the scores on the other days. For stress, the scores ranged from $M = 6.09$ ($SD = 0.44$) on day three to $M = 7.28$ ($SD = 0.52$) on day thirteen. Additionally, the stress level was relatively stable from day three to day seven, ranging from $M = 6.09$ ($SD = 0.44$) to $M = 6.31$ ($SD = 0.32$). Then, the growth in the average score was observed on the intervention day ($M = 6.88$, $SD = 1.99$) and it

continued until day ten (*M* = 6.29, *SD* = 2.27). Finally, the energy level varied from *M* = 1.31 (*SD* = 0.34) on the fourteenth day to *M* = 2.85 (*SD* = 0.43) on the eleventh day. In addition, the mean energy level of the sample was noticeably diminished on the intervention day (*M* = 1.36, *SD* = 2.46) compared to the mean scores on the previous days. In general, the average scores for subjective vitality, stress, and energy levels exhibited fluctuation over the two-week measurement period, with distinct changes observed on the intervention day.

Figure 2

Mean Scores of the Sample per Day for Subjective Vitality, Stress, and Energy (N = 34).



The individual-level visual analyses also depicted visible fluctuations in scores. Figure 3 presents the individual scores of two randomly selected participants for subjective vitality throughout the two-week period. Participant 19 attained their lowest score on day ten and the highest on day five, whereas Participant 1 attained the lowest score on day four and the highest on day six. Notably, on the intervention day, the vitality score of Participant 1 decreased, while Participant 19 demonstrated an increase. For both individuals, vitality levels visibly declined from day nine to ten.

Figure 3

Variations in Individual Subjective Vitality Scores Throughout Two Weeks (N = 2)

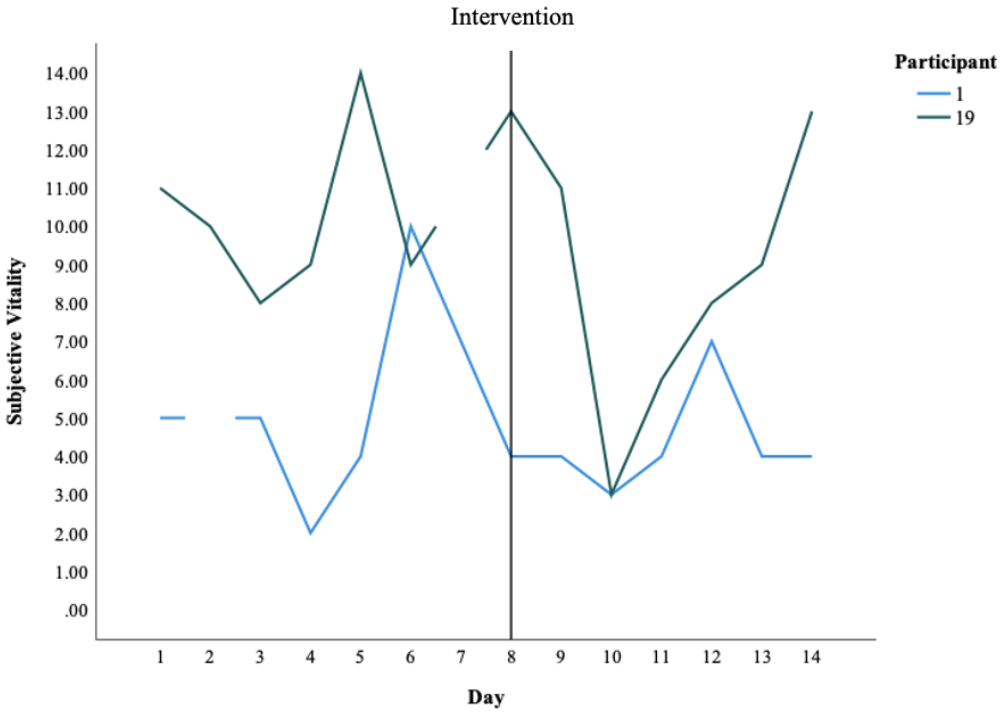
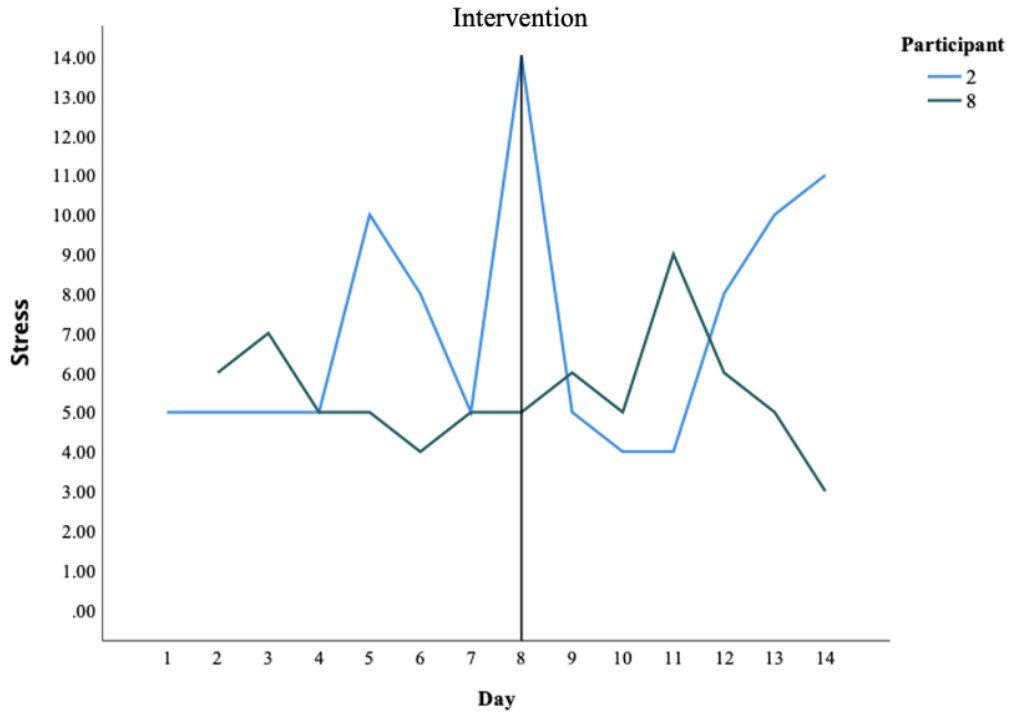


Figure 4 displays the stress scores of Participants 2 and 8. Just as individual vitality scores displayed variability, the individual stress levels were also inconsistent throughout the data collection period. Participant 8 attained their lowest stress score on day fourteen and the highest on day eleven, without any noticeable change on the intervention day. In contrast, Participant 2 experienced a rapid reduction in stress on the intervention day, coinciding with their highest obtained score. Additionally, the stress level of Participant 2 was rapidly diminishing after that until day ten when they scored the lowest.

Figure 4

Variations in Individual Stress Scores Throughout Two Weeks (N = 2)

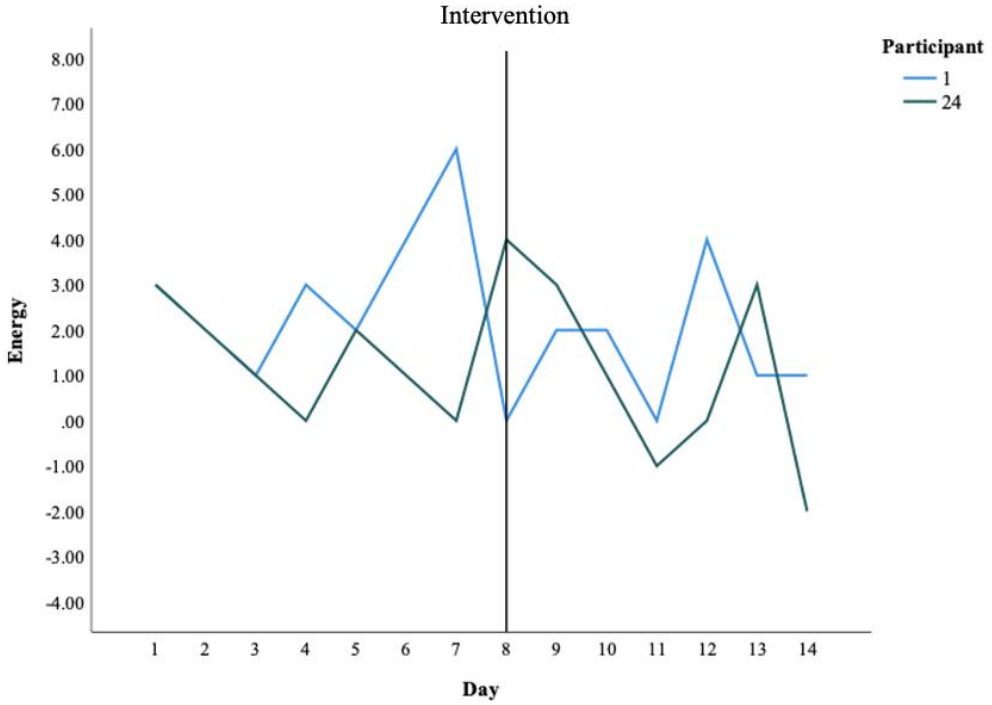


The variations in individual energy scores are illustrated in Figure 5. Participant 1 scored the lowest on day eleven and highest on day seven, while Participant 24 obtained the lowest score on the fourteenth day and the highest on the intervention day. Additionally, the energy level of Participant 1 was notably reduced on the intervention day, and then it increased on day nine. For Participant 24, the energy level was decreasing from day eight to day eleven.

Overall, the visual analyses conducted at the individual level depicted fluctuations in vitality, stress, and energy levels throughout the data collection period. Furthermore, for each randomly chosen participant, different trends, both increases and decreases, in scores were observed on the intervention day.

Figure 5

Variations in Individual Energy Scores Throughout Two Weeks (N = 2)



The Shapiro-Wilk test indicated that the residuals were not normally distributed for subjective vitality (W = .98, p < .001), energy (W = .99, p = .003), and stress (W = .96, p < .001). The inspection of the Q-Q plots confirmed that the residuals for stress were right-skewed but did not indicate significant deviations from normality for vitality and energy (Appendix Q).

The linear mixed modelling analyses established that the post-intervention period's average score was insignificantly lower than in the pre-intervention period for vitality (M = 7.82, SE = 0.27 compared to M = 8.13, SE = 0.36, t(149) = -.87, p = .384) and energy (M = 1.99, SE = 0.22 compared to M = 2.40, SE = 0.28, t(141) = 1.49, p = .139). The generalised linear mixed modelling analysis (with the gamma as the target distribution and the log link function) indicated that participants experienced 0.94 times higher mean stress levels in the week after the intervention compared to the week before. However, the difference between the pre-intervention (B = 1.85, SE = 0.04) and post-intervention weeks (B = 1.91, SE = 0.03) was not statistically significant (z = 1.63, p = .104). These outcomes contradict the hypothesis that energy and vitality would be increased, and stress decreased in the post-intervention period.

Furthermore, substantial variability was observed throughout the data collection period in vitality and energy scores as well as in residuals of stress. For subjective vitality, the highest variance was found on the intervention day (B = 10.50, SE = 2.83), and the variances on other days ranged from 5.62 (SE = 1.56) to 13.74 (SE = 3.52). For stress, the residual variance for day eight was 0.09 (SE = 0.03), and, for other days, it ranged from 0.07 (SE = 0.02) to 0.16 (SE = 0.05). Finally, for energy, the score variances ranged from 2.39 (SE = 0.69) to 6.37 (SE = 1.80). On the intervention day, the variance was 6.29 (SE = 1.71).

In conclusion, there were no statistically significant differences in stress, energy, or subjective vitality levels between the pre-intervention and post-intervention periods. Furthermore, the analyses yielded contradictory results: the paired samples t-tests suggested higher stress and lower vitality levels in the pre-intervention week, while the (generalised) linear mixed modelling implied the opposite outcomes. In addition, the Wilcoxon signed-rank test displayed increased pre-intervention fatigue levels, while linear mixed modelling indicated somewhat lower post-intervention energy levels. Finally, the visual inspection analyses revealed a distinct decrease on the intervention day in vitality and energy and an increase in stress on the group level.

Daily Activities

To illustrate an example of the responses that participants provided for each category of activities, the individual data from Participant 1 was depicted in Table 4. The participant provided relatively short answers, mentioning one or two distinct activities for each category. Additionally, their responses varied from general statements, such as “I ate and drank today,” to more specific descriptions of the performed activities, e.g. “I ate bread and pasta and drank tea.” The data for certain categories of activities overlapped. For instance, the participant indicated that they “worked at a restaurant” in the “work” category in addition to mentioning “working” as a physical activity. Another overlap was noted between the activities in the categories “self-care” and “physical activity.” Participant 1 mentioned that they “worked out” in both categories.

Table 4

The Summary of Answers for Each Daily Activities' Category from Participant 1

Activity category	Provided answers
Passive relaxation	"I listened to music", "I set on a couch", "I was on social media", "I watched television and listened to music", "I smocked shisha," I watched television for five minutes and shortly listened to music," "I watched two and a half men."
Physical activity	"I rode my horse," "I walked a bit," "I walked and worked" "I went for a walk with my dog," "I worked and walked with my horse" "riding" "riding, walking," "working and walking," "working out."
Sleeping over the day	N/A
University	"I had a lecture and a meeting," "I had two lectures today," "I studied math."
Work	"I worked at a restaurant," "I am currently at work."
Household	"I cleaned," "I cooked," "I cooked and cleaned," "I cooked, cleaned, went grocery shopping," "I cooked a simple meal," "I cooked ravioli."
Eating and drinking	"I ate and drank today," "I ate bread and past and drank tea," "I drank a chocolate milk," "I made food (maultaschen)," "I ate pasta," "I drank nice juice and ate ravioli and other."
Self-care	"I worked out," "I did a back workout," "I did yoga as part of this study."
Travelling	"I drove the car," "I drove like two hours," "I drove two hours."
Social activities	"I met a girl," "I met with my cousin," "I met my friend."

Table 5 presents performed daily activities of participants before and after the intervention, divided into the following higher-order categories: energy-giving, energy-draining, and energy-neutral. The assigned categories included the following ranges of mean scores: -1 to -0.3 (energy-draining activities), -0.2 to 0.2 (energy-neutral activities), and 0.3 to 1 (energy-giving activities). Activities from the "eating and drinking" subcategory of "energy-giving activities" provided the most

energy (*M* = 0.82, *SD* = 0.49). In comparison, activities associated with the subcategory "university" of "energy-draining activities" were the most draining (*M* = -0.53, *SD* = 0.77). Appendix R provides a detailed list of mentioned activities in each category.

Table 5

Comparison of the Performed Activities in the Pre-and Post-Intervention Periods and Associated Descriptive Statistics (N = 238)

Categories	*M (SD)*	*% (n)*		
		Pre-intervention	*Post-intervention*	*Chi-squared test*
Energy-giving activities				
Eating and drinking	0.82 (0.49)	68.1 (162)	75.6 (180)	3.37
Self-care	0.80 (0.44)	26.5 (63)	32.0 (76)	0.72
Sleeping over the day	0.78 (0.58)	13.0 (31)	13.4 (32)	0.02
Social activities	0.73 (0.63)	55.9 (133)	55.9 (133)	0
Passive relaxation	0.68 (0.61)	62.2 (148)	69.7 (166)	3.03
Physical activity	0.49 (0.82)	33.6 (80)	42.9 (102)	4.31*
Energy-neutral activities				
Travelling	-0.04 (0.80)	47.1 (112)	58.0 (138)	5.70*
Household	-0.04 (0.83)	49.6 (118)	60.9 (145)	6.19*
Energy-draining activities				
University	-0.53 (0.77)	47.1 (112)	57.6 (137)	5.26*
Work	-0.26 (0.89)	17.6 (42)	21.0 (49)	0.67

Note. *$p < .05$

The findings indicated an increase in engagement across various activity categories during the post-intervention phase. Specifically, the Chi-squared test demonstrated a statistically significant rise in post-intervention involvement in the activities related to travelling and household (energy-neutral), physical activities (energy-boosting), and university-related tasks (energy-draining), in comparison to the engagement levels observed during the pre-intervention phase. While engagement in other activity

categories also increased, the differences between the pre-and post-intervention involvement were not significant.

Discussion

The objective of the present study was to explore the differences in subjective vitality, stress, and energy in the daily lives of students before and after participation in the “Walk in Nature” intervention. The results did not indicate significant changes between the pre-and post-intervention periods for vitality, energy, and stress. Nevertheless, a significant difference was found between engagement in activities, such as household chores, travelling, physical exercises, and university-related tasks after the intervention compared to before participating in it.

Subjective Vitality, Stress, and Energy

Contrary to the expectations, no significant difference in students’ energy was established in the pretest-posttest and daily diary phases. This finding is in line with previous research conducted by Bareišytė (2021), where no changes in the students' energy levels were observed after the “Walk in Nature” intervention. The specificity of the intervention’s tasks may provide explanations for this outcome. Namely, as the intervention incorporated only relatively low-intensity physical exercises, they could have been insufficient in improving energy in the current group of students compared to the potential benefits that could be achieved with moderate-intensity exercises (Chan & Yu, 2022). On the other hand, the intervention incorporated yoga tasks, which could have been perceived as difficult and tiring for individuals who had not been engaging in regular physical activity before the study. Thus, the intervention could have exerted limited influence on their energy.

Nevertheless, this study found no differences between the pre-and post-intervention measurements of subjective vitality and stress, which contradicts results from prior research. Namely, in previous studies employing “the Walk in Nature” intervention (Ahire, 2022; Bareišytė, 2021), a significant enhancement in subjective vitality and a reduction in stress was established. The employed measurement methods may explain differences in outcomes. Namely, Ahire (2022) and Bareišytė (2021) used the individual-difference version of the Subjective Vitality Scale, assessing vitality as a trait (i.e. an ongoing characteristic), while this study used the state-level version, with participants

reporting their experiences of vitality as a state. Thus, this discrepancy in approaches to measuring vitality could have influenced the obtained outcomes.

Furthermore, unlike studies by Ahire (2022) and Bareišytė (2021) that assessed vitality and stress immediately before and after the intervention, this study explored changes in these variables one week before and after the intervention. Therefore, while the intervention promotes a short-term increase in vitality and a decrease in stress, these effects may not last for a longer term. Previous studies that examined the effectiveness of similar tasks provided in the intervention, such as yoga, concluded that a long-term reduction in stress can be accomplished only by practising yoga several times a week for a month with a session lasting around sixty minutes (Shohani et al., 2018). In addition, the decline in the levels of cortisol, the stress hormone (Woodyard, 2011), occurs only when the practice of yoga and other physical activities is consistent. Therefore, it is possible that increasing the number of sessions (and time spent) of the "Walk in Nature" intervention may provide significant results in the longer term.

The findings from the daily diary phase provide further explanations for the lack of changes in vitality, stress, and energy during the post-intervention period. For instance, substantial day-to-day variations in subjective vitality, energy, and stress levels were observed. These are natural fluctuations that may be influenced by various daily factors such as food intake, light intensity, performed activities, social interactions, etc. (Buchner et al., 2022; Smolders et al., 2013). As participants in the current study were students, variations in their stress and vitality levels may be explained by the increased number of daily stressors that they encounter, such as financial issues, deadlines, and family-related conflicts (Freire et al., 2020; Karyotaki et al., 2020; Pascoe et al., 2020) in combination with pleasant activities they engage in. In the current study, most students regularly engaged in social interactions and physical exercises, which may contribute to enhanced vitality levels (Kukić et al., 2022; Wizior, 2020). Previous studies found similar short-term fluctuations in subjective vitality within individuals (e.g., Campbell et al., 2018), stress (Beattie & Griffin, 2014; Stawski et al., 2008) and energy/fatigue (Campbell et al., 2018; Kempke et al., 2013). Smolders et al. (2013) also determined a parabolic fluctuation pattern in vitality throughout the day, with peak levels in the

afternoon. Therefore, the impact of the intervention could have been diminished by such fluctuations. Additionally, providing that participants took part in the intervention at different times of the day, its influence on their vitality could also differ per person.

The participants' average levels of subjective vitality and energy were also lowest on the intervention day, which could have been influenced by several factors. In addition to completing the diary, participants were required to travel to the campus, experience the intervention, and complete the VR-associated questionnaires. Given the potentially busy schedules of higher-education students (Arzu et al., 2006; Kayaoğlu et al., 2016), these activities required additional time investment and may have contributed to the notably increased stress, energy, and decreased vitality on that day. Furthermore, participants could engage in educational activities after the intervention, which may have heightened their exhaustion (Räisänen, 2021). Finally, a number of participants completed the diary and/or participated in the VR session during examination weeks. Previous research has demonstrated that (pre-)examination stress can negatively affect cognitive functioning, such as concentration and attention (Pradhan et al. 2014). Therefore, it is possible that not all students were able to fully experience the benefits of the “Walk in Nature” intervention due to being preoccupied with study-related thoughts and concerns.

It is worth noting that, while no significant outcomes were found, the pretest-posttest and daily diary analyses yielded conflicting results. Different measurement instruments were utilised for establishing the levels of subjective vitality, stress, and energy in the pretest-posttest and the daily diary phases of the study, which could influence the opposing outcomes from the analyses (Shiffman et al., 2008). Specifically, individuals tend to provide lower or higher estimates for their construct-related experiences when they are asked to report these experiences retrospectively compared to the more immediate diary ratings (Houtveen & Oei, 2007). In the current study, participants demonstrated more positive results on the pretest-posttest measurement instruments than on the daily diary measurements, which confirms this finding.

Daily Activities

A notable increase in the engagement of students in certain activities during the post-intervention period was observed compared to the pre-intervention period. Namely, participants were involved more in energy-providing activities, such as physical exercises. This finding may be explained by previous research suggesting that activities that are perceived to enhance energy are intrinsically motivating and enjoyable (Ryan & Frederick, 1997; Ryan et al., 2010). Thus, it is possible that, in the week after the intervention, participants actively performed behaviours that matched their personal interests. Nevertheless, this assumption is challenged by the increase in the involvement in energy-neutral (household chores and ravelling), and energy-draining activities (university tasks), suggesting that students did not prioritise activities solely focused on boosting their energy levels. Furthermore, the lack of significant changes in vitality, which was earlier associated with engagement in energy-providing activities (Ryan & Deci, 2000; Ryan et al., 2010), raises uncertainty related to the influence of the intervention on the daily activities of students.

Inconsistent with previous research by Wensik (2022), physical activities in the current study were associated with increased energy levels, while household chores with decreased energy. This can be explained by the differences in measurement approaches. Wensik (2022) measured daily activities and fatigue independently, while in the current study, the daily energy was directly dependent on the performed activity categories. This highlights that measuring energy specific to each category, as opposed to relating daily behaviours to the overall subjectively experienced energy, may yield different results. Additionally, Wensik (2022) examined the relationship between daily activities and fatigue in individuals with long-COVID, whereas the current study recruited a non-clinical sample. Therefore, the perceptions of daily energy and performed daily activities may differ between these samples due to differing health status.

Finally, activities associated with the category “university” were evaluated as the most energy-draining. This implies that activities related to academic responsibilities, such as exams, deadlines, and lectures, were notably draining for participants compared to other types of activities. This finding aligns with research that established that university students encounter sleep and eating disturbances, financial concerns (Freire et al., 2020; Karyotaki et al., 2020; Pascoe et al., 2020), social

isolation (Dahlin et al., 2005; Megivern et al., 2003; Newcomb-Anjo, 2016), and burnout (Dahlin et al., 2005). These challenges may interfere with the university-associated responsibilities of students and thus decrease the enjoyableness and energy they receive from study-related activities.

Strengths and Limitations

The current study had several benefits. First, it incorporated the pretest-posttest measurements in addition to the EMA, which enhanced the design's power to evaluate differences in the pre-and post-intervention periods (Pasnak, 2018). Second, the duration of the study was somewhat short, which benefited the compliance of the students (Rogers, 2021, Wray et al., 2014). If the study was extended to three weeks or more, the high probability that individuals would consider it too time-consuming and demanding could occur (Rogers, 2021; Wray et al., 2014). Finally, existing validated instruments, such as FAS, PSS, and SVS were employed, which benefits the reliability of the measurements.

Nevertheless, the study must be viewed in light of several limitations. Namely, the technical difficulties were experienced with TIIM during the completion of the daily diary. Students reported instances where the application did not send notifications, froze during the diary completion, and unexpectedly logged them out (in certain cases, without the possibility to log back in for a long time). These issues may have resulted in frustration, decreased motivation and dedication to complete the daily measurements (Tawfik et al., 2021) and could have affected the quality of the provided data. This could be noticed, for example, in the limited number of activities that individuals provided for each category. Furthermore, this could have contributed to the missing data in the current study, potentially affecting the statistical power (Graham, 2009).

Other technical issues were encountered during participants' engagement with the "Walk in Nature" intervention.. For instance, a malfunction in the "breathing tree" was experienced, in which the tree ceased to expand and contract. Additionally, the animated yoga instructor occasionally exhibited glitches, leading to confusion regarding how to execute certain yoga movements. Participants also reported difficulties with the instructions provided by the pre-recorded voice. It was not apparent that the instructor first demonstrates the yoga movements before the users should

perform them. Due to time constraints, these technical difficulties were not solved and thus were experienced by most participants. These issues may have led to frustration and potentially diminished the effectiveness of the intervention (Köhnen et al., 2021), which was highlighted in the poor usability evaluation and decreased possibilities of participants to examine and act in the VR environment. Additionally, these challenges could have contributed to the poorly evaluated usability and limited exploratory capacity of the participants and their ability to perform actions in the VR environment.

Another limitation concerns the indications of energy derived from daily activities were solely based on subjective self-report, and so were the further higher-order categorisations of activities as "energy-giving," "energy-draining," and "energy-neutral." In addition, there seemed to be an overlap between different activity types, as participants reported the same activities (e.g., “working”) in multiple categories. This suggests that the strategy for categorising daily activities was poor. Hence, the findings associated with daily activities in the present study cannot be generalised to the broader population.

Furthermore, the present study had an observational nature, which limits the possibility of drawing conclusions about the effects of the "Walk in Nature" intervention and the generalisability of findings. In addition, most participants in the current study had moderate baseline levels of stress, vitality, and energy. It is possible that participants with lower levels of these constructs may benefit more from participation in the “Walk in Nature” intervention, as it was developed with the goal of improving subjective vitality and stress levels. Additional research is required to establish the effectiveness and improve generalisability.

Future Research and Implications

The current study demonstrated substantial day-to-day variations in subjective vitality, stress, and energy within participants, which could have diminished the impact of the intervention. Therefore, it is recommended to consider these fluctuations when implementing the "Walk in Nature" intervention in clinical settings. For instance, the parabolic fluctuation pattern in subjective vitality throughout the day, with the lowest points in the morning and evening demonstrated by Smolders et al. (2013) could be considered. These specific moments could be targeted so that patients or clients

could benefit the most from the intervention. Additionally, it is crucial to consider the daily factors that influence these fluctuations, such as social interactions, exposure to natural light, and daily activities (Buchner et al., 2022; Smolders et al., 2013). By controlling for these factors, the intervention's effectiveness can be enhanced.

A potential approach could include the use of a single-case experimental design (SCED), which involves repeated data collection across baseline and intervention phases, with systematic manipulation of the intervention presence (Krasny-Pacini & Evans, 2018). By employing this method, the effects of the "Walk in Nature" intervention on subjective vitality, energy, and stress in the daily life of individuals and its duration can be determined (Krasny-Pacini & Evans, 2018). This method could also allow to determine changes in the daily activities of individuals. With the use of SCED, it could be also possible to implement several sessions of the “Walk in Nature” intervention with individuals with different characteristics (e.g. age and gender), which can shed light on the number of sessions that are needed to achieve a longer-term effect. Additionally, between-subjects differences in the responses to the intervention could be examined, taking into account their daily life context. This can, in turn, increase an understanding of who can benefit the most from the intervention.

Furthermore, if the EMA measurements are employed in future studies, they should be administered several times a day. Filing in the daily diary at several time points could provide a better overview of the daily variations in subjective vitality, stress, and energy and shed light on the duration of the intervention effect. Additionally, to objectively measure activities individuals engage in during the day, an Electronically Activated Recorder (EAR), which repeatedly records brief auditory snapshots of activities an individual is engaged in can be used (Mehl & Pennebaker, 2003). However, it will require more advanced knowledge of its usage and related analysis strategies.

Conclusion

In conclusion, the current study observed the changes in subjective vitality, stress, and energy in the daily lives of students before and after their engagement in the VR-based “Walk in Nature” intervention. The results revealed that there were no significant differences between the week before and the week after the intervention periods for vitality, energy, and stress. Nonetheless, a significant

change was observed in the involvement in behaviours like household chores, travel, physical exercises, and university-related activities following the intervention in contrast to their engagement prior to participation. Additionally, significant day-to-day fluctuations were observed in vitality, stress, and energy, which could have diminished the impact of the intervention. The present study had several limitations, such as poor categorisation of daily activities and technological issues that could affect the engagement of the participants and the effectiveness of the intervention. Future studies could evaluate the impact of the intervention using a single-case experimental design and increase the number of measurements of the variables during the day to explore daily fluctuations in the variables. Additionally, an increased number of sessions of the “Walk in Nature” intervention may be needed to examine longer-term effects.

References

Adhyaru, J. S., & Kemp, C. (2022). Virtual reality as a tool to promote wellbeing in the workplace. *Digital Health*, *8*. https://doi.org/10.1177/20552076221084473

Ahire, D. (2022). *Respiratory Biofeedback based Virtual Environment to Increase Subjective vitality and Reduce Stress in International Students: Usability, Feasibility and Effectiveness pilot study* (Master's thesis). University of Twente. https://essay.utwente.nl/93538/1/Ahire_MA_BMS.pdf

Akın A. (2012). The relationships between Internet addiction, subjective vitality, and subjective happiness. *Cyberpsychology, Behavior and Social Networking*, *15*(8), 404–410. https://doi.org/10.1089/cyber.2011.0609

Arslan, G., Yıldırım, M., & Aytaç, M. (2022). Subjective vitality and loneliness explain how coronavirus anxiety increases rumination among college students. *Death Studies*, *46*(5), 1042–1051. https://doi.org/10.1080/07481187.2020.1824204

Arzu, D., Tuzun, E. H., & Eker, L. (2006). Perceived barriers to physical activity in university students. *Journal of Sports Science & Medicine*, *5*(4), 615–620. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3861763/

Avlund K. (2010). Fatigue in older adults: an early indicator of the aging process? *Aging Clinical and Experimental Research*, *22*(2), 100–115. https://doi.org/10.1007/BF03324782

Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of usability studies*, *4*(3), 114-123. https://uxpajournal.org/determining-what-individual-sus-scores-mean-adding-an-adjective-rating-scale/

Bareišytė, L. (2021). *Using Virtual Reality to Improve Subjective vitality: Design and Pilot Study for a Virtual Nature Environment* (Master's thesis). University of Twente, https://essay.utwente.nl/89140/1/Bareisyte_MA_BMS.pdf

Baruch, Y., Grimland, S., & Vigoda-Gadot, E. (2014). Professional vitality and career success: Mediation, age and outcomes. *European Management Journal*, *32*(3), 518-527. https://doi.org/10.1016/j.emj.2013.06.004

Beattie, L., & Griffin, B. (2014). Accounting for within-person differences in how people respond to daily incivility at work. *Journal of Occupational and Organizational Psychology*, *87*(3), 625-644. https://doi.org/10.1111/joop.12067

Benoit, M., Guerchouche, R., Petit, P. D., Chapoulie, E., Manera, V., Chaurasia, G., Drettakis, G., & Robert, P. (2015). Is it possible to use highly realistic virtual reality in the elderly? A feasibility study with image-based rendering. *Neuropsychiatric Disease and Treatment*, *11*, 557–563. https://doi.org/10.2147/NDT.S73179

Bize, R., & Plotnikoff, R. C. (2009). The relationship between a short measure of health status and physical activity in a workplace population. *Psychology, Health & Medicine*, *14*(1), 53–61. https://doi.org/10.1080/13548500802032699

Bostic, T. J., Rubio, D. M., & Hood, M. (2000). A validation of the subjective vitality scale using structural equation modeling. *Social Indicators Research*, *52*(3), 313–324. https://doi.org/10.1023/A:1007136110218

Brooke, J. (1996). SUS: A "Quick and Dirty" Usability Scale. In *Usability Evaluation In Industry* (1st ed.). CRC Press. https://www.taylorfrancis.com/chapters/edit/10.1201/9781498710411-35/sus-quick-dirty-usability-scale-john-brooke

Buchner, L., Amesberger, G., Finkenzeller, T., Moore, S. R., & Würth, S. (2022). The modified German subjective vitality scale (SVS-GM): Psychometric properties and application in daily life. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.948906

Büssing, A., Michalsen, A., Khalsa, S. B., Telles, S., & Sherman, K. J. (2012). Effects of yoga on mental and physical health: a short summary of reviews. *Evidence-Based Complementary and Alternative Medicine: eCAM*, *2012*, 165410. https://doi.org/10.1155/2012/165410

Campbell, R., Vansteenkiste, M., Delesie, L., Tobback, E., Mariman, A., Vogelaers, D., & Mouratidis, A. (2018). Reciprocal associations between daily need-based experiences, energy,

and sleep in chronic fatigue syndrome. *Health Psychology, 37*(12), 1168–1178. https://doi.org/10.1037/hea0000621

Chan, M. L. T., & Yu, D. S. F. (2022). The effects of low-impact moderate-intensity stepping exercise on fatigue and other functional outcomes in older adults with multimorbidity: A randomized controlled trial. *Archives of gerontology and geriatrics*, *98*, 104577. https://doi.org/10.1016/j.archger.2021.104577

Chen, W., Chao, J. G., Chen, X. W., Wang, J. K., & Tan, C. (2015). Quantitative orientation preference and susceptibility to space motion sickness simulated in a virtual reality environment. *Brain Research Bulletin*, 113, 17-26. https://doi.org/10.1016/j.brainresbull.2015.01.007

Chen, F., & Sengupta, J. (2014). Forced to be bad: The positive impact of low-autonomy vice consumption on consumer vitality. *Journal of Consumer Research, 41*(4), 1089–1107. https://doi.org/10.1086/678321

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, *24*(4), 385–396. https://doi.org/10.2307/2136404

Conner, T. S., Brookie, K. L., Carr, A. C., Mainvil, L. A., & Vissers, M. C. (2017). Let them eat fruit! The effect of fruit and vegetable consumption on psychological well-being in young adults: A randomized controlled trial. *PloS One*, *12*(2), e0171206. https://doi.org/10.1371/journal.pone.0171206

Couto, N., Antunes, R., Monteiro, D., Moutão, J., Marinho, D. A., & Cid, L. (2017). Impact of the basic psychological needs in subjective happiness, subjective vitality and physical activity in an elderly Portuguese population. *Motricidade, 13*(2), 58–70. https://doi.org/10.6063/motricidade.9746

Dahlin, M., Joneborg, N., & Runeson, B. (2005). Stress and depression among medical students: a cross-sectional study. *Medical Education*, *39*(6), 594–604. https://doi.org/10.1111/j.1365-2929.2005.02176.x

D'Cunha, N. M., Nguyen, D., Naumovski, N., McKune, A. J., Kellett, J., Georgousopoulou, E. N., Frost, J., & Isbel, S. (2019). A mini-review of virtual reality-based interventions to promote well-being for people living with dementia and mild cognitive impairment. *Gerontology*, *65*(4), 430–440. https://doi.org/10.1159/000500040

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, *11*(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01

Delgado-Lobete, L., Montes-Montes, R., Vila-Paz, A., Talavera-Valverde, M. Á., Cruz-Valiño, J. M., Gándara-Gafo, B., ... & Santos-del-Riego, S. (2020). Subjective well-being in higher education: psychometric properties of the satisfaction with life and subjective vitality scales in Spanish university students. *Sustainability*, *12*(6), 2176. https://doi.org/10.3390/su12062176

De Vries, J., Michielsen, H., Van Heck, G. L., & Drent, M. (2004). Measuring fatigue in sarcoidosis: the Fatigue Assessment Scale (FAS). *British Journal of Health Psychology*, *9*(Pt 3), 279–291. https://doi.org/10.1348/1359107041557048

Diemer, J., Alpers, G. W., Peperkorn, H. M., Shiban, Y., & Mühlberger, A. (2015). The impact of perception and presence on emotional reactions: A review of research in virtual reality. *Frontiers in Psychology*, *6*, 111605. https://doi.org/10.3389/fpsyg.2015.00026

Dimitrov, D. M., & Rumrill, P. D., Jr (2003). Pretest-posttest designs and measurement of change. *Work (Reading, Mass.)*, *20*(2), 159–165. https://pubmed.ncbi.nlm.nih.gov/12671209/

Fredrickson, B. L. (2000). Extracting meaning from past affective experiences: The importance of peaks, ends, and specific emotions. *Cognition and Emotion*, *14*(4), 577–606. https://doi.org/10.1080/026999300402808

Freeman, D., Reeve, S., Robinson, A., Ehlers, A., Clark, D., Spanlang, B., & Slater, M. (2017). Virtual reality in the assessment, understanding, and treatment of mental health disorders. *Psychological Medicine*, *47*(14), 2393–2400. https://doi.org/10.1017/S003329171700040X

Freire, C., Ferradás, M. D. M., Regueiro, B., Rodríguez, S., Valle, A., & Núñez, J. C. (2020). Coping Strategies and Self-Efficacy in University Students: A Person-Centered Approach. *Frontiers in Psychology*, *11*, 841. https://doi.org/10.3389/fpsyg.2020.00841

Gadi, N., Saleh, S., Johnson, J. A., & Trinidade, A. (2022). The impact of the COVID-19 pandemic on the lifestyle and behaviours, mental health and education of students studying healthcare-related courses at a British university. *BMC Medical Education*, *22*(1), 115. https://doi.org/10.1186/s12909-022-03179-z

García-Betances, R. I., Arredondo Waldmeyer, M. T., Fico, G., & Cabrera-Umpiérrez, M. F. (2015). A succinct overview of virtual reality technology use in Alzheimer's disease. *Frontiers in Aging Neuroscience*, *7*, 80. https://doi.org/10.3389/fnagi.2015.00080

Hendriks, C., Drent, M., Elfferich, M., & De Vries, J. (2018). The Fatigue Assessment Scale: quality and availability in sarcoidosis and other diseases. *Current Opinion in Pulmonary Medicine*, *24*(5), 495–503. https://doi.org/10.1097/MCP.0000000000000496

Horisberger, A., Courvoisier, D., & Ribi, C. (2019). The Fatigue Assessment Scale as a simple and reliable tool in systemic lupus erythematosus: a cross-sectional study. *Arthritis Research & Therapy*, *21*(1), 80. https://doi.org/10.1186/s13075-019-1864-4

Houtveen, J. H., & Oei, N. Y.L. (2007). Recall bias in reporting medically unexplained symptoms comes from semantic memory. *Journal of Psychosomatic Research*, *62*(3), 277–282. https://doi.org/10.1016/j.jpsychores.2006.11.006

Hudson, S., Matson-Barkat, S., Pallamin, N., & Jegou, G. (2019). With or without you? Interaction and immersion in a virtual reality experience. *Journal of Business Research*, *100*, 459-468. https://doi.org/10.1016/j.jbusres.2018.10.062

ISO. (2019). *Analyse Studentenwelzijn: En analyse van bestaande databronnen over studentenwelzijn in het hoger onderwijs*. Interstedelijk Studenten Overleg. https://www.iso.nl/wp-content/uploads/2019/11/Analyse-Studentenwelzijn-ISO.pdf

Karyotaki, E., Cuijpers, P., Albor, Y., Alonso, J., Auerbach, R. P., Bantjes, J., Bruffaerts, R., Ebert, D. D., Hasking, P., Kiekens, G., Lee, S., McLafferty, M., Mak, A., Mortier, P., Sampson, N. A.,

Stein, D. J., Vilagut, G., & Kessler, R. C. (2020). Sources of Stress and Their Associations With Mental Disorders Among College Students: Results of the World Health Organization World Mental Health Surveys International College Student Initiative. *Frontiers in Psychology*, *11*, 1759. https://doi.org/10.3389/fpsyg.2020.01759

Kayaoğlu, M. N., Erbay, Ş., Flitner, C., & Saltaş, D. (2016). Examining students' perceptions of plagiarism: A cross-cultural study at tertiary level. *Journal of Further and Higher Education*, *40*(5), 682-705. https://doi.org/10.1080/0309877X.2015.1014320

Kazdin, A. E. (2023). Interventions in everyday life to improve mental health and reduce symptoms of psychiatric disorders. *American Psychologist.* Advance online publication. https://doi.org/10.1037/amp0001158

Kempke, S., Luyten, P., Claes, S., Van Wambeke, P., Bekaert, P., Goossens, L., & Van Houdenhove, B. (2013). The prevalence and impact of early childhood trauma in chronic fatigue syndrome. *Journal of Psychiatric Research, 47*, 664 – 669. http://dx.doi.org/10.1016/j.jpsychires .2013.01.021

Khoury, B., Sharma, M., Rush, S. E., & Fournier, C. (2015). Mindfulness-based stress reduction for healthy individuals: A meta-analysis. *Journal of Psychosomatic Research*, *78*(6), 519–528. https://doi.org/10.1016/j.jpsychores.2015.03.009

Kim, G., & Biocca, F. (2018). Immersion in Virtual Reality Can Increase Exercise Motivation and Physical Performance. In J. Y. Chen, & G. Fragomeni (Eds.), *Virtual, Augmented and Mixed Reality: Applications in Health, Cultural Heritage, and Industry - 10th International Conference, VAMR 2018, Held as Part of HCI International 2018, Proceedings* (pp. 94-102). (Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); Vol. 10910 LNCS). Springer Verlag. https://doi.org/10.1007/978-3-319-91584-5_8

Köhnen, M., Dreier, M., Seeralan, T., Kriston, L., Härter, M., Baumeister, H., & Liebherz, S. (2021). Evidence on Technology-Based Psychological Interventions in Diagnosed Depression: Systematic Review. *JMIR Mental Health*, *8*(2). https://doi.org/10.2196/21700

Krasny-Pacini, A., & Evans, J. (2018). Single-case experimental designs to assess intervention effectiveness in rehabilitation: A practical guide. *Annals of Physical and Rehabilitation Medicine*, *61*(3), 164-179. https://doi.org/10.1016/j.rehab.2017.12.002

Kubzansky, L. D., & Thurston, R. C. (2007). Emotional vitality and incident coronary heart disease: benefits of healthy psychological functioning. *Archives of General Psychiatry*, *64*(12), 1393–1401. https://doi.org/10.1001/archpsyc.64.12.1393

Kukić, F., Koropanovski, N., Vesković, A., & Petrović, N. (2022). Physical activity as a means to improve subjective vitality of university students. *Research Quarterly for Exercise and Sport*, 1–9. https://doi.org/10.1080/02701367.2022.2119196

Lang, X., Wang, Q., Huang, S., Feng, D., Ding, F., & Wang, W. (2022). Relations among perceived stress, fatigue, and sleepiness, and their effects on the ambulatory arterial stiffness index in medical staff: A cross-sectional study. *Frontiers in Psychology*, *13*, 1010647. https://doi.org/10.3389/fpsyg.2022.1010647

Lavrusheva, O. (2020). The concept of vitality: Review of the vitality-related research domain. *New Ideas in Psychology*, *56*, 100752. https://doi.org/10.1016/j.newideapsych.2019.100752

Lee, E. (2012). Review of the psychometric evidence of the Perceived Stress Scale. *Asian Nursing Research*, *6*(4), 121-127. https://doi.org/10.1016/j.anr.2012.08.004

Lewis, J.R., Sauro, J. (2009). The Factor Structure of the System Usability Scale. In: Kurosu, M. (eds) Human Centered Design. HCD 2009. Lecture Notes in Computer Science, vol 5619. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-02806-9_12

Mandal, S. (2013). Brief introduction of virtual reality & its challenges. *International Journal of Scientific & Engineering Research*, *4*(4), 304-309. https://www.semanticscholar.org/paper/Brief-Introduction-of-Virtual-Reality-%26-its-Mandal/b879c50ac2827e11575c589d5c199e30f83e97bc

Martela, F., DeHaan, C. R., & Ryan, R. M. (2016). On Enhancing and Diminishing Energy Through Psychological Means. In *Elsevier eBooks* (pp. 67–85). https://doi.org/10.1016/b978-0-12-801850-7.00004-4

Mattila, O., Korhonen, A., Pöyry, E., Hauru, K., Holopainen, J., & Parvinen, P. (2020). Restoration in a virtual reality forest environment. *Computers in Human Behavior*, *107*, 106295. https://doi.org/10.1016/j.chb.2020.106295

Matud, M. P., Díaz, A., Bethencourt, J. M., & Ibáñez, I. (2020). Stress and Psychological Distress in Emerging Adulthood: A Gender Analysis. *Journal of Clinical Medicine*, *9*(9). https://doi.org/10.3390/jcm9092859

Megivern, D., Pellerito, S., & Mowbray, C. (2003). Barriers to higher education for individuals with psychiatric disabilities. *Psychiatric Rehabilitation Journal*, *26*(3), 217–231. https://doi.org/10.2975/26.2003.217.231

Meehan, M., Insko, B., Whitton, M., & Brooks Jr, F. P. (2002). Physiological measures of presence in stressful virtual environments. *Acm Transactions on Graphics (tog)*, *21*(3), 645-652. https://doi.org/10.1145/566654.566630

Mehl, M. R., & Pennebaker, J. W. (2003). The sounds of social life: A psychometric analysis of students' daily social environments and natural conversations. *Journal of Personality and Social Psychology*, *84*(4), 857–870. https://doi.org/10.1037/0022-3514.84.4.857

Michielsen, H. J., De Vries, J., & Van Heck, G. L. (2003). Psychometric qualities of a brief self-rated fatigue measure: The Fatigue Assessment Scale. *Journal of Psychosomatic Research*, *54*(4), 345–352. https://doi.org/10.1016/s0022-3999(02)00392-6

Miksza, P., Evans, P., & McPherson, G. E. (2021). Wellness among university-level music students: a study of the predictors of subjective vitality. *Musicae Scientiae*, *25*(2), 143-160. https://doi.org/10.1177/1029864919860554

Morina, N., Ijntema, H., Meyerbröker, K., & Emmelkamp, P. M. (2015). Can virtual reality exposure therapy gains be generalized to real-life? A meta-analysis of studies applying behavioral assessments. *Behaviour Research and Therapy*, *74*, 18–24. https://doi.org/10.1016/j.brat.2015.08.010

Myers, A. M., Malott, O. W., Gray, E., Tudor-Locke, C., Ecclestone, N. A., Cousins, S. O., & Petrella, R. (1999). Measuring accumulated health-related benefits of exercise participation

for older adults: the Vitality Plus Scale. *The Journal of Gerontology. Series A, Biological sciences and medical sciences*, *54*(9), M456–M466. https://doi.org/10.1093/gerona/54.9.m456

Newcomb-Anjo, S. E., Villemaire-Krajden, R., Takefman, K., & Barker, E. T. (2016). The unique associations of academic experiences with depressive symptoms in emerging adulthood. *Emerging Adulthood*. https://doi.org/10.1177/2167696816657233

Newland, P., & Bettencourt, B. A. (2020). Effectiveness of mindfulness-based art therapy for symptoms of anxiety, depression, and fatigue: A systematic review and meta-analysis. *Complementary Therapies in Clinical Practice*, *41*, 101246. https://doi.org/10.1016/j.ctcp.2020.101246

Niemiec, C. P., Ryan, R. M., Patrick, H., Deci, E. L., & Williams, G. C. (2010). The energization of health-behavior change: Examining the associations among autonomous self-regulation, subjective vitality, depressive symptoms, and tobacco abstinence. *The Journal of Positive Psychology*, *5*(2), 122–138. https://doi.org/10.1080/17439760903569162

Ohyama, S., Nishiike, S., Watanabe, H., Matsuoka, K., Akizuki, H., Takeda, N., & Harada, T. (2007). Autonomic responses during motion sickness induced by virtual reality. *Auris Nasus Larynx*, *34*(3), 303-306. https://doi.org/10.1016/j.anl.2007.01.002

Oyeniyi, O. F., Bain, S. F., & Furgerson, K. L. (2016). Stress factors experienced by international students while attending a South Texas university. *Higher Educ J*, 30-38. https://www.researchgate.net/publication/357157500_Stress_factors_experienced_by_international_students_while_attending_a_South_Texas_university

Partonen, T., & Lönnqvist, J. (2000). Bright light improves vitality and alleviates distress in healthy people. *Journal of Affective Disorders*, *57*(1-3), 55–61. https://doi.org/10.1016/s0165-0327(99)00063-4

Pascoe, M. C., Hetrick, S. E., & Parker, A. G. (2020). The impact of stress on students in secondary school and higher education. *International Journal of Adolescence and Youth*, *25*(1), 104–112. https://doi.org/10.1080/02673843.2019.1596823

Pasnak, R. (2018). To pretest or not to pretest. *Biomed Sci &Tech Res, 5*(2). http://dx.doi.org/10.26717/BJSTR.2018.05.001185

Peters, S. A., Bots, M. L., den Ruijter, H. M., Palmer, M. K., Grobbee, D. E., Crouse, J. R., 3rd, O'Leary, D. H., Evans, G. W., Raichlen, J. S., Moons, K. G., Koffijberg, H., & METEOR study group (2012). Multiple imputation of missing repeated outcome measurements did not add to linear mixed-effects models. *Journal of clinical epidemiology*, *65*(6), 686–695. https://doi.org/10.1016/j.jclinepi.2011.11.012

Plante, T. G., Cage, C., Clements, S., & Stover, A. (2006). Psychological benefits of exercise paired with virtual reality: Outdoor exercise energizes whereas indoor virtual exercise relaxes. *International Journal of Stress Management*, *13*(1), 108–117. https://doi.org/10.1037/1072-5245.13.1.108

Pollack, T. M., Duong, H. T., Nhat Vinh, D. T., Phuong, D. T., Thuy, D. H., Nhung, V. T. T., Uyen, N. K., Linh, V. T., Van Truong, N., Le Ai, K. A., Ninh, N. T., Nguyen, A., Canh, H. D., & Cosimi, L. A. (2022). A pretest-posttest design to assess the effectiveness of an intervention to reduce HIV-related stigma and discrimination in healthcare settings in Vietnam. *Journal of the International AIDS Society*, *25 Suppl 1*(Suppl 1), e25932. https://doi.org/10.1002/jia2.25932

Pradhan, G., Mendinca, N. L., & Kar, M. (2014). Evaluation of Examination Stress and Its Effect on Cognitive Function among First Year Medical Students. *Journal of Clinical and Diagnostic Research : JCDR*, *8*(8), BC05. https://doi.org/10.7860/JCDR/2014/9014.4680

Price, M., & Anderson, P. (2007). The role of presence in virtual reality exposure therapy. *Journal of Anxiety Disorders*, *21*(5), 742-751. https://doi.org/10.1016/j.janxdis.2006.11.002

Price, M., Mehta, N., Tone, E. B., & Anderson, P. L. (2011). Does engagement with exposure yield better outcomes? Components of presence as a predictor of treatment response for virtual reality exposure therapy for social phobia. *Journal of Anxiety Disorders*, *25*(6), 763-770. https://doi.org/10.1016/j.janxdis.2011.03.004

Räisänen, M., Postareff, L., & Lindblom-Ylänne, S. (2021). Students' experiences of study-related exhaustion, regulation of learning, peer learning and peer support during university studies. *European Journal of Psychology of Education, 36,* 1135-1157. https://doi.org/10.1007/s10212-020-00512-2

Reese, G., Mehner, M., Nelke, I., Stahlberg, J., & Menzel, C. (2022a). Into the wild … or not: Virtual nature experiences benefit well-being regardless of human-made structures in nature. *Frontiers in Virtual Reality, 3*. https://doi.org/10.3389/frvir.2022.952073

Reese, G., Stahlberg, J., & Menzel, C. (2022b). Digital shinrin-yoku: Do nature experiences in virtual reality reduce stress and increase well-being as strongly as similar experiences in a physical forest? *Virtual Reality*, 1-11. https://doi.org/10.1007/s10055-022-00631-9

Remor E. (2006). Psychometric properties of a European Spanish version of the Perceived Stress Scale (PSS). *The Spanish journal of psychology*, *9*(1), 86–93. https://doi.org/10.1017/s1138741600006004

Rijal, D., Paudel, K., Adhikari, T. B., & Bhurtyal, A. (2023). Stress and coping strategies among higher secondary and undergraduate students during COVID-19 pandemic in Nepal. *PLOS Global Public Health*, *3*(2). https://doi.org/10.1371/journal.pgph.0001533

RIVM (2022). *Monitor Mentale gezondheid en Middelengebruik Studenten hoger onderwijs | Deelrapport I. Mentale gezondheid* (No. 2021–0194). RIVM, Trimbos-instituut en GGD GHOR Nederland. https://doi.org/10.21945/RIVM-2022-0100

Robillard, G., Bouchard, S., Fournier, T., & Renaud, P. (2003). Anxiety and presence during VR immersion: a comparative study of the reactions of phobic and non-phobic participants in therapeutic virtual environments derived from computer games. *Cyberpsychology & Behavior: The Impact of the Internet, Multimedia and Virtual Reality on Behavior and Society*, *6*(5), 467–476. https://doi.org/10.1089/109493103769710497

Robillard, G., Bouchard, S., Renaud, P., & Cournoyer, L. G. (2002). Validation canadiennefrançaise de deux mesures importantes en réalité virtuelle: l'Immersive Tendencies Questionnaire et le Presence Questionnaire. Poster presented at the 25e congrès annuel de la Société Québécoise

pour la Recherche en Psychologie (SQRP), TroisRivières. http://w3.uqo.ca/cyberpsy/index.php/documents-utiles/

Rogers M. L. (2021). Feasibility and acceptability of ecological momentary assessment in a fully online study of community-based adults at high risk for suicide. *Psychological Assessment*, *33*(12), 1215–1225. https://doi.org/10.1037/pas0001054

Rolstad, S., Adler, J., & Rydén, A. (2011). Response burden and questionnaire length: is shorter better? A review and meta-analysis. *Value in Health: The Journal of the International Society for Pharmacoeconomics and Outcomes Research*, *14*(8), 1101–1108. https://doi.org/10.1016/j.jval.2011.06.003

Rose, D. M., Seidler, A., Nübling, M., Latza, U., Brähler, E., Klein, E. M., Wiltink, J., Michal, M., Nickels, S., Wild, P. S., König, J., Claus, M., Letzel, S., & Beutel, M. E. (2017). Associations of fatigue to work-related stress, mental and physical health in an employed community sample. *BMC Psychiatry*, *17*(1), 167. https://doi.org/10.1186/s12888-017-1237-y

Ryan, R. M., Bernstein, J. H., & Warren Brown, K. (2010). Weekends, work, and well-being: Psychological need satisfactions and day of the week effects on mood, vitality, and physical symptoms. *Journal of Social and Clinical Psychology*, *29*(1), 95–122. https://doi.org/10.1521/jscp.2010.29.1.95

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037/0003-066x.55.1.68

Ryan, R. M., & Frederick, C. M. (1997). On energy, personality, and health: subjective vitality as a dynamic reflection of well-being. *Journal of Personality*, *65*(3), 529–565. https://doi.org/10.1111/j.1467-6494.1997.tb00326.x

Ryan, R. M., Weinstein, N., Bernstein, J., Brown, K. W., Mistretta, L., & Gagné, M. (2010). Vitalizing effects of being outdoors and in nature. *Journal of Environmental Psychology*, *30*(2), 159-168. https://doi.org/10.1016/j.jenvp.2009.10.009

Satici, S. A. (2020). Hope and loneliness mediate the association between stress and subjective vitality. *Journal of College Student Development*, *61*(2), 225–239. https://doi.org/10.1353/csd.2020.0019

Seth, A. K., Suzuki, K., & Critchley, H. D. (2012). An interoceptive predictive coding model of conscious presence. *Frontiers in psychology*, *2*, 395. https://doi.org/10.3389/fpsyg.2011.00395

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annual review of clinical psychology*, *4*, 1–32. https://doi.org/10.1146/annurev.clinpsy.3.022806.091415

Shohani, M., Badfar, G., Nasirkandy, M. P., Kaikhavani, S., Rahmati, S., Modmeli, Y., Soleymani, A., & Azami, M. (2018). The effect of yoga on stress, anxiety, and depression in women. *International Journal of Preventive Medicine*, *9*, 21. https://doi.org/10.4103/ijpvm.IJPVM_242_16

Siedlecki S. L. (2020). Quasi-experimental research designs. *Clinical Nurse Specialist CNS*, *34*(5), 198–202. https://doi.org/10.1097/NUR.0000000000000540

Smith, A. P. (2018). Cognitive Fatigue and the Wellbeing and Academic Attainment of University Students. *Journal of Education, Society and Behavioural Science*, *24*(2), 1–12. https://doi.org/10.9734/JESBS/2018/39529

Smolders, K., de Kort, Y., & van den Berg, S. (2013). Daytime light exposure and feelings of vitality: Results of a field study during regular weekdays. *Journal of Environmental Psychology*, *36*, 270-279. https://doi.org/10.1016/j.jenvp.2013.09.004

Stawski, R. S., Sliwinski, M. J., Almeida, D. M., & Smyth, J. M. (2008). Reported exposure and emotional reactivity to daily stressors: the roles of adult age and global perceived stress. *Psychology and aging*, *23*(1), 52–61. https://doi.org/10.1037/0882-7974.23.1.52

Stone, A. A., Kessler, R. C., & Haythomthwatte, J. A. (1991). Measuring daily events and experiences: Decisions for the researcher. *Journal of Personality*, *59*(3), 575-607. https://doi.org/10.1111/j.1467-6494.1991.tb00260.x

Tawfik, D. S., Sinha, A., Bayati, M., Adair, K. C., Shanafelt, T. D., Sexton, J. B., & Profit, J. (2021). Frustration With Technology and its Relation to Emotional Exhaustion Among Health Care Workers: Cross-sectional Observational Study. *Journal of Medical Internet Research*, *23*(7). https://doi.org/10.2196/26817

Trull, T. J., & Ebner-Priemer, U. W. (2009). Using experience sampling methods/ecological momentary assessment (ESM/EMA) in clinical assessment and clinical research: introduction to the special section. *Psychological assessment*, *21*(4), 457–462. https://doi.org/10.1037/a0017653

Tyssen, R., Vaglum, P., Grønvold, N. T., & Ekeberg, Ø. (2001). Suicidal ideation among medical students and young physicians: A nationwide and prospective study of prevalence and predictors. *Journal of Affective Disorders*, *64*(1), 69–79. https://doi.org/10.1016/S0165-0327(00)00205-6

Ugur, E., Kaya, Ç., & Özçelik, B. (2019). Subjective vitality mediates the relationship between respect toward partner and subjective happiness on Teachers. *Universal Journal of Educational Research*, *7*(1), 126-132. https://eric.ed.gov/?id=EJ1201395

Van Berkel, N., Ferreira, D., & Kostakos, V. (2017). The experience sampling method on mobile devices. ACM Computing Surveys (CSUR), 50(6), 1-40. https://doi.org/10.1145/3123988

Verma, P., Kumar, R., Tuteja, J., & Gupta, N. (2021, February). Systematic review of virtual reality & its challenges. *In 2021 Third International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV)* (pp. 434-440). IEEE. https://doi.org/10.1109/ICICV50876.2021.9388631

Wang, J., Li, D., Bai, X., Cui, J., Yang, L., Mu, X., & Yang, R. (2021). The physical and mental health of the medical staff in Wuhan Huoshenshan Hospital during COVID-19 epidemic: A Structural Equation Modeling approach. *European Journal of Integrative Medicine*, *44*, 101323. https://doi.org/10.1016/j.eujim.2021.101323

Weale, V., Love, J., Clays, E., & Oakman, J. (2023). Using EMA and Physiological Data to Explore the Relationship between Day-to-Day Occupational Stress, Musculoskeletal Pain and Mental

Health among University Staff: A Study Protocol. *International journal of environmental research and public health*, *20*(4), 3526. https://doi.org/10.3390/ijerph20043526

Weigelt, O., Siestrup, K., & Prem, R. (2021). Continuity in transition: Combining recovery and day-of-week perspectives to understand changes in employee energy across the 7-day week. *Journal of Organizational Behavior*, *42*(5), 567–586. https://doi.org/10.1002/job.2514

Wensink, M. (2022). *Physical and ental fatigue and their risk factors in people with long-COVID after hospital discharge* (master's thesis). University of Twente, Enschede, the Netherlands.

Witmer, B.G. & Singer. M.J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments*, 7(*3*), 225-240. https://doi.org/10.1162/105474698565686

Wizior, K. (2020). *Exploring the Influence of Social Interactions on Subjective Vitality: A Daily Diary Study* (PhD dissertation). Pace University. https://digitalcommons.pace.edu/dissertations/AAI28001114

Woodyard, C. (2011). Exploring the therapeutic effects of yoga and its ability to increase quality of life. *International Journal of Yoga*, *4*(2), 49-54. https://doi.org/10.4103/0973-6131.85485

Wray, T. B., Merrill, J. E., & Monti, P. M. (2014). Using ecological momentary assessment (EMA) to assess situation-level predictors of alcohol use and alcohol-related consequences. *Alcohol Research: Current Reviews*, *36*(1), 19-27. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4432855/

Zaccaro, A., Piarulli, A., Laurino, M., Garbella, E., Menicucci, D., Neri, B., & Gemignani, A. (2018). How breath-control can change your life: A aystematic review on psycho-physiological correlates of slow breathing. *Frontiers in Human Neuroscience*, *12*, 353. https://doi.org/10.3389/fnhum.2018.00353

Appendix A

Subjective Vitality Scale (SVS)

Start of Block: Subjective Vitality

Q10 In the next block you will be asked questions concerning subjective vitality. Subjective vitality refers to positive feeling of aliveness and energy.

Q11 Please respond to each of the following statements by indicating how you felt during the **past week**:

	1 (Not at all)	2	3	4 (Somewhat true)	5	6	7 (Very true)
I felt alive and vital. (2)	○	○	○	○	○	○	○
I did not feel very energetic (3)	○	○	○	○	○	○	○
Sometimes I felt so alive I just wanted to burst (5)	○	○	○	○	○	○	○
I had energy and spirit (6)	○	○	○	○	○	○	○
I looked forward to each new day (7)	○	○	○	○	○	○	○
I nearly always felt alert and awake (8)	○	○	○	○	○	○	○
I felt energized (9)	○	○	○	○	○	○	○

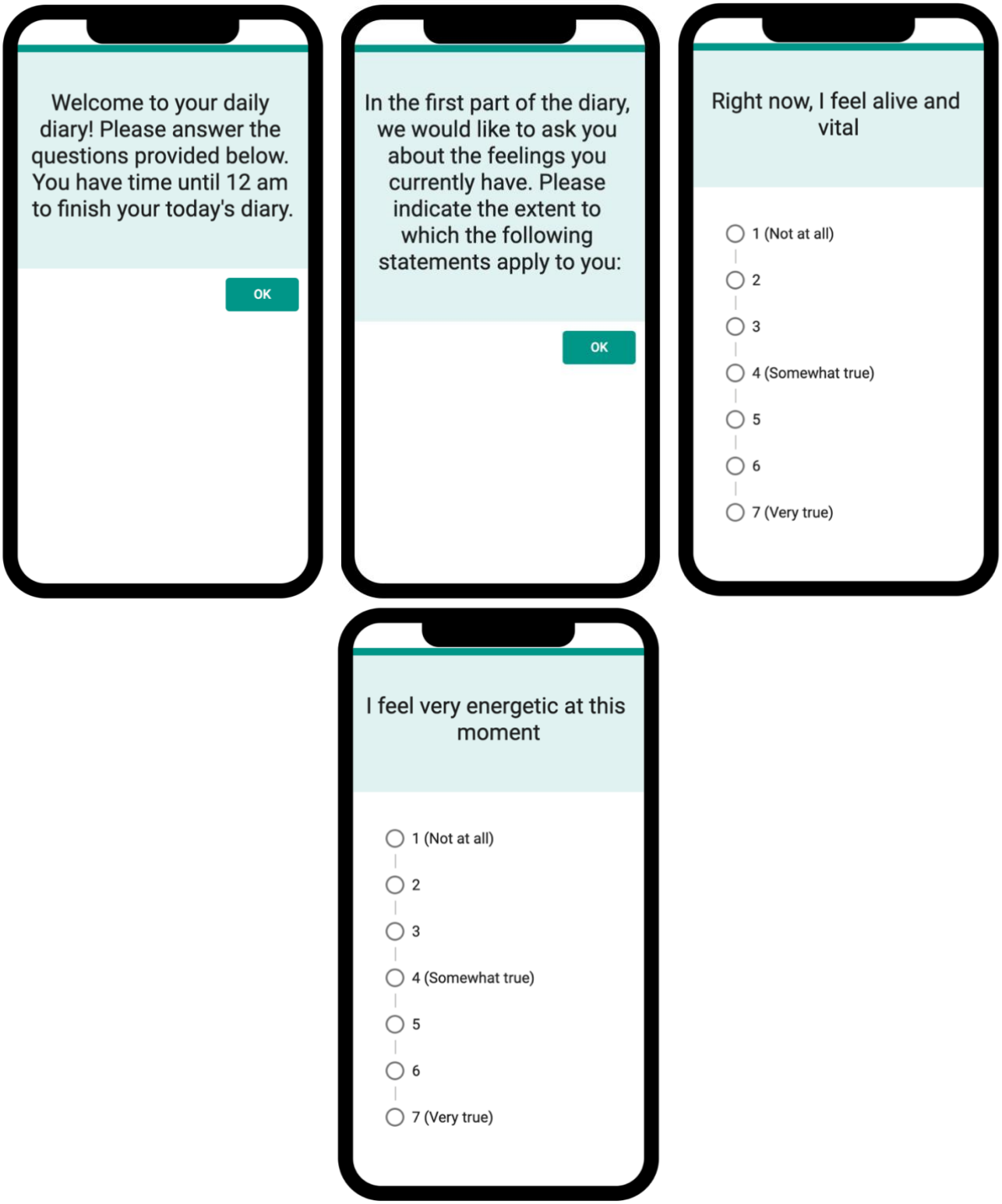
End of Block: Subjective Vitality

Appendix B

Introduction and Subjective Vitality Items in Daily Diary

Figure B

Introduction and Subjective Vitality Items



Appendix C

Perceived Stress Scale (PSS)

Start of Block: Stress

Q12 The questions in this scale ask about your feelings and thoughts during the past week. In each case, you will be asked to indicate how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer fairly quickly. That is, don't try to count up the number of times you felt a particular way; rather indicate the alternative that seems like a reasonable estimate.

Q13 In the next part, you will be respond to questions related to stress.

	Never	Almost never	Sometimes	Fairly often	Very often
In the last week, how often have you been upset because of something that happened unexpectedly? (1)	○	○	○	○	○
In the last week, how often have you felt that you were unable to control the important things in your life? (2)	○	○	○	○	○
In the last week, how often have you felt nervous and stressed? (3)	○	○	○	○	○
In the last week, how often have you felt confident	○	○	○	○	○

about your ability to handle your personal problems? (4)					
In the last week, how often have you felt that things were going your way? (5)	○	○	○	○	○

In the last week, how often have you found that you could not cope with all the things that you had to do? (6)	○	○	○	○	○
In the last week, how often have you been able to control irritations in your life? (7)	○	○	○	○	○
In the last week, how often have you felt that you were on top of things? (8)	○	○	○	○	○
In the last week, how often have you been angered because of things that happened that were outside of your control? (9)	○	○	○	○	○
In the last week, how often have you felt difficulties were piling up so high that you could not overcome them? (10)	○	○	○	○	○

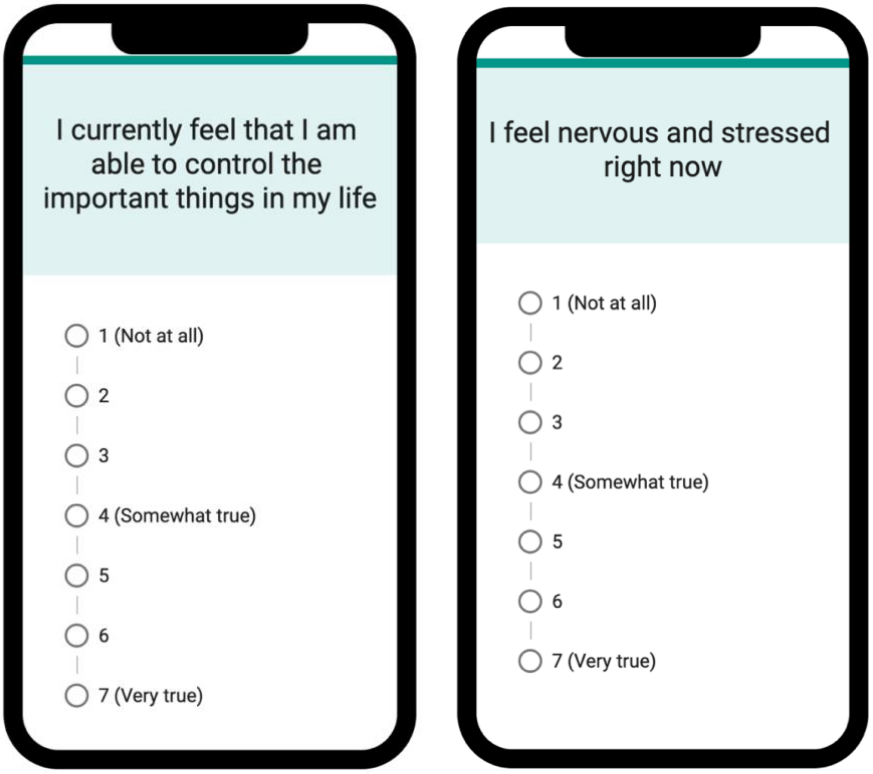
End of Block: Stress

Appendix D

Stress Items in Daily Diary

Figure D

Stress Items



Appendix E

Fatigue Assessment Scale (FAS)

Start of Block: Fatigue

Q14 This is the final part. Here, you will be asked several questions about fatigue (a feeling of constant tiredness or weakness)

Q15 The following ten statements refer to how you felt during **the past week**. Per statement you can choose one out of five answer categories, varying from Never to Always. Please circle the answer to each question that is applicable to you. Please give an answer to each question, even if you do not have any complaints at the moment.

	Never (1)	Sometimes (2)	Regularly (3)	Often (4)	Always (5)
I was bothered by fatigue (1)	○	○	○	○	○
I got tired very quickly (2)	○	○	○	○	○
I did not do much during the day (3)	○	○	○	○	○
I did not have enough energy for everyday life (4)	○	○	○	○	○
Physically, I felt exhausted (5)	○	○	○	○	○
I had problems to start things (6)	○	○	○	○	○
I had problems to think clearly (7)	○	○	○	○	○

I felt no desire to do anything (8)	○	○	○	○	○
Mentally, I felt exhausted (9)	○	○	○	○	○
When I was doing something, I could concentrate quite well (10)	○	○	○	○	○

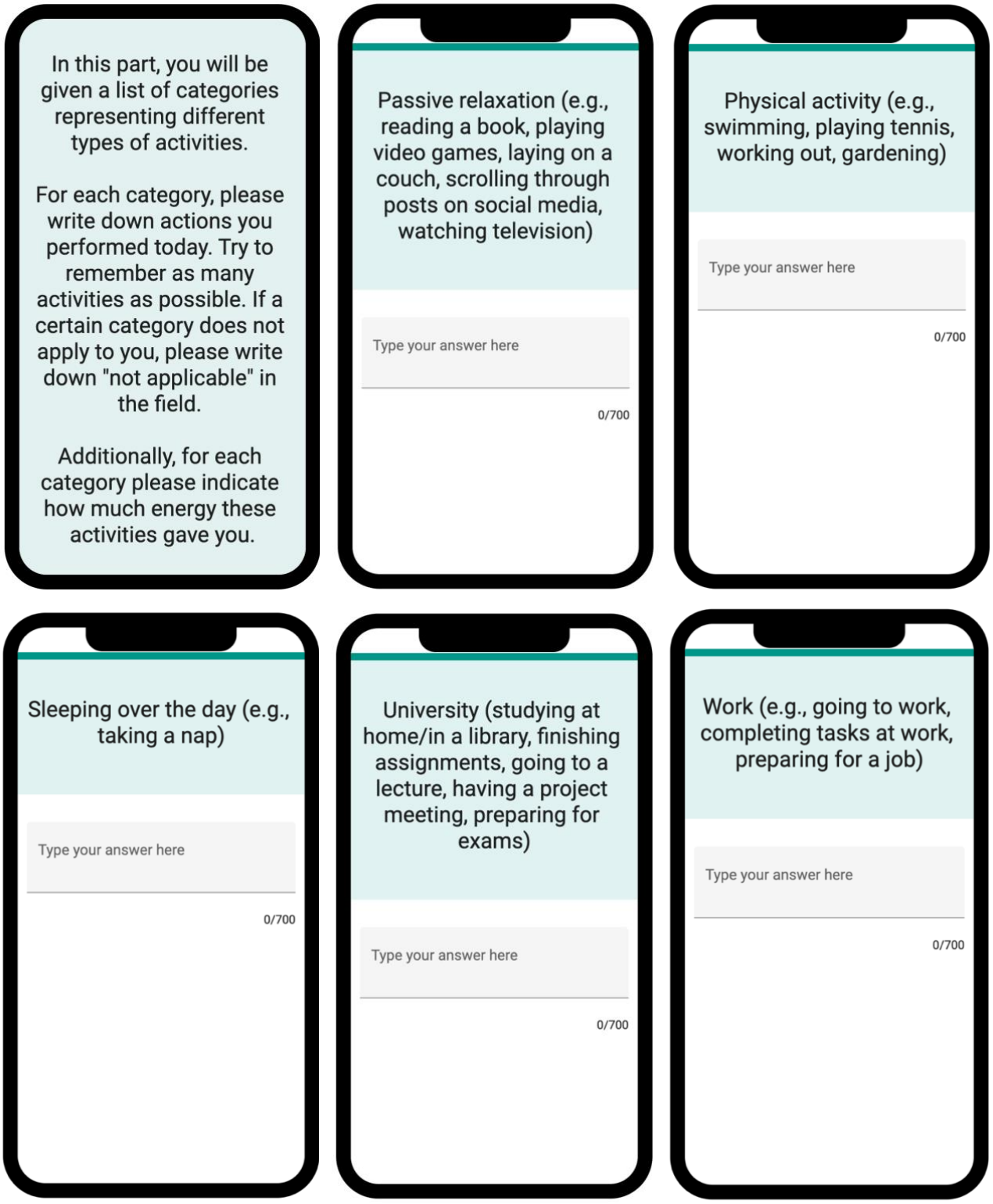
End of Block: Fatigue

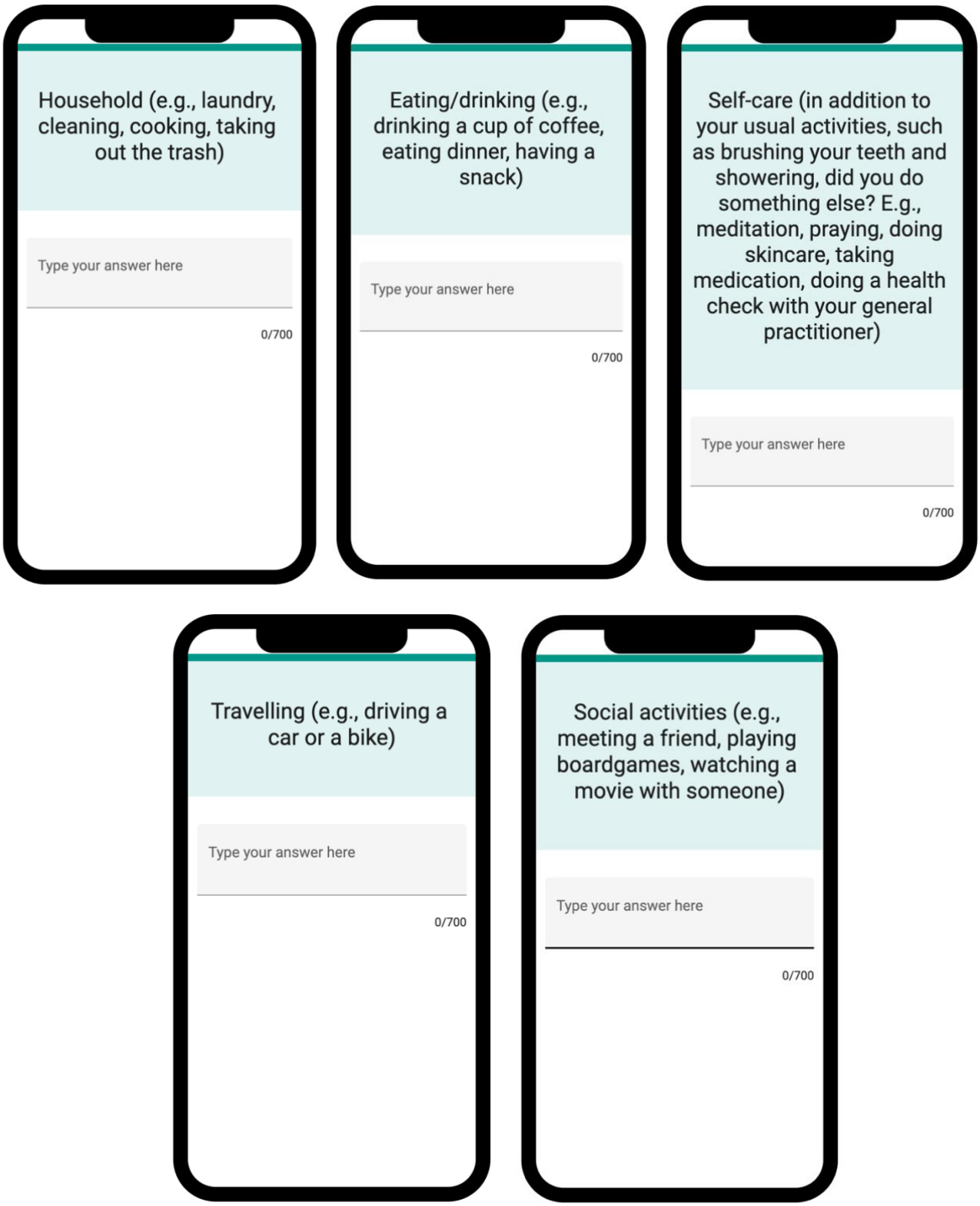
Appendix F

Daily Activities

Figure F

Daily Activities Items



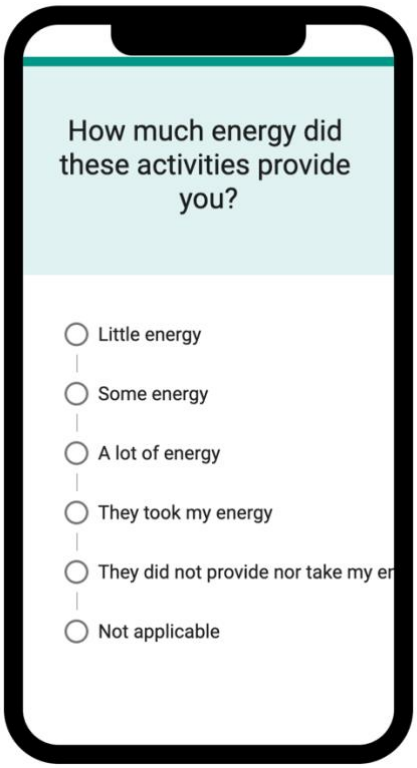

Household (e.g., laundry, cleaning, cooking, taking out the trash)
Type your answer here
0/700
Eating/drinking (e.g., drinking a cup of coffee, eating dinner, having a snack)
Type your answer here
0/700
Self-care (in addition to your usual activities, such as brushing your teeth and showering, did you do something else? E.g., meditation, praying, doing skincare, taking medication, doing a health check with your general practitioner)
Type your answer here
0/700
Travelling (e.g., driving a car or a bike)
Type your answer here
0/700
Social activities (e.g., meeting a friend, playing boardgames, watching a movie with someone)
Type your answer here
0/700

Appendix G

Energy Item in Daily Diary

Figure G

Energy Item



Note. Missing part of the answer category “they did not provide nor take my energy” is an artefact of the rendered image, the text was fully visible in the real application.

Appendix H

Immersive Tendencies Questionnaire (ITQ)

Start of Block: Introduction

Q1 This survey contains questions about your experiences with Virtual Reality "Walk in Nature" experiences.

Q2 Please indicate the number which was assigned to you by the researcher

_____

End of Block: Introduction

Start of Block: Immersive tendencies

Q3 In this part of the survey, you will be asked to provide answers regarding immersive tendencies (subjective sensation of being in the Virtual Reality environment).

Q4 Do you easily become deeply involved in movies or tv dramas?

	Never		Occasionally			Often
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q5 Do you ever become so involved in a television program or book that people have problems getting your attention?

	Never		Occasionally			Often
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q6 How mentally alert do you feel at the present time?

Not alert Moderately Fully alert

1 2 3 4 5 6 7

Answer on a scale from 1 to 7 ()	

Q7 Do you ever become so involved in a movie that you are not aware of things happening around you?

Never Occasionally Often

1 2 3 4 5 6 7

Answer on a scale from 1 to 7 ()	

Q8 How frequently do you find yourself closely identifying with the characters in a story line?

Never Occasionally Often

1 2 3 4 5 6 7

Answer on a scale from 1 to 7 ()	

Q9 Do you ever become so involved in a video game that it is as if you are inside the game rather than moving a joystick and watching the screen?

Never Occasionally Often

1 2 3 4 5 6 7

Answer on a scale from 1 to 7 ()	

Q10 How physically fit do you feel today?

Not fit Moderately fit Extremely fit

1 2 3 4 5 6 7

Answer on a scale from 1 to 7 ()	

Q11 How good are you at blocking out external distractions when you are involved in something?

Not very good Somewhat good Very good

1 2 3 4 5 6 7

Answer on a scale from 1 to 7 ()	

Q12 When watching sports, do you ever become so involved in the game that you react as if you were one of the players?

Never Occasionally Often

1 2 3 4 5 6 7

Answer on a scale from 1 to 7 ()	

Q13 Do you ever become so involved in a daydream that you are not aware of things happening around you?

	Never			Occasionally			Often
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q14 Do you ever have dreams that are so real that you feel disoriented when you awake?

	Never			Occasionally			Often
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q15 When playing sports, do you become so involved in the game that you lose track of time?

	Never			Occasionally			Often
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q16 How well do you concentrate on enjoyable activities?

	Not at all			Moderately well			Very well
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q17 How often do you play arcade or video games? (OFTEN should be taken to mean every day or every two days, on average.)

	Never			Occasionally			Often
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q18 Have you ever gotten excited during a chase or fight scene on TV or in the movies?

	Never			Occasionally			Often
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q19 Have you ever gotten scared by something happening on a TV show or in a movie?

	Never			Occasionally			Often
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q20 Have you ever remained apprehensive or fearful long after watching a scary movie?

	Never			Occasionally			Often
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q21 Do you ever become so involved in doing something that you lose all track of time?

	Never			Occasionally		Often
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

End of Block: Immersive tendencies

Appendix I

Presence Questionnaire (PQ)

Start of Block: Presence

Q22 In this part, you will be asked questions regarding presence in the Virtual Reality environment (i.e. the feeling of being physically and spatially located in an environment).

Q23 How much were you able to control events?

	Not at all		Somewhat			Completely
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q24 How responsive was the environment to actions that you initiated (or performed)?

	Not responsive		Moderately responsive			Completely responsive
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q25 How natural did your interactions with the environment seem?

	Extremely artificial		Borderline			Completely natural
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q26 How much did the visual aspects of the environment involve you?

	Not at all		Somewhat			Completely
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q27 How natural was the mechanism which controlled movement through the environment?

	Extremely artificial		Borderline			Completely natural
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q28 How compelling was your sense of objects moving through space?

	Noy at all		Moderately compelling			Very compelling
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q29 How much did your experiences in the virtual environment seem consistent with your real world experiences?

	Not consistent		Moderately consistent			Very consistent
	1	2	3	4	5	6	7

Answer on a scale from 1 to 7 ()	

Q30 Were you able to anticipate what would happen next in response to the actions that you performed?

Not at all Somewhat Completely

1 2 3 4 5 6 7

Answer on a scale from 1 to 7 ()	

Q31 How completely were you able to actively survey or search the environment using vision?

Not at all Somewhat Completely

1 2 3 4 5 6 7

Answer on a scale from 1 to 7 ()	

Q32 How compelling was your sense of moving around inside the virtual environment?

Not compelling Moderately compelling Very compelling

1 2 3 4 5 6 7

Answer on a scale from 1 to 7 ()	

Q33 How closely were you able to examine objects?

	Not at all		Somewhat			Extensively
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q34 How well could you examine objects from multiple viewpoints?

	Not at all		Somewhat			Extensively
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q35 How involved were you in the virtual environment experience?

	Not involved		Mildly involved			Completely engrossed
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q36 How much delay did you experience between your actions and expected outcomes?

	No delays		Moderate delays			Long delays
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q37 How quickly did you adjust to the virtual environment experience?

	Not at all		Slowly			Less than one minute
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q38 How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

	Not proficient		Reasonably proficient			Very proficient
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q39 How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

	Not at all		Interfered somewhat			Prevented task performance
	1	2	3	4	5	6	7
Answer on a scale from 1 to 7 ()							

Q40 How much did the control devices interfere with the performance of assigned tasks or with other activities?

	Not at all		Interfered somewhat			Interfered greatly

	1 2 3 4 5 6 7
Answer on a scale from 1 to 7 ()	

Q41 How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

	Not at all Somewhat Completely 1 2 3 4 5 6 7
Answer on a scale from 1 to 7 ()	

Q42 How much did the auditory aspects of the environment involve you?

	Not at all Somewhat Completely 1 2 3 4 5 6 7
Answer on a scale from 1 to 7 ()	

Q43 How well could you identify sounds?

	Not at all Somewhat Completely 1 2 3 4 5 6 7
Answer on a scale from 1 to 7 ()	

Q44 How well could you localize sounds?

	Not at all 1	2	Somewhat 3	4	5	6	Completely 7
Answer on a scale from 1 to 7 ()							

Q45 How well could you actively survey or search the virtual environment using touch?

	Not at all 1	2	Somewhat 3	4	5	6	Completely 7
Answer on a scale from 1 to 7 ()							

Q46 How well could you move or manipulate objects in the virtual environment?

	Not at all 1	2	Somewhat 3	4	5	6	Extensively 7
Answer on a scale from 1 to 7 ()							

End of Block: Presence

Appendix J

System Usability Scale

Start of Block: System Usability

Q47 In the final part, you will answer questions about system usability (the quality of your experience in the Virtual Reality environment).

Q48 System usability

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
I think that I would like to use this system frequently (1)	○	○	○	○	○
I found the system unnecessarily complex (2)	○	○	○	○	○
I thought the system was easy to use (3)	○	○	○	○	○
I think that I would need the support of a technical person to be able to use this system (4)	○	○	○	○	○
I found the various functions in this system were well integrated (5)	○	○	○	○	○

I thought there was too much inconsistency in this system (6)	○	○	○	○	○
I would imagine that most people would learn to use this system very quickly (7)	○	○	○	○	○
I found the system very cumbersome to use (8)	○	○	○	○	○
I felt very confident using the system (9)	○	○	○	○	○
I needed to learn a lot of things before I could get going with this system (10)	○	○	○	○	○

End of Block: System Usability

Appendix K

Screenshots from the “Walk in Nature”

Figure K1

VR-based forest environment

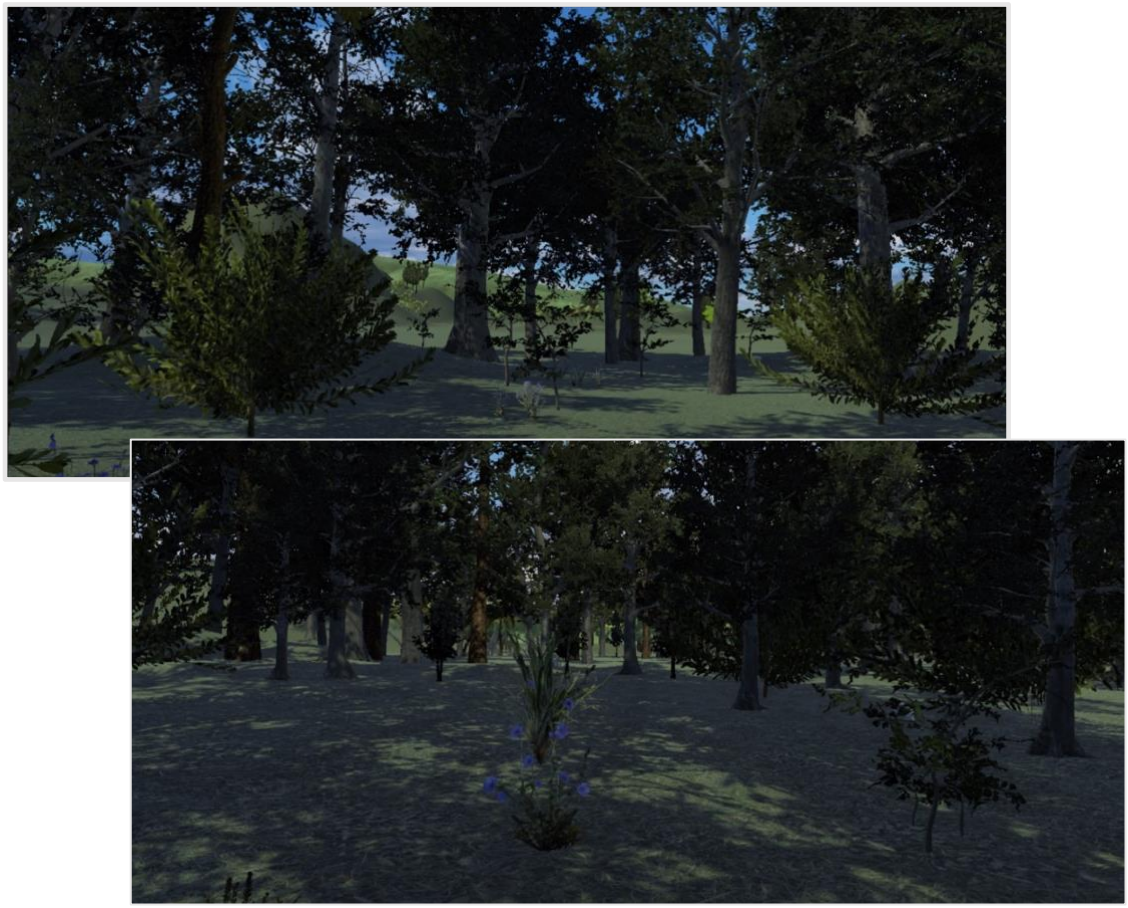


Figure K2

The "breathing tree" exercise

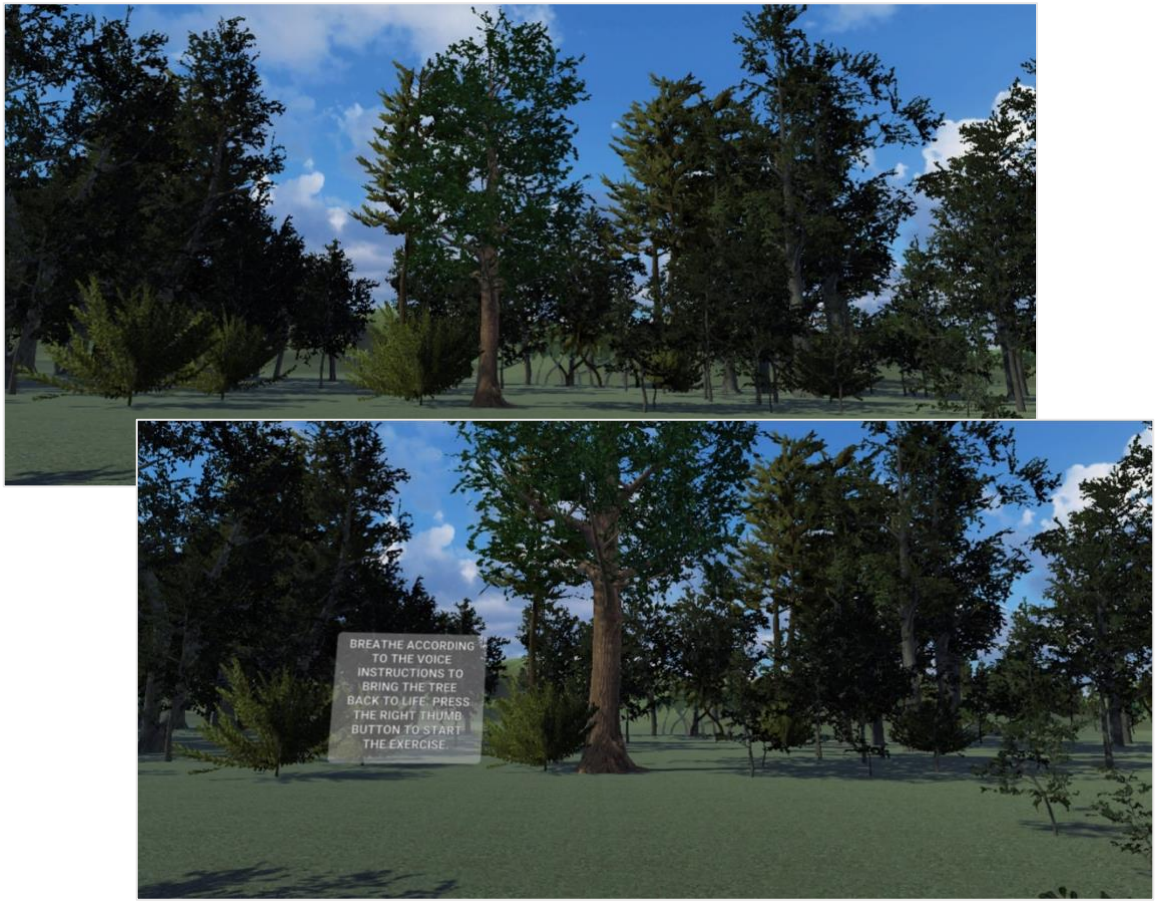
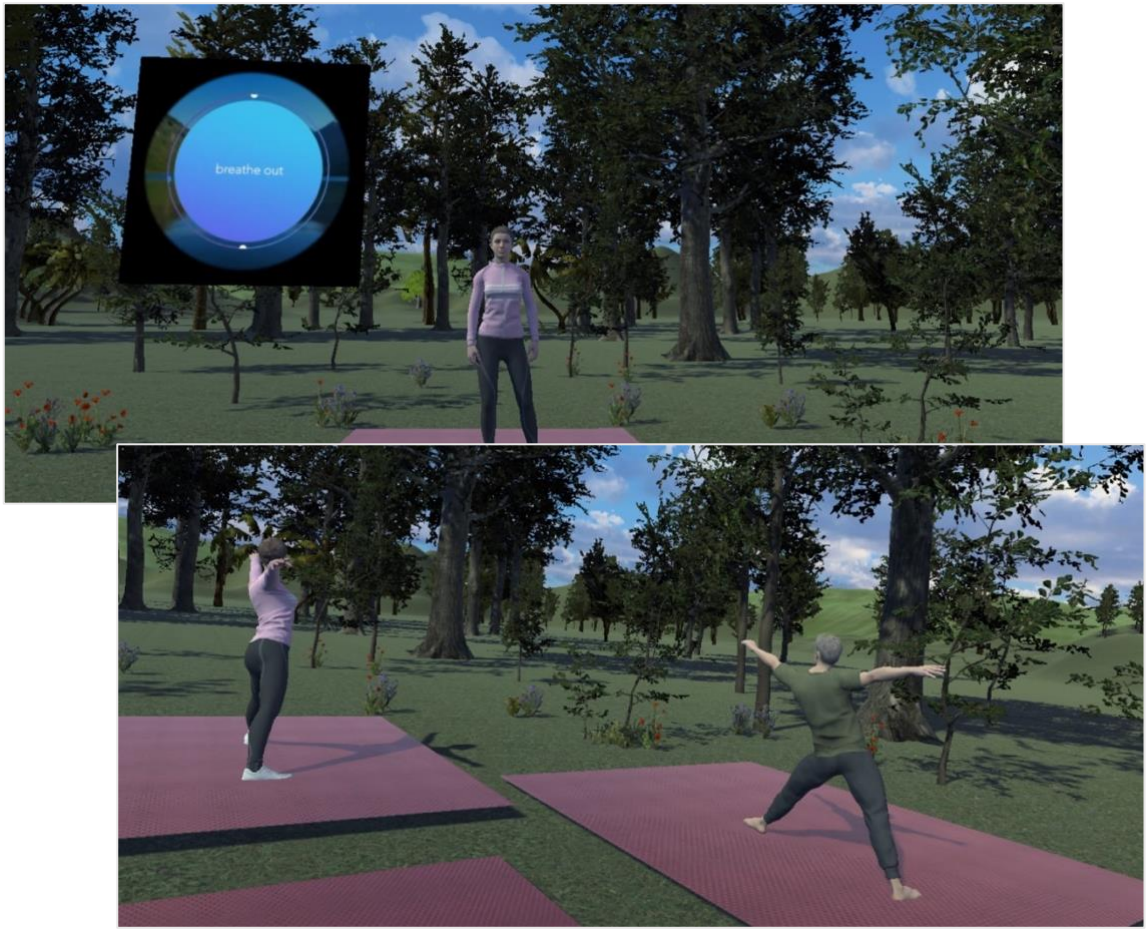


Figure K3

The "butterfly task"

Figure K4

The "social yoga" task



Appendix L

Introduction to the Survey and Informed Consent

Start of Block: Informed consent

Introduction **Information sheet for participating in a survey**

You are being invited to participate in a research study titled What Happens in Daily Life? Using the "Walk in Nature" Intervention for Improving Subjective Vitality, Energy, and Stress in Students. This study is being conducted by XX [name and surname of the researcher], the Psychology Master student from the Faculty of Behavioural, Management and Social Sciences at the University of Twente. The purpose of this research study is to investigate the changes in the daily lives of students in subjective vitality [positive feeling of aliveness and energy (Ryan & Frederick, 1997), stress, and energy after participation in the "Walk in Nature" intervention.

During this research, you will be filling in online questionnaires about your feelings and experiences via Qualtrics and the TIIM application, which you will have to install on your phone. You will have to complete three questionnaires via Qualtrics in total: one a week before, one directly after, and one a week later after the intervention. Each will take you approximately 10 minutes. Additionally, you will be filling in daily diary in TIIM during the period of 2 weeks, which will take you 3-5 minutes a day. Furthermore, you will experience the Virtual Reality 'Walk in Nature" intervention once during this two-week period. It will take approximately 30 minutes to complete.

After participating in the Virtual Reality intervention, you may feel less stressed and more energised. However, there is a possibility that motion sickness could occur. If that happens, the research will be stopped immediately. Additionally, you will have a chance to win 10 euros after completing the intervention if you decide to participate in a lottery among other participants.

Your participation is entirely voluntary, and you can withdraw at any time. If you prefer to stop, you can let the researcher know by sending an email (see contact details below). Additionally,

you can contact the researcher via email within 10 days after participation if you wish to withdraw the data that has been collected.

We believe there are no known risks with this research study; however, as with any online-related activity, the risk of a breach is always possible. Your personal data, such as name and email address, will be collected to assign you to a study in the TIIM mobile phone application and arrange an appointment for experiencing the Virtual Reality intervention. Your personal information will only be accessible by the researcher and will not be shared with anyone, and your answers on the questionnaires will be confidential and anonymised. To ensure anonymity, your name and email address will be replaced by a random personal number. Information about your gender, age, nationality, and level of current education will be collected as well. These data and other data collected via the questionnaires will be stored for a minimum of 10 years to meet the requirement of accountability for scientific research in secure storage facilitated by the University of Twente. Your data will be used for the Master thesis of the researcher and possibly other academic publications.

Study contact details for further information:

XX [Name, surname, and email address of the researcher]

Contact Information for Questions about Your Rights as a Research Participant: If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact *the Secretary of the Ethics Committee/domain Humanities & Social Sciences of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-bms@utwente.nl*.

Informed consent

I have read and understood the information presented above. I give my consent to voluntarily participate in the study and allow my personal data to be processed (namely, my email address and name).

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If I have read and understood the information presented above. I give my consent to voluntarily part... = No

End of Block: Informed consent

Appendix M

Screening and Background Questionnaires

Q2 Do you have any limitations in hearing, sight (particularly, sensitivities to rapidly changing light) or body movement which may affect your interaction with Virtual Reality? If yes, please specify.

- ○ No (1)
- ○ Yes (2) _____

Skip To: End of Survey If Do you have any limitations in hearing, sight (particularly, sensitivities to rapidly changing li... = Yes

Q3 Do you have epilepsy or history of motion sickness, active nausea, or vomiting when using Virtual Reality?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If Do you have epilepsy or history of motion sickness, active nausea, or vomiting when using Virtual... = Yes

Q4 Do you have lepidopterophobia (fear of butterflies)?

- ○ Yes (1)
- ○ No (2)

Skip To: End of Survey If Do you have lepidopterophobia (fear of butterflies)? = Yes

End of Block: Screening Questionnaire

Start of Block: Background Questionnaire

Q5 Please provide your email address (this information will be used to contact you)

_____

Q6 Please indicate your gender

- Male (1)
- Female (2)
- Non-binary / third gender (3)
- Prefer not to say (4)

Q7 Please indicate your age in numbers

_____

Q8 Please indicate your nationality

▼ Afghan (1) ... Zimbabwean (225)

Q9 Which degree are you currently pursuing?

- University of applied sciences (2)
- University Bachelor (3)
- University Master (5)
- PhD (6)

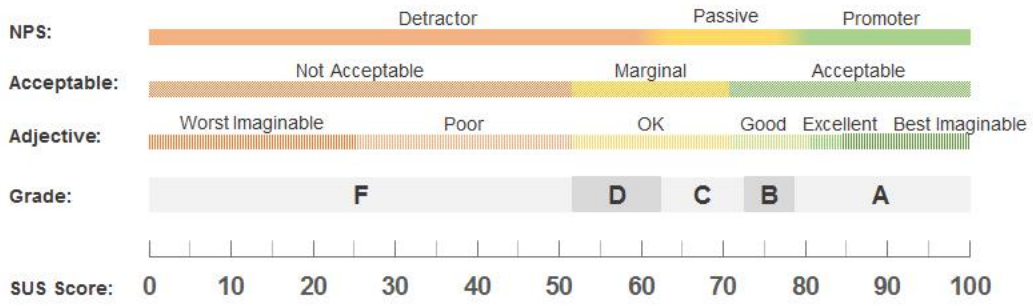
End of Block: Background Questionnaire

Appendix N

The proprietary scale for SUS scores

Figure N

NPS categories, acceptability, adjectives, and grades associated with raw SUS scores



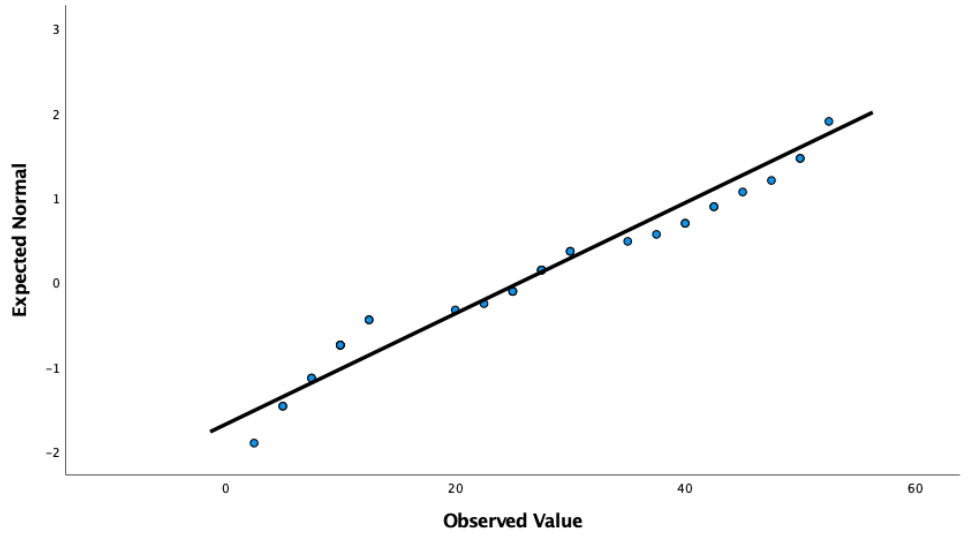
Note. Developed by Bangor, A., Kortum, P., & Miller, J. (2009). Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of usability studies*, *4*(3), 114-123. https://uxpajournal.org/determining-what-individual-sus-scores-mean-adding-an-adjective-rating-scale/

Appendix O

Distribution of the SUS Scores

Figure O

Q-Q plot of the SUS scores

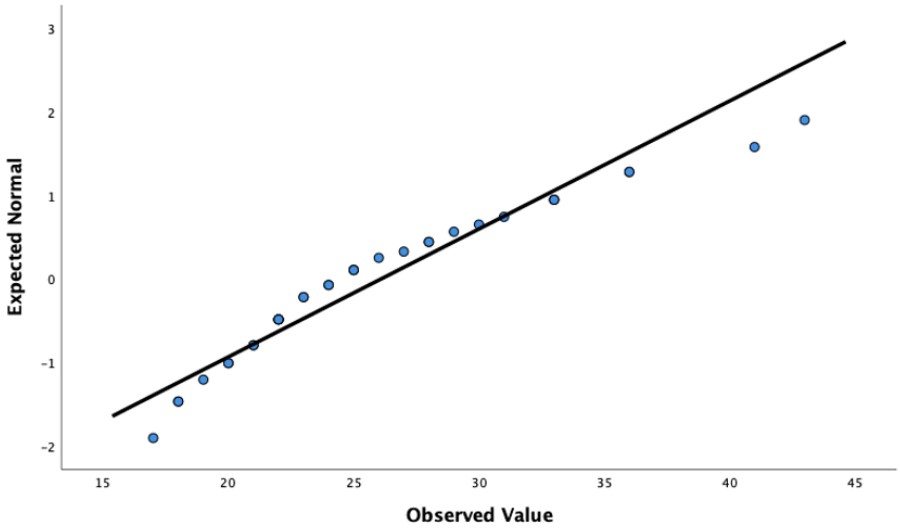


Appendix P

Distribution of the Posttest FAS Scores

Figure P

Q-Q plot of the posttest FAS scores



Appendix Q

Distribution of Residuals for Stress, Vitality, and Energy

Figure Q1

Q-Q Plot of the Residuals for the Variable Stress

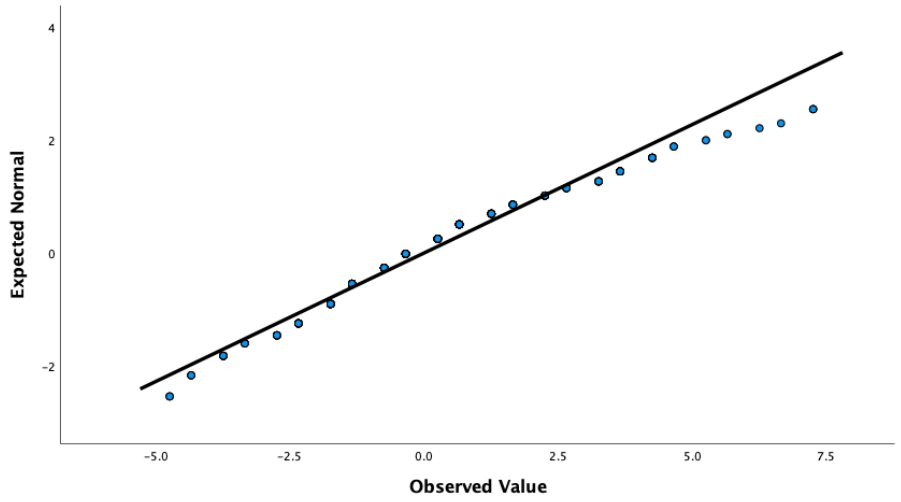


Figure Q2

Q-Q Plot of the Residuals for the Variable Subjective Vitality

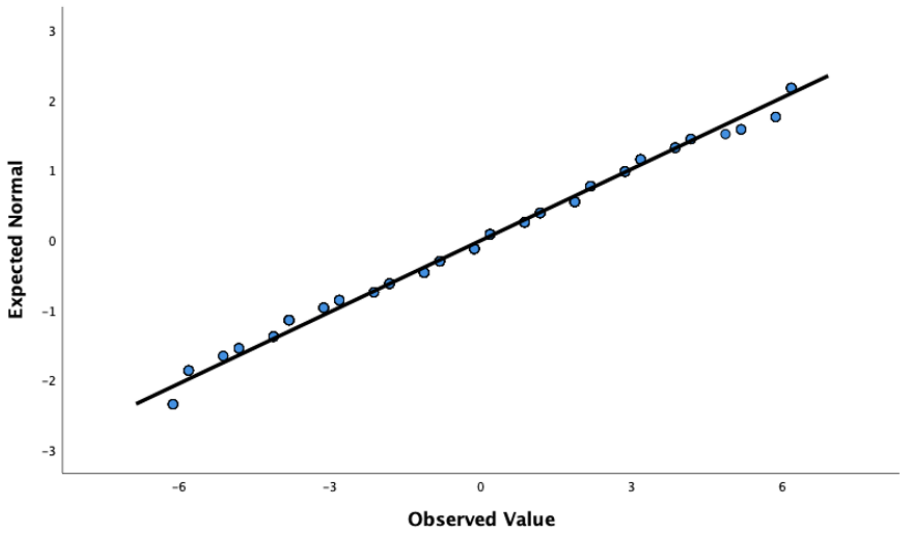
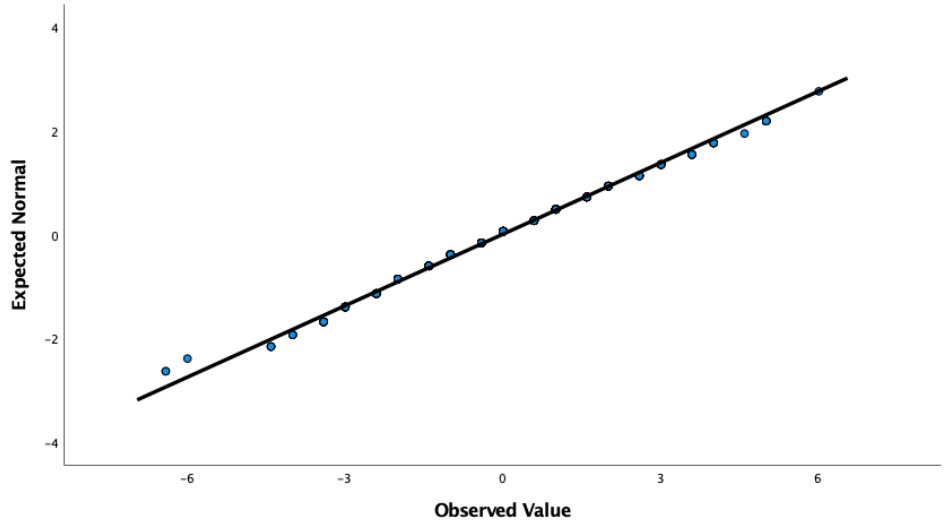


Figure Q3

Q-Q Plot of the Residuals for the Variable Energy



Appendix R

Daily Activities

Table R

Categories of daily activities with examples

Types	Examples
Passive relaxation	Scrolling through social media, Watching TV/Netflix, smoking weed/vape/shisha, laying on a couch/in bed listening to music, playing video games, drawing, reading, meditating, taking a nap, texting, talking to friends, going to a café.
Physical activity	Running, jogging, walking (with a dog/horse), horse riding, dancing, gardening, playing tennis/football/lacrosse/volleyball, working out at a gym/at home, working.
Sleeping over the day	Napping (planned or unplanned), laying down.
University	Attending lectures/workshops/tutorials/exams/project meetings, doing assignments, coding, working on a project/thesis, writing reports/thesis, studying at a library/at home, extracurricular activities, having a language class, presenting projects.
Work	Writing/checking emails, working on a portfolio/CV, having online meeting, attending a job exam, doing calls, doing work tasks.
Household	Vacuum cleaning, doing dishes, cleaning, cooking/baking, doing groceries, mopping floor, doing laundry, fixing/repairing furniture, sorting documents/papers out, watering plants, feeding pets.
Eating and drinking	Having one/two/three meals or having breakfast/lunch/dinner, snacking (sweets, fruits), drinking coffee/alcohol/chocolate milk/energy drink/soft drunks etc., eating nothing, eating fast food, pasta, meat etc.
Self-care	Doing skincare, having a haircut/styling one’s hair, taking medicine/vitamins, vgoing to a hospital, doing manicure, doing breathing exercises/meditating, attending a therapy session, shaving, working out, playing piano, going for a car ride.
Travelling	Riding a bike/scooter, taking a bus/train/plane somewhere (university, work, training session), driving a car, having a driving lesson, walking, picking up someone

Types	Examples
Social activities	Being with family/boyfriend, watching a movie/tv with someone, walking a dog with someone, talking to roommates, calling parents, meeting friends/fellow students/project group/family/partner/neighbours, chatting with friends, joking with friends, playing video games with someone, going somewhere with friends, doing sports with someone, shopping with someone