Tailor-made Breathing: Mixed-Methods Study on Tailoring a Virtual Reality Breathing Exercise for Versatile Applications

Eleanor Azra Dirlik

Faculty of Behavioural, Management and Social Sciences, University of Twente

Master Health Psychology and Technology

25 EC Thesis

First Supervisor: Dr. Christina Bode

Second Supervisor: Prof. Dr. Matthijs L. Noordzij

07 July 2025

Abstract

The current study investigated how system-controlled tailoring should be combined with virtual reality (VR) breathing interventions and its impact on subjective vitality and motivation as this is an understudied topic. It was hypothesised that the experimental (tailored) group would experience higher subjective vitality and motivation. Perception of tailoring was explored with a focus on personal relevance, motivators, and barriers. A convergent parallel mixed-methods experimental design with permuted block randomisation was conducted. Overall, a pretest-posttest of subjective vitality and motivation, and an inductive semi-structured interview was employed with 38 participants, 18 in the experimental group (M_{age}=22.1, SD_{age}=2.6) and 20 in the control group (M_{age}=24.6, SD_{age}=2.4). Data analysis included an independent samples t-test, 2x2 RM-ANOVA, a linear mixed model, and thematic analysis. The results revealed no significant quantitative difference in subjective vitality and motivation within or between groups. However, almost double the number of participants in the control group mentioned a desire for a form of adaptation to increase personal relevance and motivation. None of the experimental group was allocated to level 1, and some reported a discrepancy between their skill level and the breathing exercise. The present study contributed to development and knowledge in VR breathing interventions by proposing a system-controlled method of tailoring as a standardised method is missing from current literature. The results revealed potential to explore the accuracy of the screening tool, and consider the interoceptive awareness, preferences, and gender of participants, which were not considered currently. Adjustment of such factors and the virtual environment could improve effectiveness.

Keywords: system-controlled tailoring, user-controlled tailoring, subjective vitality, motivation, virtual reality intervention, structured breathing exercises, mixed-method

Virtual Reality Interventions with Breathing Exercises 5
Tailoring within VR Breathing Interventions 6
Mechanisms to Increase Motivation by Tailoring 7
Past Research 7
Current Study 8
Research Questions 8
Methods 9
Study Design 9
Experimental Group 10
Control Group 11
Participants 11
Materials 13
Tailoring Walk in Nature 13
Possible Adverse Effects. 14
Breathing Questionnaire 15
Breathing Tree Development. 16
Subjective Vitality Scale 16
Motivation Questions 17
Interview Questions 17
Statistical Methods 18
Quantitative Analysis 18
Qualitative Analysis 18
Mixed-Methods Analysis 18
Results 18
Impact of Tailoring on Subjective Vitality 20
Impact of Tailoring on Motivation 23
Customisation of Guidance Elements 24
Customisation of Environment 24
VR as a Hindrance and Facilitator 25

Interactive Visual Reinforcement 25
Conclusion 25
Impact of Tailoring on User Experience 26
Difficulty Level 26
Adaptation 27
Conclusion 28
Discussion 28
Breathing Exercise Screening and Difficulty 28
Role of the User's Input in Tailoring 29
Preference for User-Controlled Tailoring 30
Strengths 30
Implementation of Theory in Tailoring Development 30
Mixed-Methods Study Design 31
Comparability and Tailoring Framework 31
Limitations 32
Study Design, Measurements and Analysis 32
Sample Demographic 32
Future Recommendations 32
Conclusion 33
Appendix A 41
Appendix B 43
Appendix C 45
Appendix D 48
Appendix E 51
Appendix F 52
Appendix G 53
Appendix H 54
Appendix I 55

Tailor-made Breathing: Mixed-Methods Study on Tailoring a Virtual Reality Breathing Exercise for Versatile Applications

E-Health interventions that target a wide range of symptoms with a blanket solution are susceptible to high attrition rates and decreased engagement, resulting in reduced long-term effectiveness (Klooster et al., 2024). This suggests that a user-tailored approach is needed. Tailoring within virtual reality (VR) can offer such an approach, as it demonstrates increased engagement and is preferred by users compared to non-tailored interventions (Pardini et al., 2022). A scoping review found that tailored VR breathing exercises exhibit positive effects on mental health by decreasing anxiety and increasing relaxation, and on physical health by balancing the autonomic nervous system (Pancini et al., 2025). Within recent years, breathing exercises have been combined with VR to increase engagement; however, how such exercises are incorporated into virtual reality environments (VREs) has not been formally summarised (Pancini et al., 2025; Patibanda et al., 2017). In addition, many tailored VR breathing exercises do not explicitly describe how the intervention was tailored (Pardini et al., 2024). Therefore, the aim of the current study is to determine the effectiveness of tailoring a VR breathing intervention on subjective vitality, motivation, and the user's perception of such tailoring.

Virtual Reality Interventions with Breathing Exercises

Virtual reality offers engaging health interventions that augment the effectiveness of breathing exercises and encourage transference of breathing skills to other contexts (Pancini et al., 2025). Structured breathing exercises can involve various forms, such as slow-paced breathing or alternate nostril breathing (Pancini et al., 2025). Structured breathing exercises within VR increase activation of the parasympathetic nervous system, decrease pain processing (Cortez-Vázquez et al., 2024) and anxiety whilst stimulating relaxation (Pancini et al., 2025). The benefits of VR breathing exercises are linked to subjective vitality, which alludes to the "self-conscious experience of energy and aliveness" both mentally and physically and measures the "positive affective component of subjective well-being" (Buchner et al., 2022; Delgado-Lobete et al., 2020, p. 2; Castillo et al., 2017). This effect might be seen mostly in combination with other exercises, demonstrated by small pilot studies utilising the Walk in Nature intervention (discussed below) (Bareišytė, 2021; Korporaal, 2023). Such effects were seen in combination with physical exercises, lacking clarity on the singular effect of VR breathing exercises on

subjective vitality. Effects of mind-body techniques on subjective vitality are mixed: autogenic training has shown promising effects (Ortigosa-Márquez et al., 2015), whereas the Wim Hof method has not (Ketelhut et al., 2023). Furthermore, a meta-analysis determined that VR breathing interventions are no more effective than non-VR breathing interventions in impacting mental health outcomes (Cortez-Vázquez et al., 2024). Thus, research focusing on tailoring for various contexts, settings, and populations to improve implementation and application is needed.

Tailoring within VR Breathing Interventions

Tailored VREs may prove more effective than other technological interventions, demonstrating a larger decrease in anxiety and tension than guided imagery (Pardini et al., 2024). Tailoring for the current study is defined as a form of adapting the content or system itself to individuals or specific user groups through alterations deemed relevant to the user(s) (Klooster et al., 2024; McHugh et al., 2022). This provides the opportunity to modify VREs, with many focusing on user-controlled inputs, such as the user selecting the music or avatars (Hutmacher & Appel, 2023; Pardini et al., 2022; Pardini et al., 2023). Tailoring has demonstrated a small to moderate effect size ($OR = 1.79$) for altering outcomes of health professionals (Baker et al., 2015). Crucially, tailoring lacks a standardised definition which outlines its concept and working mechanism, impacting comprehension and implementation within health interventions (McHugh et al., 2022; Sbitan et al., 2025). Methodology detailing utilisation of tailoring within research is mostly absent, creating difficulty in replication and analysis of its effects and mechanisms (McHugh et al., 2022). For a review of the terms related to tailoring, see Appendix A.

Based on a scoping review, most VR breathing interventions are focused on user-controlled tailoring, resulting in the mechanisms of system-controlled interventions being understudied (Pancini et al., 2025). System-controlled tailoring utilises if-then algorithms, where *if* a certain answer is selected (e.g. “yes”), *then* the user is partitioned into a predetermined homogenous category deemed relevant to them (e.g. “nature environment”) (Klooster et al., 2024; Hutmacher & Appel, 2022; McHugh et al., 2022). Orji et al. (2017) report that system-controlled apparatus improves “usefulness, ease of use, interactivity, and relevance” whereas user-controlled systems “increase self-efficacy, trust, [and] feeling of control” (p. 418). Within the health field, system-controlled tailoring is favoured by users due to the belief that user-controlled systems are time-consuming and troublesome to navigate, especially if the user is

insecure in making choices affecting health behaviours. Moreover, user-controlled systems have the potential to distract users from the purpose of the intervention (Orji et al., 2017). Most studies focus on the effect of tailoring on the user experience rather than the process of tailoring on the intervention itself (Pardini et al., 2022; Pardini et al., 2023; Patibanda et al., 2017). Therefore, a knowledge gap in how breathing exercises in VR should be combined with system-controlled tailoring (if-then formats) remains. Investigating this knowledge gap is critical if tailoring is to be adopted in healthcare (Klooster et al., 2024; Sbitan et al., 2025).

Mechanisms to Increase Motivation by Tailoring

The effects of tailoring within VR can be expounded via the Elaboration Likelihood Model (ELM) of Petty and Cacioppo (1986). Namely, tailoring aims to promote behaviour change by improving engagement through personally significant cues and information (Bol et al., 2020; Klooster et al., 2024). For example, there is a higher probability of textual information being read when deemed personally relevant by the user (Bol et al., 2020). According to the ELM, personal relevance results in detailed comprehension of information, improved recall, and increased intentions to change health behaviour (Bol et al., 2020). Hutmacher and Appel (2023) propose another model based on the Self-Determination Theory (SDT) of Ryan and Deci (2000). As in SDT, motivation to initiate, maintain, or change behaviour is influenced by feelings of autonomy, competence, and relatedness. Satisfaction of all three is likely to be realised through autonomously motivated behaviour (self-managing one's own behaviour) rather than controlled behaviour (adapting behaviour based on reward expectations). Fulfilling all three needs through autonomously motivated behaviour results in well-being. Tailoring can increase autonomy and competence through eliminating inapt options whilst providing personally relevant and engaging options (Hutmacher & Appel, 2023). Therefore, it is pertinent to determine whether system-controlled tailoring corroborates this theory.

Past Research

Pilot studies have investigated the effectiveness of a VR intervention involving a breathing tree, a butterfly task, and social yoga exercise. The intervention that was investigated, Walk in Nature (WiN), offers promise for a cost-effective and accessible intervention for treating various mental and/or physical complaints (Bareišytė, 2021). However, different effects of WiN have been revealed, as Bareišytė (2021) and Korporaal (2023) found that the intervention

increases subjective vitality, whilst Minina (2023) discovered no difference between pre- and post-intervention. Furthermore, it is pertinent to investigate whether the effects can be replicated on a heterogenous sample as it has mainly been explored on university students (Bareišytė, 2021; Korporaal, 2023) or axial spondylarthritis patients (Franke, 2024; Weenink, 2024). Participants have advocated for adaptation of the exercises to the disease activity and history of the user (Franke, 2024; Weenink, 2024). Therefore, it is relevant to determine whether adding system-controlled tailoring improves motivation to engage with the intervention.

Current Study

The present study aimed to clarify the process and determine the impact of system-controlled tailoring of a structured breathing exercise within WiN on subjective vitality and motivation to continue use of the intervention. These were relevant measures as subjective vitality measures general well-being (Buchner et al., 2022) and motivation determines future health behaviour (Hutmacher & Appel, 2023). Due to development of tailoring WiN based on self-reported experience and skill level, inquiring into user perception of tailoring was vital as well. The outcome of tailoring was determined via quantitative measures of subjective vitality and motivation. The process of tailoring was determined through qualitative data gathered from semi-structured interviews. With both aims of equal importance, a convergent parallel mixed-methods study was chosen. Furthermore, the current study aimed to recruit a heterogenous sample as previous research failed to do so despite the target being at-home use by a diverse population. Although the entire experience of WiN is expected to increase subjective vitality, Korporaal (2023) discovered no difference in effectiveness for students in the VRE without exercises for five minutes compared to students completing all exercises. Due to this and the timeframe of the present study, only the breathing exercise of WiN was investigated.

Research Questions

Given the knowledge gap, the current study had two aims of an explorative nature. The first aim was to determine the effectiveness of system-controlled tailoring (with if-then scenarios) on subjective vitality and motivation. The first research question was as follows: (1) To what extent does tailoring with a system-controlled method focused on skill level and prior experience with breathing exercises impact subjective vitality and motivation to continue use of the VR intervention? It was hypothesised that the tailored group would demonstrate significantly higher

quantitative scores on subjective vitality and motivation compared to the control group. The second aim was to determine the user's perception of tailoring, explored through the second research question: (2) How does the user perceive tailoring within a VR breathing intervention as compared to the non-tailored version, and does this impact motivation? This was investigated with a focus on whether the user would prefer other methods of tailoring, whether the experimental group perceived that the exercise was more personally relevant to them, and the motivators and barriers determined by each group through qualitative data collection.

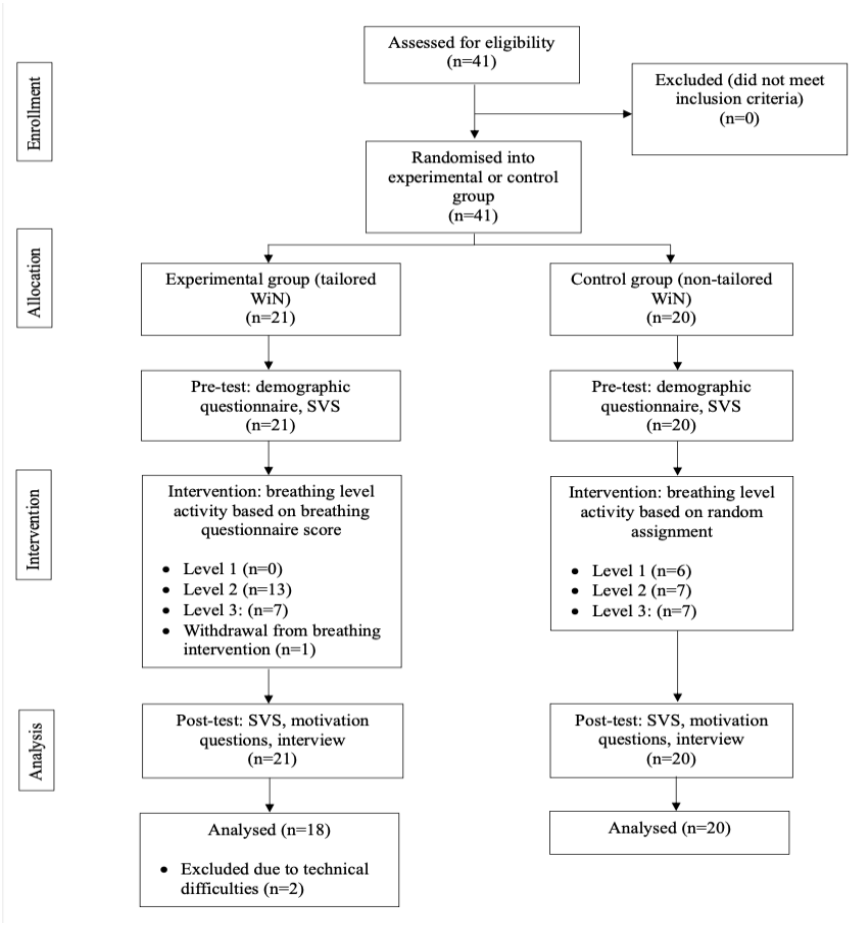
Methods

Study Design

A convergent parallel mixed-methods experimental design with permuted block randomisation was conducted. A mixed-methods trial design was chosen due to its significance in providing a holistic perspective and deeper understanding of the studied topic in health research (Wasti et al., 2022). An inductive, semi-structured interview was chosen, as it suited the exploratory approach. Participants were randomly allocated to either the experimental or control group, with an allocation ratio of 1:1 in blocks of four to avoid predictability by the researcher. After determining the possible blocks (such as experimental, experimental, control, control), the blocks were randomised via R 4.5.0 (R Core Team, 2025) prior to the study to avoid bias, seen in Appendix B. Pre-intervention data collection for both groups consisted of subjective vitality, whereas post-intervention data collection included subjective vitality, motivation, and qualitative data. Participant recruitment took place between 29 April 2025 and 20 May 2025, whilst data collection occurred from 21 May 2025 to 28 May 2025. The study design can be seen in Figure 1.

Figure 1

Visual flowchart of study design



Ethical approval was obtained from the Humanities & Social Sciences Ethics Committee of the University of Twente (UT), registered under project number 250627. It was possible for participants to experience motion sickness or nausea from VR, or dizziness from breathing exercises; however, no further possible harm was highlighted.

Experimental Group

The tailoring variable involved the breathing exercise difficulty, further conceptualized as breath control (Cortez-Vázquez et al., 2024). Upon entering the VRE, both the experimental and control group were presented with a forest environment and a welcome text. Within the experimental group, participants then completed a breathing questionnaire to determine their experience and self-reported skill level as seen in Figure 2. Based on their answers, a score was calculated, determining the exercise level that they were presented with afterwards.

Figure 2



Control Group

After reading the welcome text, the control group was immediately directed towards the breathing exercise. As three levels of the breathing exercise were created, randomisation of exercise level occurred by placing the block "level 1, level 2, level 3" into R and running a random block generator. This followed a permuted block design, with an allocation ratio of 1:1:1 to each level. The randomised block sequence utilised can also be found within Appendix B.

Participants

The power analysis within G*Power 3.1 (Faul et al., 2007) based on the effect size found by Korporaal (2023) revealed that a minimum of 14 participants was required to achieve 80% power. The current study aimed at recruiting 40 participants to achieve robust findings. Inclusion criteria involved being 18 years of age or older and being fluent in English. Exclusion criteria involved epilepsy or known disturbances with VR (motion sickness, nausea), known disturbances with breathing exercises (shortness of breath, dizziness), and severe visual or hearing impairments. Participants were recruited through posters, convenience sampling, and the SONA system offered by the UT. In total, 41 participants were recruited, with 38 included in the data analysis. One participant was excluded because of termination due to dizziness, and two participants were excluded due to technical issues. From the experimental group, the breathing questionnaire scores of participants resulted in 12 participants being assigned level 2 and seven participants being assigned level 3, whereas no participants were assigned level 1. Of the non-working students (n=29), 12 were studying for a bachelor's degree and 17 a (pre-)master's

degree. Participant nationality (non-exhaustive) included German (*n*=11), Dutch (*n*=7), Indian (*n*=5), and Polish (*n*=2). Overall, participant demographics can be seen in Table 1.

Table 1

Demographic characteristics of study sample

Baseline characteristics	Experimental group		Control group	
	n	%	n	%
Gender				
Female	5	13.2	14	36.8
Male	13	34.2	6	15.8
Age (Mean ±SD)	22.1 ±2.6		24.6 ±2.4	
Nationality				
European	12	31.6	13	34.2
Asian	6	15.8	5	13.1
African	0	0	1	2.6
South-American	0	0	1	2.6
Employment				
Student	13	34.2	16	42.1
Working student	5	13.1	3	7.9
Full-time worker	0	0	1	2.6

All data was collected at the UT in Flexperiment Room 7 of the BMS Lab. After showing interest, participants were contacted via email, telephone, or SONA with the information sheet two days prior to participation, found in Appendix C. Study information was provided in written format, and informed consent was gathered via Qualtrics (University of Twente, version 2025) prior to the study. A randomised participant ID was created with a random number generator from 100-1000 via Google (https://g.co/kgs/7v7c43F) to provide a non-sequential ID for anonymity and to reduce bias from the researcher (Lim & In, 2019).

Participants first filled out the pre-intervention survey, consisting of the following questions: (1) In which year were you born?, (2) With which gender do you identify?, (3) What is your country of origin?, (4) What is your current student/employment status? Subsequently, the participant filled out the subjective vitality scale (SVS) and then undertook the breathing exercise. After completion, the participant was redirected to Qualtrics again to fill out the SVS once more, in addition to the motivation questions. Lastly, consent to be audio recorded for the interview was verbally recorded, and the interview commenced. Participants were initially informed that the aim of the research was to determine the effects of the breathing exercise on subjective vitality and motivation. After the interview, participants were debriefed regarding the experimental condition they were allocated to and informed that the aim of the study was to investigate tailoring. Participants were then asked to reconfirm or withdraw their initial consent.

Materials

Tailoring Walk in Nature

The WiN environment was run on Unity 6 LTS (Unity Game Engine, 2024), and the Occulus Quest 2 headset from the BMS Lab was used. Tailoring was based on breath control, which encompasses changing the breath frequency per minute, depth, and inhalation to exhalation (i/e) ratio. The technique of slow breathing (<12 breaths per minute) was chosen as it shows greater improvements in mood compared to mindfulness and decreased physiological measures such as blood pressure and heart rate compared to neurofeedback (Cortez-Vázquez et al., 2024). The ideal breaths per minute (BPM) for improved mental and physical health is 6, with a range of 4.5-6.5 BPM being best for improving heart rate variability (Shaffer et al., 2020; Zaccaro et al., 2018). A systematic review found that the impact of slow breathing increases with exercise duration, pace, and complexity of the breathing ratio (Bentley et al., 2023). For example, although a low i/e ratio demonstrates benefits for feelings of positive energy and stress, it also presents more difficulties (van Diest et al., 2014), and breathing exercises lasting less than five minutes are ineffective (Bentley et al., 2023). For these reasons, it was decided to alter breath pace, i/e ratio, and session duration according to each exercise difficulty level (Bentley et al., 2023; van Diest et al., 2014). This suggests a linear progression of the breathing exercise, with level 1 being 5 minutes, and levels 2 and 3 being 10 and 15 minutes respectively. Based on time, level 1 would involve 38, level 2 would contain 60, and level 3 would involve 65 breathing cycles. This creates a 22-cycle gap between level 1 and 2, and only a 5-cycle difference between

level 2 and 3, having implications for the relationship between the number of cycles and outcome variables. Consequently, it was decided that level 1 should contain at least 38 cycles for a minimum of 5 minutes of breathing activity, but for linear progression this was rounded up to 40 (Bentley et al., 2023). The final breathing pattern based on number of breathing cycles was:

- Level 1: 3 second inhale – 1 second hold – 3 second exhale – 1 second hold
    - 40 breathing cycles (330 seconds)
- Level 2: 3 second inhale – 1 second hold – 5 second exhale – 1 second hold
    - 50 breathing cycles (500 seconds)
- Level 3: 4 second inhale – 2 second hold – 6 second exhale – 2 second hold
    - 60 breathing cycles (840 seconds)

Although 4.5-6.5 BPM is desired (Shaffer et al., 2020), a resonance of 6 BPM can increase the risk of hyperventilation by overcompensation (Vlemincx & Cortez-Vázquez, 2024). Therefore, it was decided that the lowest BPM should be in line with the highest difficulty level. The breathing pace per activity level was 7.5 BPM for level 1, 6 BPM for level 2, and 4.3 BPM for level 3. Level 3 resulted in a BPM of 4.3 instead of 4.5 due to a longer i/e ratio.

Possible Adverse Effects. While the effectiveness of breathing exercises has been demonstrated, certain samples have experienced negative effects. Namely, Conrad and colleagues (2007) found that individuals with panic disorder and regular tension self-reported increased outcomes of anxiety and depression compared to the control group when slow breathing. This has been corroborated by recent reviews stating that slow breathing can lead to overcompensating by deep breathing, which may cause hyperventilation (Vlemincx & Cortez-Vázquez, 2024) or dizziness (Gholamrezaei et al., 2020). It is also possible that individuals experience anxiety from relaxation, or breathlessness due to a fixed breathing pattern (Vlemincx & Cortez-Vázquez, 2024). Vlemincx and Cortez-Vázquez (2024) propose that one mechanism to avoid this is to provide tailored interventions based on traits such as anxiety sensitivity, breathing patterns, and preferences. Despite a minority of participants experiencing such effects in the mentioned studies, it must be taken into account from an ethical standpoint. Therefore, exclusion criteria involved prior experience of difficulties with breathing exercises. In this regard, the control group can provide clarity on whether tailoring would solve the possible adverse effects of breathwork.

Breathing Questionnaire

As to date, there is a lack of validated questionnaires to measure breathing skill level and experience. Therefore, a quantitative questionnaire with an if-then algorithm had to be created to segment users into different levels. For cohesiveness with the SVS, participants could determine their agreement with a statement on a Likert-type scale of 7, with 1 indicating "not at all true", 4 indicating "somewhat true", and 7 indicating "very true". This involved seven questions, with the minimum summative score being 7 and the maximum being 49. Individuals with a score of 7-20 were allocated level 1, scores 21-34 level 2, and scores 35-49 level 3. An example of the algorithm is therefore as follows: *if* the user scores between 7 and 20, *then* they are given level 1. The questionnaire was placed in the VRE to establish tailoring within the intervention itself. The questions were piloted with three individuals with English as their native or non-native language. Based on this, the third question was changed from "I have experience with practicing structured breathing exercises..." to "In general, I have practiced structured breathing exercises..." to provide continuity. The following example was added to question four to improve clarity: "(such as inhaling for 4 seconds and exhaling for 8 seconds)". Moreover, question five was altered from "I can control my breathing rate comfortably" to "I have control over my breathing".

Within the questionnaire, two constructs were developed: past experience and skill. Questions 1 to 3 concern experience with breathing exercises, whereas questions 4 to 7 focus on skill (technical level). It has been demonstrated that inexperience can diminish the stress-reducing impact of breathing exercises when a higher technical skill level is required (Bentley et al., 2023). Moreover, the effect of consistent breathwork practice is thought to be linked to familiarity and consistency (Bentley et al., 2023). Therefore, both familiarity and experience with structured breathing exercises were chosen as determinants. A distinction between experience in general and in the past week was made to account for individuals new to breathwork and those who regularly practice. It was also chosen with the aim of WiN in mind, allowing for the system to adapt to individuals who use the intervention consistently. As mentioned, breath pace, i/e ratio, and session duration impact effectiveness; therefore, the questions regarding skill pertained to these factors (Bentley et al., 2023; van Diest et al., 2014; Sharma et al., 2013; Zaccaro et al., 2018). For example, question 4 stated, "I can comfortably extend my exhalation longer than my inhalation", whereas question 5 stated "I have control over my breathing". Question 7 stated "I can

comfortably complete a breathing exercise for 10 minutes", providing an indication of skill based on duration. The full breathing questionnaire can be found in Appendix D.

Breathing Tree Development. The environment was chosen to be a forest to adhere to WiN and findings that outdoor VREs for breathing exercises show greater decreases in tension (Jeong et al., 2022). The user was prompted to breathe the tree back to life to increase the vitality of the tree and themselves. Previous studies have found that movement of a tree based on the participant's breath can hinder concentration on breathing and interrupt relaxation (Miner et al., 2024). As participants in WiN have experienced discrepancy in the tree movements with their breath, combined with the challenge of adding another measurement device, it was decided to move the tree according to a predetermined sequence. The tree expands upon the inhalation, pauses at the expanded size for the hold, contracts to its starting size for the exhalation, and pauses at that size once again, mimicking the movement of the chest when breathing. At 50% completion, and two cycles before the last breathing cycle, the tree leaves change colour whilst the tree vertically expands to stimulate growth. This provides a positive reward for the user. A video of a bubble expanding and contracting with the text "Breathe in", "Rest", and "Breathe out" was added to provide guidance. Lastly, audio guidance provided instructions and encouragement. For example, the audio guidance stated, "Do you notice anything different about the tree? It looks like it's coming back to life. That's because of your breathing." In line with suggestions that VRE development should be transparent within research, specifics and files used for the project can be found in Appendix E (Cortez-Vázquez et al., 2024). The values of the sizes for tree growth and colours of the leaves were determined by the researcher via Unity. Codes for testing movement of the tree and bubble were written in Xcode (Apple, 2025, Version 16.3).

Subjective Vitality Scale

The SVS of Ryan and Frederick (1997) has demonstrated high convergent validity and internal consistency, being accepted as a reliable measure (α =.84-.89) (Ryan & Frederick, 1997; Bostic et al., 2000; Castillo et al., 2017). However, based on Bostic and colleagues' (2000) validation, question 2 ("I don't feel very energetic right now") was removed to better measure the construct of vitality (Bostic et al., 2000). Participants could answer each question based on a 7-point Likert-type scale, with 1 implying "not at all true", 4 implying "somewhat true", and 7 as "very true". The minimum score that participants could obtain was 6, whilst the maximum score was 42. A SVS score was calculated by averaging the answers to all items. The individual

difference level version of the SVS regards subjective vitality as an ongoing characteristic based on general feelings in life, whereas the state level is focused on answers related to the time at which the participant is answering the questionnaire. Due to the pre-post design, the state level SVS was selected, which can be found in Appendix F.

Motivation Questions

To date, there is a lack of validated scales to measure motivation to use a VR intervention again. Therefore, this study utilised researcher-created questions to determine whether the participants would be motivated to use the intervention again based on whether or not they deem the level of the breathing activity assigned to them as appropriate to their skill level. This allowed for quantitative data collection to compare the groups. The questions were formed on a Likert-type scale, with 1 (not at all true) being the lowest possible answer and 7 (very true) being the highest. This was chosen to provide continuity from both the SVS and breathing questionnaire. The statements were pilot tested again, leading to minor changes to improve clarity and distinction between concepts. The finalised questions can be found in Appendix G.

Interview Questions

A Zoom H4N Pro Voice/Sound Recorder was used to record all interviews. The interview was conducted and coded by the researcher and took place with every participant. The questions were constructed based on the definition of tailoring (see page 6). For example, the participant was asked: “Do you believe that this breathing exercise within VR is relevant and would be beneficial for you specifically? Why/why not?”. Moreover, participants were asked their preference regarding tailoring to determine whether the experimental group experienced tailoring. This was asked via the following question: “In what (other) ways would you prefer the breathing exercise to adapt to you specifically?” After piloting these questions, the only change made was adding examples of other ways in which tailoring could occur as it was noted that participants may struggle otherwise. An inductive, semi-structured interview format with four open questions was chosen to mitigate bias and increase validity while being in line with the exploratory approach (Bergelson et al., 2022). The interview questions can be found in Appendix H.

Statistical Methods

Quantitative Analysis

A 2x2 (group x time) repeated-measures ANOVA (RM-ANOVA) was conducted to analyse the within- and between-subject effects for subjective vitality, whereas an independent samples t-test was conducted to analyse motivation scores. After the RM-ANOVA, a linear mixed model analysis for subjective vitality was conducted to account for random effects and within- and between-subject variation simultaneously. For this, the statistical software SPSS (version 29.0.2.0) was used. Data was exported from Qualtrics into an Excel file.

Qualitative Analysis

Thematic analysis with inductive coding was performed to analyse the data from the semi-structured interviews. This thematic analysis was conducted by the researcher based on a guide developed by Braun and Clarke (2006) for psychology research. Inductive coding is data-driven, allowing for patterns and themes to naturally surface from the data (Naeem et al., 2023). The analysis consisted of the following structure: (1) familiarisation with the data, (2) creating initial codes, (3) discovering themes, (4) reviewing themes, (5) defining and labelling themes, and (6) compose a narrative report (Braun & Clarke, 2006). Braun and Clarke's (2006) 15-point criteria for a high-quality thematic analysis were consulted. All interviews were transcribed using Amberscript (Amberscript Global B.V., 2023), with the researcher manually editing any errors.

Mixed-Methods Analysis

The quantitative and qualitative data were collected in parallel but were analysed separately. After analysis, the data was combined to determine whether the qualitative data could elaborate upon the quantitative data, strengthening the depth of the findings (Wasti et al., 2022).

Results

The aim of the study was to investigate the effect of system-controlled tailoring of a VR breathing exercise. The results will be discussed by comparing the groups in the following order: impact on subjective vitality, motivation, and user experience. The quantitative results showed no significant difference within or between groups and the qualitative data revealed homogeneity within most themes. The theme for which the experience of the tailored group was different was adaptation. As seen in Figure 1, the control group had an equal distribution (n=20), whereas in

the experimental group 11 participants were assigned level 2 and seven were assigned level 3. The descriptive statistics for quantitative data can be found in Table 2, whereas the frequency of themes from the interviews can be seen in Table 3. The interview consisted of four questions regarding ways to adapt the intervention, personal relevance, and motivation to continue and discontinue the intervention. The following themes were identified via inductive thematic analysis: (1) mental states, (2) customisation, (3) VR as a hindrance and facilitator, (4) interactive visual reinforcement, (5) difficulty level, and (6) adaptation. Overall, both groups referred to akin themes with similar frequency (see Appendix I for the coding scheme).

Table 2

Descriptive overview for subjective vitality and motivation

Variables	Experimental group		Control group	
	M	*SD*	*M*	*SD*
Subjective Vitality				
Pre-intervention	4.2	1.3	4.8	1.0
Post-intervention	4.4	1.3	4.9	1.1
Motivation				
Post-intervention	4.3	1.3	3.9	1.7

Table 3

Descriptive overview of frequency of reports for identified themes

Inductive Themes	Level 1	Level 2	Level 3	**Total**
	exp/con	*exp/con*	*exp/con*	*exp/con*
Mental States				
Calmness	-/1	3/1	2/2	**5/4**
Subjective Vitality	-/1	1/1	1/0	**2/2**
Stress	-/0	2/1	0/0	**2/1**
Customisation	-/4	8/7	7/7	**15/18**
VR as a Hindrance & Facilitator	-/4	7/5	5/5	**12/14**
Interactive Visual Reinforcement	-/5	7/5	5/3	**12/13**

Difficulty Level	-/4	8/3	5/4	**13/11**
Adaptation	-/3	4/3	1/6	**5/12**

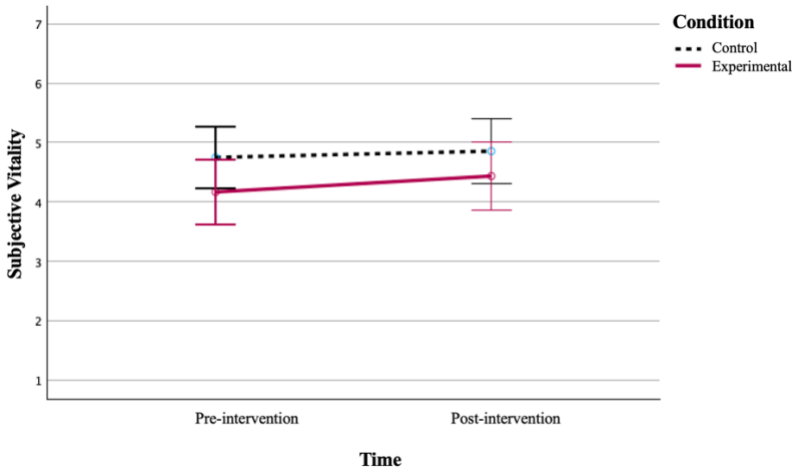
Note: Within the experimental group, none of the participants indicated answers to be allocated to level 1, resulting in no data (-). "Exp": experimental group; "con": control group.

Impact of Tailoring on Subjective Vitality

Regarding the first research question, it was found that tailoring did not significantly impact subjective vitality. For the RM-ANOVA, sphericity was met through the 2x2 experimental design. The assumption of normality was met for both pre-SVS scores, W (38) = .97, p = .427, and post-SVS scores, W (38) = .97, p = .432. Homogeneity of variances was also met for both pre-SVS scores, F (1, 36) = 1.13, p = .294, and post-SVS scores, F (1, 36) = 0.52, p = .477. No outliers were detected when using the thresholds Q1-3xIQR to Q3+3xIQR. Mean pre- and post-intervention scores on SVS for both groups can be seen in Table 2 and Figure 3, demonstrating the following differences for the experimental group (ΔM = 0.3, SD_Δ = 1.3) and those in the control group (ΔM = .1, SD_Δ = 1.1). The main effect of condition on subjective vitality was found to be non-significant: α = .05, F (1, 36) = 2.32, p = .136, η^2= .061. The main effect of time was also non-significant, F (1, 36) = 0.91, p = .346, partial η^2= .025. Lastly, the group x time interaction was non-significant as well, F (1, 36) = 0.18, p = .678, partial η^2= .005.

Figure 3

SVS score between groups and time points



A linear mixed model was conducted to further test the fixed effects of time, condition, and the time×condition interaction, including random slopes and intercepts. This approach was chosen, using Restricted Maximum Likelihood, to model individual change over time whilst accounting for baseline variation. The assumptions of linearity and homoscedasticity were met via interpreting the scatterplot of residuals and predicted values. The assumption of normality was assessed and met via a Q-Q plot. Lastly, independence was assumed between groups after taking the random effect of participant into account. No multicollinearity was found as all VIF values were below 10. The associations and significance of the model can be seen in Table 4. The fixed intercept was significant ($p < .001$), which was expected given that the SVS begins at 1. Both fixed effects of time and condition were non-significant. The fixed interaction was non-significant, suggesting that change over time does not differ by condition. As seen in Table 5, the residual variance was significant ($p < .001$), indicating within-subject variability over time. Lastly, there was no significant variability between individuals at the pre-intervention timepoint.

Table 4

Linear Mixed Model of Time, Condition, and their Interaction on Subjective Vitality

Predictor	Estimate (β)	SE	95% CI	t	p-value
Intercept (ref: Control)	3.898	0.49	[2.91, 4.88]	8.03	<.001
Time	0.269	0.29	[-0.32, .86]	.924	.362
Condition (ref: Control)	0.798	0.67	[-0.56, 2.16]	1.19	.243
Time × Condition	-1.690	0.403	[-0.99, .65]	-0.42	.679

Note: Condition = 0: control group (non-tailored)

Table 5

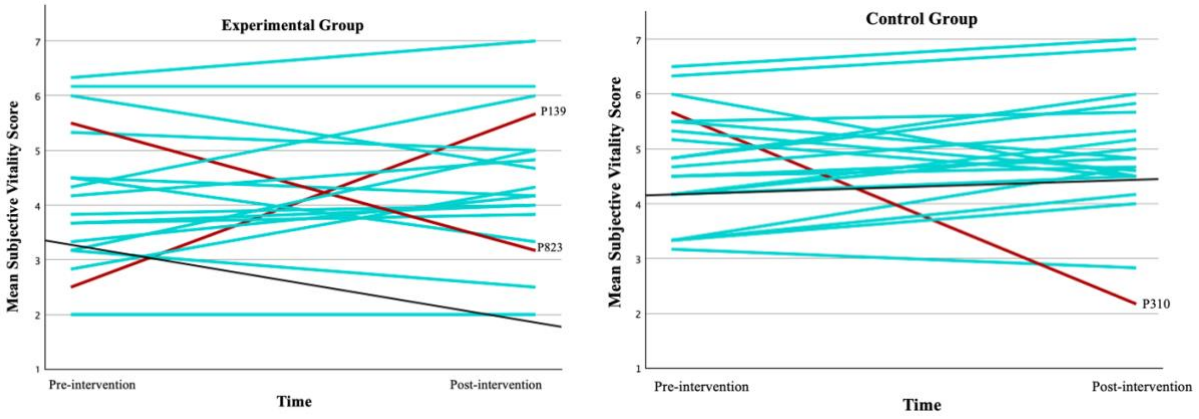
Random Intercept and Random Error on Subjective Vitality Scores

Effect	Variance (σ^2)	SE	p-value
Intercept (subject)	0.54	0.40	.152
Residual (within)	0.74	0.20	<.001

This lack of difference within and between the groups can be understood from the interviews (Table 3). Namely, the first theme identified for both groups was mental states, consisting of the subthemes calmness, subjective vitality, and stress, discussed in this order respectively. This theme was defined as participants explicitly mentioning a certain feeling because of the intervention when asked whether the intervention was relevant to them or what would (de-)motivate them. Frequency of reports within the control group (n=4) was similar to the experimental group (n=5) for calmness. Sensations of calmness could impact the experience of subjective vitality in both directions for both groups. For example, P643 noted "it makes me feel more relaxed and calmed down than energized" and experienced an increase in SVS of 0.84. In contrast, P823 reported a sense of calmness but experienced a large decrease which is seen in Figure 4. This decrease could be explained by VRE factors, as P823 reported the syncing problems of the guidance elements and the abundance of visual stimuli as difficult to follow.

Figure 4

Spaghetti plots of the linear mixed model for both groups



Note: The red lines are defined as SVS scores 2 standard deviations away from the SVS mean. The fixed effect line can be seen in black.

For sensations of vitality, the findings were homogeneous. Although six participants experienced level 2 as a challenge in the experimental group, four of them reported increased SVS scores. This difference is most evident for P139, as seen in Figure 4, who scored a 2.5 pre-intervention and 5.67 post-intervention (out of 7). The difference for P139 can explained by their experience of a subjective state of vitality: "I feel better and more energised". In contrast, the

other three participants did not qualitatively mention vitality. This effect could be due to the visual aids, as P139 mentioned the breathing tree as helpful amongst the exercise difficulty.

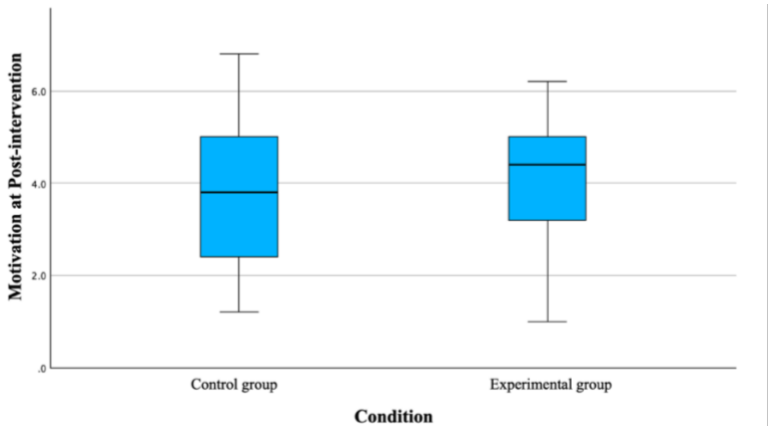
Furthermore, despite reporting stress, one participant in the experimental group experienced an increase in SVS. Other participants reporting stress experienced a decrease. In Figure 4, the substantial decrease in subjective vitality for P310 is explained due to stress and adverse effects. P310 felt dizzy due to the difficulty of the breathing exercise and pixelation of the VRE: “my heart was pounding...I have anxiety and that’s how it felt”. The number of reports for each mental state was similar between the two groups.

Impact of Tailoring on Motivation

The post-intervention motivation score was out of 7, determining motivation to use the intervention again when feeling stressed, to increase vitality, and user perception of tailoring. The assumption of normality, W (38) = .97, p = .421, and the assumption of homogeneity of variances, F (36) = 1.32, p = .258, were met. In Figure 5, the experimental group seems to have higher scores than the control group. However, there was no significant difference between post-intervention scores of the experimental group (M = 4.3, SD = 1.3) and the control group (M = 3.9, SD = 1.7); t (36) = -1.02, p = .157, d = -.332. The random intercept was significant, estimated at 1.52 (SE = .7, p = .032) and expected due to the Likert-type scale.

Figure 5

Motivation score between groups



This finding was corroborated by the thematic analysis, where the themes of customisation, VR as a hindrance and facilitator, and interactive visual reinforcement were

identified. Customisation refers to two subthemes: (1) customisation of guidance elements, defined as mention of a preference for selecting a specific format of guidance (tree, video, audio), and (2) customisation of environment. The latter refers to explicit mentioning of a desire to change visuals or objects within the VRE to increase personal relevance and motivation.

Customisation of Guidance Elements

From the control group, nine participants discussed favouring the user selecting which guidance elements to follow during the breathing exercise (see page 16). Opinions varied, as participants mentioned preference for following different combinations of guidance elements. In the control group, nine participants mentioned this theme. Three participants reported the audio guidance resulted in them feeling pressured, stating "[the audio] for me is like the epitome of discouraging, that it feels like it doesn't trust my ability to breathe." (P297). Additionally, two participants explicitly stated that too much instruction would discourage them from using the intervention again. These results may have been impacted by the desynchronisation issues, demonstrated by one participant's statement that the tree had a calming effect amidst the visual overstimulation (the tree and bubble) (P249). For the experimental group, 11 participants explicitly mentioned the desire to customise the guidance elements. For example: "without the bubble, I think it would be really difficult to follow the voice" (P865), but opinions on which elements provided most clarity for following the exercise differed in this group as well. There was no major difference in frequency of reports of between groups. It is possible that a lack of customisation of guidance elements impacted motivation scores, as this theme was mainly mentioned when asked what aspects of the intervention would discourage future use.

Customisation of Environment

Mention of desiring customisation of the VRE was independent of the breathing exercise. In the control group, nine participants mentioned desiring customisation of the environment when asked about aspects of the intervention that could be more adaptable. For example, participants mentioned flowers or user-selection of the setting, such as a forest or beach. P699 noted, "if I would do this like every single day, it would be nice to have some customisation and not always look at the same tree...just [so] that it doesn't get boring", exemplifying the impact of this theme on motivation. For the experimental group, four participants mentioned this theme, suggesting a difference between the groups. P313 referred to the lack of environmental customisation as

discouraging: “that kind of discouraged me that...not really much was changing”. Therefore, a difference in the frequency of reports between groups is evident; however, the reasoning is similar as both groups mention it as a demotivating factor.

VR as a Hindrance and Facilitator

This theme was recognised as participants mentioning a high threshold for accessibility to and set-up of VR, and perceiving VR as a hindrance or facilitator for breathing exercises. When asked whether the intervention was personally relevant or what would discourage future use, 14 participants in the control group mentioned VR as a hindrance or facilitator. For example, P968 stated, “I would prefer [to] go to an actual forest” and P567 mentioned that they “like to usually close [their] eyes”. For the experimental group, three reported VR as a hindrance during stressful periods as “the whole idea of having something like that in VR for me is already a bit stressful” (P180). As one of the questions on the motivation scale was related to future use in stressful situations, this suggests an impact on the quantitative results. This impact could be bidirectional, as five participants declared increased motivation due to the engagement and novelty facilitated by VR: “It's a more fun and more engaging way of doing meditation” (P139).

Interactive Visual Reinforcement

Furthermore, this theme included mention of the storyline of breathing the tree back to life, and such visual changes guiding the user through their interaction with the VRE. This was cited as a factor increasing motivation when asked what aspects of the intervention would motivate future use. Within the control group, P297 discussed realising that their breathing has an impact: “I know it will have an impact on me but...it’s not that obvious so it’s really good to have this very like tactile...impact”. This perception was linked to subjective vitality for P978: “it was really nice to look at and have like a tree as the symbolism of...regaining my energy”. This theme was mentioned by roughly the same number of participants in the experimental group, exemplified by P872: “[the tree] was like an embodiment of my breathing pattern”. Thus, visual reinforcement via the breathing tree was largely regarded as a motivator by both groups.

Conclusion

Overall, both the experimental and control group referred to the same motivators and barriers, with relatively the same frequency. This adds to the explanation of the non-significant quantitative findings of motivation. The states of calmness, subjective vitality, and stress

highlight that the various mental states of participants impacted their experience, and thus, SVS results. In addition, within the VRE, the audio did not sync to the bubble and movement of the tree. This resulted in 17 participants mentioning that the desynchronisation would demotivate them from future use of the intervention. This was not regarded as its own theme due to being considered a technical limitation and further explored in the discussion.

Impact of Tailoring on User Experience

Regarding the second research question, the mixed-methods analysis revealed that the experience of the user in the tailored group was not different from the control group. Both groups reported similar experiences regarding difficulty level of the breathing exercise except for identifying factors that motivate future use. This will be explored further, as appropriateness of the difficulty level is the variable upon which tailoring occurred through an if-then algorithm.

Difficulty Level

There was no difference between groups on the theme difficulty level, which was recognised as the participant's perception of the (mis-)alignment of the breathing exercise with their skill level and experience. Within this, six participants in the control group experienced the difficulty level as ill-matched, compared to five participants finding it well-matched. For the experimental group, the ratio was similar, with eight participants reporting misalignment and five reporting alignment: "since I've done breathing exercises before, I feel like the pace of the breathing was honestly alright" (P186, level 2). Although six participants in the experimental group reported level 2 as difficult, 12/19 participants were allocated to level 2 based on their answers to the Breathing Questionnaire. The complications for level 2 were its duration and i/e ratio: "I struggled to breathe in for that long and breathe out for that long" (P643). Therefore, comparing the experience of participants from level 2 in the experimental group to the control group was disbalanced. The between-group effects for subjective vitality and motivation could have been affected due to not being able to compare level 1 of the control group to the experimental group. The qualitative data provides clarity regarding commonalities between the groups despite an imbalance in participants. When asked about factors discouraging future use, participants reported that experiencing difficulty without the possibility for adjustment was demotivating, suggesting an impact on motivation scores.

Adaptation

Contrasting the previous theme, participants mentioned desiring adaptation within the intervention to *increase* motivation. The theme of adaptation was defined as the user mentioning a desire for the VRE to adjust to their own breathing rate, mainly through biofeedback such as heart rate or breath. One example involves participant suggestions for the VRE to provide a baseline based on the user's breathing rhythm, therefore being adaptable to their rhythm and provide feedback on their success rate. This theme was treated separately to tailoring as the latter includes more variables than biofeedback. Within the control group, P310 (level 2) mentioned the following due to finding the breathing exercise demanding: "I would really want the intervention, the VR, to adapt to my own breathing level...otherwise I don't see the point". P212 (level 2) elucidated the impact of this theme on motivation: "not being able to tailor it to what you want or how you're feeling...would discourage me...if I could tailor it to me more, I would probably use it more". The number of participants who mentioned a lack of adaptation in the control group (n=12) was almost double that of those in the experimental group (n=5), highlighted in Table 3.

Additionally, two participants in the control group explicitly mentioned that they did not "feel there was any adaptability" (P846), whereas some participants in the experimental group mentioned not wanting to change the adaptability. For example, P378 from the experimental group (level 2), stated, "customizing it to my own breathing... I wouldn't change much regarding that" and P993 (level 3) stated "I don't actually want it to adapt that much...that's probably like a good breathing rate to calm your heart rate down". Most control group participants mentioned adaptation as a suggestion for increasing motivation due to the difficulty level, whereas the experimental group focused on customisation of guidance elements. Considering that from a holistic perspective there was no difference between groups on motivation, this effect appears to be an exception. This may be explained by adverse effects as only the control group (n=2) reported dizziness, with both participants reporting decreases in SVS. For example, P846 (level 3) experienced lightheadedness and suggested that biofeedback could avoid this adverse effect. This effect is also noted through low motivation scores (range = 1-7) for both P846 (M=1.8) and P310 (M=1.6). Although one participant in the experimental group experienced dizziness, their data was excluded from analysis due to early termination.

Conclusion

In sum, participants reported both alignment and misalignment of skill level with the exercise level at a similar frequency between groups. Groups differed regarding their perception of desiring more adaptation within the VRE, influenced by adverse effects. Overall, the themes of (1) mental states, (2) customisation, (3) VR as a hindrance and facilitator, (4) interactive visual reinforcement, (5) difficulty level, and (6) adaptation were identified.

Discussion

The current mixed-methods study aimed to increase knowledge regarding the process and outcome of tailoring a VR breathing intervention, offering an opportunity to increase the quality of e-health interventions. This was done through investigating the intervention's effect on subjective vitality, motivation, and exploring its impact on the user. Tailoring with a system-controlled mechanism for breathing exercises did not impact subjective vitality and motivation to continue use of the intervention. Notably, subjective vitality and motivation were impacted by the participants' subjective experience, such as feeling calm or stressed. Motivation was also impacted by various VRE elements and alignment of the difficulty level. Overall, the findings between the groups were mostly balanced.

Regarding the second research question, the findings indicate no difference, except for the non-tailored group reporting a higher frequency of desire for adaptation. Experiencing the breathing level as too difficult could explain why the non-tailored group wanted the exercise to adjust to them. The tailored group had mixed results regarding feeling that the VRE was tailored, but there was no substantial difference between groups regarding the difficulty level. Additionally, the desynchronisation of the audio to the bubble and tree could have impacted the findings. Mention of the desynchronisation as demotivating demonstrates its impact on user experience and motivation in each group, diminishing any potential differences between-groups.

Breathing Exercise Screening and Difficulty

The following findings suggest a failure within the screening tool: (1) no difference in frequency between groups regarding difficulty level being (ill-)matched, and (2) most participants in the experimental group being assigned to level 2 with half finding the exercise too difficult. Some participants within the experimental group believed themselves as having

adequate experience, with one rating a 6/7 for confidence in completing a 10-minute breathing exercise. However, this participant reported difficulty in following the exercise, stating that their prior experience consisted of 2–3-minute exercises. This could have impacted motivation scores, as adaptability to the user's skill level was included within the questionnaire. This could also be due to a lack of consideration of attributes such as anxiety sensitivity or interoceptive awareness, breathing patterns, and preferences, which Vlemincx and Cortez-Vázquez (2024) propose as variables for tailoring. These were not considered in the current study due to exclusion of individuals with known adverse effects from breathing exercises and a focus on system-controlled tailoring instead of breathing patterns and preferences.

Moreover, it is possible that the exercise levels were too difficult regardless of the screening process. In Steffen and colleagues' (2021) study, participants breathed at 12 BPM instead of 6 BPM as intended. Similarly, it is likely that the actual breathing rate of participants varied as their breathing was not monitored in the current study. In line with SDT, it has been found that participants experiencing a lower i/e ratio (such as in level 1) report a higher sense of control, which could bolster feelings of autonomy and improve the effectiveness of tailoring (van Diest et al., 2014). Additionally, this study was limited by not determining the control group's experience and skill level prior to random allocation. With this information, group comparability could have been enhanced, and confounding factors could have been controlled for, improving understanding of within- and between-group differences.

Role of the User's Input in Tailoring

Supporting Orji and colleagues' (2017) findings regarding system-controlled tailoring, some participants mentioned ease of use, personal relevance due to the VRE, and interactivity due to visual reinforcement. Although some participants advocated for having user-controlled inputs, it is clear from the lack of bodily awareness in some participants that the user's role in tailoring needs to be carefully evaluated. Literature suggests a lack of harmony between subjective and physiological health outcomes for breathwork specifically, impacting interoceptive awareness (Desmedt et al., 2025; Vlemincx & Cortez-Vázquez, 2024). With breath control improving physiological effects and VR increasing bodily awareness, it is important to take interoceptive awareness into account given that system-controlled tailoring is favoured due to the user's insecurity in making health-related choices (Orji et al., 2017; Vlemincx & Cortez-

Vázquez, 2024). As suggested by participants, biofeedback could be added to provide such awareness. Yet, it presents its own limitations such as diverting user attention, interrupting relaxation, difficulties with calibration, and requirement of devices (Miner et al., 2024).

Preference for User-Controlled Tailoring

The findings have implications for WiN and e-health interventions in general, as tailoring the experience to specific attributes or preferences of the user is needed. For example, Franke (2024) found that previous participants requested visual instructions, yet in the current study some participants reported overstimulation from such guidance. Although literature suggests system-controlled tailoring is preferred, the benefits of user-controlled tailoring appear to be more in line with the SDT and Hutmacher and Appel's (2023) model and explain the results. Most participants from the current study mentioned features of adapting the breathing exercise and VRE that could be categorised as user-controlled tailoring. User-controlled tailoring has been found to improve self-efficacy and perceptions of control (Orji et al., 2017), pertaining to the SDT's explanation that tailoring influences behaviour through satisfaction of autonomy and competence (Ryan & Deci, 2000). This proposes that system and user-controlled tailoring should be combined to extract the benefits of both. This is especially relevant considering that tailoring strengthens autonomy and competence through eliminating irrelevant options, which user-controlled tailoring can fall susceptible to (Hutmacher & Appel, 2023). Another finding that could explain low motivation scores is VR-related barriers, such as wanting to close one's eyes.

Strengths

Implementation of Theory in Tailoring Development

The knowledge gap regarding the combination of system-controlled tailoring with VR breathing exercises offers an opportunity to tailor in various ways. One of the study's strongest points involved the balance between theory and implementation for tailoring the breathing exercise given the current lack of a framework. Within the Double-Diamond model (British Design Council, 2005), the Discover stage consisted of consulting literature. Within the Define stage, the knowledge was synthesised, suggesting that the breathing exercise levels be differentiated on the variable of time (Bentley et al., 2023; van Diest et al., 2014; Shaffer et al., 2020; Zaccaro et al., 2018). Within the Develop phase, the levels were created, yet the discrepancy between theory and design became apparent, influencing user experience and the

investigated relationship. Therefore, a systematic manner with levels based on breathing cycles was created, which was delivered in the final stage. This highlights the study's foundation in theoretical insights as well as the difficulty of applying these insights into design systems such as tailoring. Theory should guide the segmentation of individuals for the algorithm (Klooster et al., 2024). Yet, theory should not be used as guidance if it does not provide information regarding intra- or interindividual variances on the tailoring variable (Klooster et al., 2024).

Mixed-Methods Study Design

Another one of the strongest points of the research involves the mixed-methods study design, ensuring deeper insights and stronger inferences of the collected data (Wasti et al., 2022). This is for example shown in the insights regarding subjective vitality: although Bareišytė (2021) and Korporaal (2023) found a significant effect on students, Minina (2023) and the present study did not. This could be due to Minina (2023) and the present study's use of the state-level of SVS, whereas Bareišytė (2021) utilised the individual difference version. Interview insights offer reflection upon these findings, as participants reported feelings of calmness or stress following the intervention, which the individual difference version would have missed.

Comparability and Tailoring Framework

Given Korporaal's findings that the WiN exercises do not need to be experienced to increase subjective vitality in university students, this study suggests otherwise. Korporaal's (2023) findings were impacted by participants not completing exercises and lacking visual guidance, which was addressed in the current study. Based on other pilot studies (Bareišytė, 2021), the current study's investigation of only the breathing exercise offered strengths in distinguishing the effect of the tree yet could have influenced the intervention's impact on subjective vitality. Permuted block randomisation of participants improved comparability between the groups and reduced selection bias, ensuring that the effects of confounding factors were minimised (Lim & In, 2019). Furthermore, the study provides future projects with a foundation of questions via the Breathing Questionnaire and framework for tailoring its exercises. This framework involves tailoring based on experience and skill, with recommendations to add preferences and duration of previous exercises.

Limitations

Study Design, Measurements and Analysis

The pretest-posttest design of the study presents a limitation as the number of sessions, long-term practice, and training (self- or expert-guided), influences the effectiveness of breathwork (Bentley et al., 2023; Jeong et al., 2022). As WiN is aimed for at-home use, future research should address this by providing breath training within the VRE, longitudinal data collection and repeated use of the intervention at home. To ensure effectiveness, more than six sessions over more than one week is required (Bentley et al., 2023). In addition, the Breathing Questionnaire and motivation questions were researcher-created, raising limitations regarding the reliability and validity of these tools and subsequent findings. With only one researcher in the project and predetermined expectations for the second research question, it is possible that researcher bias influenced the qualitative results.

Sample Demographic

Ultimately, despite aiming for a heterogeneous sample, the study failed and consisted of university students (n=37), resulting in student sampling bias (Wild et al., 2022). University students are unrepresentative of a broader non-student population even when age-matched, eliciting questions regarding the generalisability of the findings (Wild et al., 2022). The study's gender imbalance in both groups also limit generalisability (see Table 1). Although evidence regarding gender differences in breathing exercises is limited, it has been demonstrated that women experience higher effects in psychological outcomes such as self-compassion compared to men (Rojiani et al., 2017). This may have resulted in a Type II error, with gender confounding differences between groups on both a numeric and subjective level.

Future Recommendations

Although interindividual variances surrounding breath pace, i/e ratio, and duration were considered, the findings suggest that this could be improved upon. Based on the screening and difficulty level limitations, it is recommended to add questions accounting for the duration of prior exercises and preferences to the Breathing Questionnaire. This would create more distinction between levels 1 and 2 for users to be segmented more accurately. Future studies should include screening for the non-tailored group by providing the Breathing Questionnaire, without their answers determining their exercise level. The questionnaire should also take

participants' interoceptive awareness into account. Refinement of the framework and measures of interoceptive awareness is needed, making addition of this concept difficult (Desmedt et al., 2025). Interoceptive awareness through breath monitors and confidence in completing the exercise could be utilised to determine the tailoring algorithm, where if the alignment between the user's accuracy and sensibility is above a certain percentage they are allocated the Breathing Questionnaire. If not, the user may receive breathing exercises focused on improving interoceptive awareness before progressing. For example, a pre-intervention demonstration of one's breathing pattern with the tree would be valuable to add if awareness needs to be improved. However, this should be completed in one session as at-home accessibility remains a priority.

Participants in the current study suggested ways to implement user-controlled tailoring, such as user selection of the guidance elements (audio, bubble, other) or the VRE (forest/beach setting, flowers or trees). Future research can explore such opportunities whilst not distracting the user or being time consuming (Orji et al., 2017). Participants reported desires such as closing their eyes due to preconceived notions of breathwork, suggesting that future studies should explore WiN as a complete intervention to mitigate this effect. Lastly, future studies should recruit outside of a university setting with stratified randomization based on gender and utilise repeated use of the WiN intervention at home. A standardised approach for thematic analysis or qualitative analysis via researchers unrelated to the project is also required.

Conclusion

In conclusion, this study aimed to explore the impact of system-controlled tailoring on subjective vitality, motivation, and the user's experience of the intervention. Whilst the results were non-significant and homogenous for most themes, participants highlighted the need for user-controlled tailoring in a VR-based breathing exercise. This has implications for future development of WiN, suggesting that revision of the screening process is needed. Recommendations for future research involve improving the study design, adjusting the VRE, and considering interoceptive awareness. The current study provided its framework for tailoring, which was missing from previous research. This study contributed to knowledge of system-controlled tailoring and emphasises the need to develop a standardised method of tailoring VR breathing exercises to offer individualised e-health interventions.

References

Amberscript Global B.V. (2023). *Amberscript* [Computer Software]. https://www.amberscript.com/en/

Apple (2025). Xcode (Version 16.3) [Computer Software]. App Store. https://developer.apple.com/xcode/

Baker, R., Camosso-Stefinovic, J., Gillies, C., Shaw, E. J., Cheater, F., Flottorp, S., Robertson, N., Wensing, M., Fiander, M., Eccles, M. P., Godycki-Cwirko, M., Van Lieshout, J., & Jäger, C. (2015). Tailored interventions to address determinants of practice. *Cochrane Library*, *2015*(4). https://doi.org/10.1002/14651858.cd005470.pub3

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].

Bentley, T. G. K., D'Andrea-Penna, G., Rakic, M., Arce, N., LaFaille, M., Berman, R., Cooley, K., & Sprimont, P. (2023). Breathing Practices for Stress and Anxiety Reduction: Conceptual Framework of Implementation Guidelines based on a systematic review of the published literature. *Brain Sciences*, *13*(12), 1–52. https://doi.org/10.3390/brainsci13121612

Bergelson, I., Tracy, C., & Takacs, E. (2022). Best practices for reducing bias in the interview process. *Current Urology Reports*, *23*(11), 319–325. https://doi.org/10.1007/s11934-022-01116-7

Bostic, T. J., Rubio, D. M., & Hood, M. (2000). A validation of the subjective vitality scale using structural equation modeling. Social Indicators Research, 52, 313-324.

British Design Council. (2005). *The Double Diamond*. https://www.designcouncil.org.uk/our-resources/the-double-diamond/

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

Castillo, I., Tomás, I., & Balaguer, I. (2017). The Spanish-Version of the Subjective Vitality Scale: Psychometric Properties and Evidence of Validity. *The Spanish Journal of Psychology*, *20*. https://doi.org/10.1017/sjp.2017.22

Conrad, A., Müller, A., Doberenz, S., Kim, S., Meuret, A. E., Wollburg, E., & Roth, W. T. (2007). Psychophysiological effects of breathing Instructions for stress Management.

Applied Psychophysiology and Biofeedback, *32*(2), 89–98. https://doi.org/10.1007/s10484-007-9034-x

Cortez-Vázquez, G., Adriaanse, M., Burchell, G. L., Ostelo, R., Panayiotou, G., & Vlemincx, E. (2024). Virtual Reality Breathing Interventions for Mental Health: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Applied Psychophysiology and Biofeedback*, *49*(1), 1–21. https://doi.org/10.1007/s10484-023-09611-4

Delgado-Lobete, L., Montes-Montes, R., Vila-Paz, A., Talavera-Valverde, M., Cruz-Valiño, J., Gándara-Gafo, B., Ávila-álvarez, A., & 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

Desmedt, O., Luminet, O., Maurage, P., & Corneille, O. (2025). Discrepancies in the Definition and Measurement of Human Interoception: A Comprehensive Discussion and Suggested Ways Forward. *Perspectives on Psychological Science*, *20*(1), 76–98. https://doi.org/10.1177/17456916231191537

Van Diest, I., Verstappen, K., Aubert, A. E., Widjaja, D., Vansteenwegen, D., & Vlemincx, E. (2014). Inhalation/Exhalation ratio modulates the effect of slow breathing on heart rate variability and relaxation. *Applied Psychophysiology and Biofeedback*, *39*(3–4), 171–180. https://doi.org/10.1007/s10484-014-9253-x

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Franke, M. (2024). The feasibility of virtual reality as exercise therapy for axial spondyloarthritis in a home and a physiotherapy setting. [Master's thesis, University of Twente].

Gholamrezaei, A., Van Diest, I., Aziz, Q., Vlaeyen, J. W. S., & Van Oudenhove, L. (2020). Psychophysiological responses to various slow, deep breathing techniques. *Psychophysiology*, *58*(2). https://doi.org/10.1111/psyp.13712

Hu, G., Yao, P., Wan, M., Bao, W., & Zeng, W. (2022). Detection and classification of diseased pine trees with different levels of severity from UAV remote sensing images. *Elsevier*, *72*. https://doi.org/10.1016/j.ecoinf.2022.101844

Hutmacher, F., & Appel, M. (2022). The Psychology of Personalization in Digital Environments: From Motivation to Well-Being – A Theoretical integration. *Review of General Psychology*, *27*(1), 26–40. https://doi.org/10.1177/10892680221105663

Jeong, H. S., Oh, J., Paik, M., Kim, H., Jang, S., Kim, B. S., & Kim, J. (2022). Development and feasibility Assessment of Virtual Reality-Based Relaxation Self-Training Program. *Frontiers in Virtual Reality*, *2*. https://doi.org/10.3389/frvir.2021.722558

Ketelhut, S., Querciagrossa, D., Bisang, X., Metry, X., Borter, E., & Nigg, C. R. (2023). The effectiveness of the Wim Hof method on cardiac autonomic function, blood pressure, arterial compliance, and different psychological parameters. *Scientific Reports*, *13*(1). https://doi.org/10.1038/s41598-023-44902-0

Klooster, I. T., Kip, H., Beyer, S. L., Van Gemert-Pijnen, L. J. E. W. C., & Kelders, S. M. (2024). Clarifying the concepts of personalization and tailoring of eHealth Technologies: Multimethod Qualitative study. *Journal of Medical Internet Research*, *26*, e50497. https://doi.org/10.2196/50497

Korporaal, L. A. (2023). *Studying the Effect of Added Exercises to VR Nature on Feelings of Subjective Vitality, Energy Tension and Stress in Students.* [Master's thesis, University of Twente].

Lim, C., & In, J. (2019). Randomization in clinical studies. *Korean Journal of Anesthesiology*, *72*(3), 221–232. https://doi.org/10.4097/kja.19049

Miner, N., Abdollahi, A., Myers, C., Kosa, M., Ghaednia, H., Schwab, J. H., Harteveld, C., & Troiano, G. M. (2024). Stairway to Heaven: A Gamified VR Journey for Breath Awareness. *Conference on Human Factors in Computing Systems*, 1–19. https://doi.org/10.1145/3613904.3641986

Minina, A. (2023). *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.* [Master's thesis, University of Twente].

McHugh, S. M., Riordan, F., Curran, G. M., Lewis, C. C., Wolfenden, L., Presseau, J., Lengnick-Hall, R., & Powell, B. J. (2022). Conceptual tensions and practical trade-offs in tailoring implementation interventions. *Frontiers in Health Services*, *2*. https://doi.org/10.3389/frhs.2022.974095

Naeem, M., Ozuem, W., Howell, K., & Ranfagni, S. (2023). A Step-by-Step process of thematic analysis to develop a conceptual model in qualitative research. *International Journal of Qualitative Methods*, *22*. https://doi.org/10.1177/16094069231205789

Orji, R., Oyibo, K., & Tondello, G. F. (2017). A Comparison of System-Controlled and User-Controlled Personalization Approaches. *Adjunct Proceedings of ACM UMAP Conference,* 413–418. https://doi.org/10.1145/3099023.3099116

Ortigosa-Márquez, J. M., Carranque-Cháves, G. A., & Mendo, A. H. (2015). Effects of autogenic training on lung capacity, competitive anxiety and subjective vitality. *Biomedical Research*, *26*(1), 71–76. https://www.researchgate.net/publication/273256916_Effects_of_autogenic_training_on_lung_capacity_competitive_anxiety_and_subjective_vitality

Pancini, E., Di Natale, A. F., & Villani, D. (2025). Breathing in virtual reality for promoting mental health: a scoping review. *Virtual Reality*, *29*(1). https://doi.org/10.1007/s10055-024-01096-8

Pardini, S., Gabrielli, S., Dianti, M., Novara, C., Zucco, G., Mich, O., & Forti, S. (2022). The Role of Personalization in the User Experience, Preferences and Engagement with Virtual Reality Environments for Relaxation. *International Journal of Environmental Research and Public Health*, *19*(12), 7237. https://doi.org/10.3390/ijerph19127237

Pardini, S., Gabrielli, S., Gios, L., Dianti, M., Mayora-Ibarra, O., Appel, L., Olivetto, S., Torres, A., Rigatti, P., Trentini, E., Leonardelli, L., Bernardi, M., Lucianer, M., Forti, S., & Novara, C. (2023). Customized virtual reality naturalistic scenarios promoting engagement and relaxation in patients with cognitive impairment: a proof-of-concept mixed-methods study. *Scientific Reports*, *13*(1). https://doi.org/10.1038/s41598-023-47876-1

Pardini, S., Gabrielli, S., Olivetto, S., Fusina, F., Dianti, M., Forti, S., Lancini, C., & Novara, C. (2024). Can personalized Virtual Reality be better than Guided Imagery in enhancing the impact of Progressive Muscle Relaxation Training?: A Pilot Randomized Controlled Study on an Italian university sample (Preprint). *JMIR Mental Health*, *11*, e48649. https://doi.org/10.2196/48649

Patibanda, R., Mueller, F., Leskovsek, M., & Duckworth, J. (2017). Life Tree: Understanding the design of breathing exercise games [Journal-article]. *CHI PLAY '17*. https://doi.org/10.1145/3116595.3116621

Petty, R. E., & Cacioppo, J. T. (1986). The elaboration likelihood model of persuasion. In *Communication and Persuasion*. Springer-Verlag. https://doi.org/10.1007/978-1-4612-4964-1

Qualtrics XM (2005). Qualtrics (Version April 2025) [Computer Software]. Retrieved from https://www.qualtrics.com

R Core Team (2025). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Rojiani, R., Santoyo, J. F., Rahrig, H., Roth, H. D., & Britton, W. B. (2017). Women benefit more than men in response to college-based meditation training. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.00551

Ryan, R. M., Deci, E. L., & University of Rochester. (2000). Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. In American Psychological Association, *American Psychologist, 55*, 68–78. https://selfdeterminationtheory.org/SDT/documents/2000_RyanDeci_SDT.pdf

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, 529-565.

Sbitan, L., Alzraikat, N., Tanous, H., Saad, A. M., & Odeh, M. (2025). From one size fits all to a tailored approach: integrating precision medicine into medical education. *BMC Medical Education*, *25*(1). https://doi.org/10.1186/s12909-024-06138-y

Shaffer, F., & Meehan, Z. M. (2020). A Practical Guide to resonance Frequency Assessment for heart rate Variability Biofeedback. *Frontiers in Neuroscience*, *14*. https://doi.org/10.3389/fnins.2020.570400

Sharma, V. K., Trakroo, M., Subramaniam, V., Rajajeyakumar, M., Bhavanani, A. B., & Sahai, A. (2013). Effect of fast and slow pranayama on perceived stress and cardiovascular parameters in young health-care students. *International Journal of Yoga*, *6*. https://pmc.ncbi.nlm.nih.gov/articles/PMC3734635/

Steffen, P. R., Bartlett, D., Channell, R. M., Jackman, K., Cressman, M., Bills, J., & Pescatello, M. (2021). Integrating breathing techniques into psychotherapy to improve HRV: Which approach is best? *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.624254

Unity Game Engine (2024). *Unity* (Version 6) [Computer Software]. https://unity.com/products/unity-engine

Vlemincx, E., & Cortez-Vázquez, G. (2024). Slow breathing for anxiety: A critical perspective towards personalization. In *Anxiety Disorders and Related Conditions,* 67–86. https://doi.org/10.1007/978-3-031-56798-8_4

Vulink, C. (2024). The Effects of Instruction on At-Home Use of the Virtual Reality Environment 'Walk in Nature'. [Bachelor's thesis, University of Twente].

Wasti, S. P., Simkhada, P., Van Teijlingen, E., Sathian, B., & Banerjee, I. (2022). The growing importance of Mixed-Methods research in health. *Deleted Journal*, *12*(1), 1175–1178. https://doi.org/10.3126/nje.v12i1.43633

Weenink, M. (2024). Walk in Nature: exploring the potential of Virtual Reality as exercise therapy in the management of axial Spondyloarthritis. [Master's thesis, University of Twente].

Wild, H., Kyröläinen, A., & Kuperman, V. (2022). How representative are student convenience samples? A study of literacy and numeracy skills in 32 countries. *PLoS ONE*, *17*(7), e0271191. https://doi.org/10.1371/journal.pone.0271191

Zaccaro, A., Piarulli, A., Laurino, M., Garbella, E., Menicucci, D., Neri, B., & Gemignani, A. (2018). How Breath-Control Can Change Your Life: A systematic review on Psycho-Physiological correlates of slow breathing. *Frontiers in Human Neuroscience*, *12*. https://doi.org/10.3389/fnhum.2018.00353

AI Statement

During the preparation of this work, the author used CHATGPT-4 in order to assist in programming the code for randomisation of experimental condition and breathing exercise level within R, as well as the code for movement of the tree in C#. This was done before data collection, and therefore no data was placed into AI. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the work.

Appendix A

Tailoring has often been used synonymously with personalisation and customisation. However, these terms signify different concepts. It is important to define such concepts to standardize research on tailoring (Klooster et al., 2024).

Definitions of Concepts Related to Tailoring

Concept	Definition	Example
Tailoring	Adapting the content or the system itself to either individuals or specific user groups through alterations deemed relevant to the user(s). Uses if-then algorithms for segmentation. Focused on decision rules and computerisation that connects information from the individual user to user group characteristics.	If the user selects answer option C to question 2, then the user is presented with information about the effects of smoking.
Personalisation	Utilises individual characteristics and information, such as preferences, environmental or mental determinants, connected to the content and functionalities for segmentation. Segmentation occurs on an individual level. Focused on identification (user's name) and raising expectations (stating that the information is specifically designed for the user).	The avatar's name is the name of the user.
Segmentation	Partitioning of individuals into homogenous categories based on user characteristics. Allows for customisation (of a message or system) to occur.	All users that respond stating they are smokers receive information related to smoking. Non-smokers do not receive this information.
Customisation	Alteration of a system by the user themselves (user-initiated changes).	Teammates for an activity are suggested to

	the user based on their predefined preferences.

Note. Definitions from this table are based on the work of Klooster and colleagues (2024), with the exception of the definition of tailoring. The definition of tailoring utilised both Klooster et al (2024), McHugh et al. (2022) and Bol et al.'s (2020) definitions. Hutmacher and Appel (2022) add that customisation is a user-initiated process, whereas tailoring and personalisation involve a system-initiated process.

Appendix B

RStudio Code for Randomisation

Randomisation for Research Condition:

```
generate_block_randomization <- function(n, block_size = 4, groups = c("Control", "Experimental")) { if (n %% block_size != 0) { stop("Total number of participants must be divisible by block size") }

assignments <- c() num_blocks <- 10

for (i in 1:num_blocks) { block <- rep(groups, each = block_size / length(groups)) # equal representation assignments <- c(assignments, sample(block)) # shuffle within the block }

return(assignments) }

set.seed(123)

randomized_list <- generate_block_randomization(n = 40, block_size = 4)

randomized_list
```

Randomisation for Control Group:

```
activity_levels <- c("1", "2", "3")

block_size <- length(activity_levels)

num_blocks <- 14

randomized_conditions <- unlist(
        lapply(1:num_blocks, function(i) sample(activity_levels))

randomized_conditions
```

Table 6

Randomisation of Research Condition

Block	Random Assignment
1	experimental, experimental, control, control
2	experimental, control, experimental, control
3	experimental, control, control, experimental
4	control, control, experimental, experimental
5	experimental, control, experimental, control
6	control, experimental, experimental, control
7	experimental, control, control, experimental
8	control, control, experimental, experimental
9	control, control, experimental, experimental
10	control, experimental, control, experimental

Table 7

Randomisation of Assignment of Breathing Activity Level within Control Group by Block

Block	Random Assignment
1	Level 1, level 2, level 3
2	Level 2, level 1, level 3
3	Level 3, level 2, level 1
4	Level 3, level 1, level 2
5	Level 1, level 3, level 2
6	Level 3, level 2, level 1
7	Level 3, level 2, level 1

Appendix C

Information Sheet and Informed Consent Form

Welcome to the Walk in Nature Study!

The purpose of this research is to determine the effects of a VR-based breathing intervention on subjective vitality (how alive and energetic you feel) and motivation to use the intervention again. This research aims to target a wide audience, as the end purpose of the Walk in Nature intervention is for at-home use by a broad range of individuals suffering from different complaints. Therefore, this study will involve questions regarding demographic data and subjective vitality. Following these questions, you will enter the "Walk in Nature" virtual environment and complete the breathing activity. Afterwards, you will answer questions regarding subjective vitality again, motivation, and an interview will take place to determine your experience during the VR environment.

This research can take up to 45 minutes. If you would like to participate, you will experience the virtual environment either from the control or experiment group, which has been predetermined via a randomised calculation. Both groups will get a breathing intervention. After participation (intervention and interview), the researcher will inform you of which group you were assigned to.

Benefits and Risks

Please note that this research:

- has been approved by the BMS Ethics Committee
- is completely voluntary, and you may withdraw or restrict use of your data at any point in time without providing an explanation
- may provide temporary, immediate benefits after the breathing exercise via stress reduction or feelings of relaxation
- may cause nausea, motion sickness, or dizziness from wearing a virtual reality headset
- may cause light headedness, shortness of breath, or frustration from breathing exercises
- If you notice these symptoms associated with VR or breathing exercises, research will be immediately terminated.

Data

Age, nationality, and gender will be collected anonymously and will be used to describe the sample. All data collected will be anonymously and safely stored, under the General Data Protection Regulation (GDPR) guidelines. Your data will only be retained for as long as necessary for the research. After the research is completed, all data will be archived in a safe storage systems by the University of Twente for 10 years to meet requirements of verification and accountability within scientific research. The researcher has collected your contact information and name to determine contact for participation. Upon the day of the experiment, this information will be deleted, and your answers will be recorded anonymously via being assigned a random participant number.

Contact

If you have any remaining questions or concerns, please feel free to contact the researcher. 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 providing your consent below, you acknowledge the following:

- My participation in the study is voluntary, and I understand that I can refuse to answer questions and can withdraw from the study at any time, without having to give a reason.
- I have read and understood the study information, and have been able to ask questions about the study. My questions have been answered to my satisfaction.
- I am 18+ years of age
- I understand that taking part in the study involves myself, the participant, answering a survey questionnaire completed via Qualtrics, in which the answers to each question will be collected.
- I understand that taking part in the study involves the following risks: feeling nauseous, dizzy, motion-sick, or short of breath from either virtual reality or breathing exercises. However, I have no history of epilepsy, motion sickness, or shortness of breath either from virtual reality, breathing exercises, or both.
- I have no severe visual or hearing impairments.

- I understand that personal information collected about me that can identify me, such as my age and nationality, will not be shared with anyone. After participation, I understand that my data will be anonymised.
- I give permission for the questionnaire answers that I provide to be archived in UT-drive and GitLab by the University of Twente, so it can be safely stored and used for future research and learning.
  - I consent, begin the study
  - I do not consent, I do not wish to participate

Informed Consent for Interview (Audio Recording)

I, participant number (your participant number), provide my consent to being audio recorded for the Walk in Nature study and for this audio recording to be transcribed as text later on. I consent to possibly being anonymously quoted for use in the master's thesis. I understand that this is done so that the researcher can collect data about my subjective experience during the virtual reality intervention.

Reminder

Dear participant,

Thank you once again for signing up to the Walk in Nature (breathing exercise within VR) study. In two days, you will participate at TIME. If possible, please arrive at the location 5 minutes before your participation time to ensure that there are no delays due to a busy schedule.

Please find attached the information sheet regarding the study. This will be presented to you on the day of the study again, as you will be asked to provide your consent to participate. If you have any questions or concerns before participation, please feel free to discuss them with the researcher.

Appendix D

Breathing Questionnaire

Q1_Experience Level

Please select the appropriate number to indicate how true the following statement is for you *in general.*

I have knowledge about structured breathing exercises (such as meditation, box breathing, alternate nostril breathing).

1	2	3	4	5	6	7
Not at all true						Very true

Q2_Experience Level

Please select the appropriate number to indicate how true the following statement is for you *in the past week.*

I have practiced structured breathing exercises (such as meditation, box breathing, alternate nostril breathing) in the past week.

1	2	3	4	5	6	7
Not at all true						Very true

Q3_Experience Level

Please select the appropriate number to indicate how true the following statement is for you *in general.*

In general, I have practiced structured breathing exercises (such as meditation, box breathing, alternate nostril breathing).

1	2	3	4	5	6	7
Not at all true						Very true

Q4_TechnicalLevel

Please select the appropriate number to indicate how true the following statement is for you *in general.*

I can comfortably extend my exhalation longer than my inhalation (such as inhaling for 4 seconds and exhaling for 8 seconds)

1	2	3	4	5	6	7
Not at all true						Very true

Q5_TechnicalLevel

Please select the appropriate number to indicate how true the following statement is for you *in general.*

I have control over my breathing.

1	2	3	4	5	6	7
Not at all true						Very true

Q6_TechnicalLevel

Please select the appropriate number to indicate how true the following statement is for you *in general.*

I often find that my breathing is shallow.

1	2	3	4	5	6	7
Not at all true						Very true

Q7_TechnicalLevel

Please select the appropriate number to indicate how true the following statement is for you *in general.*

I can comfortably complete a breathing exercise for 10 minutes.

1	2	3	4	5	6	7
Not at all true						Very true

To create a summative score, all questions should be added together. This can be followed by completing the following equation: SCORE = (Q1+Q2+Q3+Q4+Q5+Q7) + Q6edited*.

*Q6edited indicates that scores from Q6 should be reverse scored. For example, if an individual scores 2, this score should be calculated as 6 when creating the summative score.

Appendix E

Due to privacy and licensing rights of the Walk in Nature intervention, this appendix has been redacted.

Appendix F

State Level Subjective Vitality Scale

Taken from Ryan and Frederick (1997). The second question ("I don't feel very energetic right now") was removed.

Please respond to each of the following statements in terms of how you are feeling **right now**. Indicate how true each statement is for you at this time, using the following scale:

1	2	3	4	5	6	7
not at all true			somewhat true			very true

1. At this moment, I feel alive and vital.
2. I don't feel very energetic right now.
3. Currently I feel so alive I just want to burst.
4. At this time, I have energy and spirit.
5. I am looking forward to each new day.
6. At this moment, I feel alert and awake.
7. I feel energized right now.

Appendix G

1. Please select the appropriate number to indicate how true the following statement is for you *for this experiment:* I felt that the virtual environment adapted the breathing task to my prior experience with structured breathing exercises.
    a. 1 (Not at all true), 2, 3, 4, 5, 6, 7 (Very true)
2. Please select the appropriate number to indicate how true the following statement is for you *for this experiment:* I felt that the virtual environment adapted the breathing task to my skill level.
    a. 1 (Not at all true), 2, 3, 4, 5, 6, 7 (Very true)
3. Please select the appropriate number to indicate how true the following statement is for you *in general:* I would use this virtual reality intervention again in the future to increase my energy and the feeling of being alive.
    a. 1 (Not at all true), 2, 3, 4 (Somewhat true), 5, 6, 7 (Very true)
4. Please select the appropriate number to indicate how true the following statement is for you *in general:* When dealing with a problem, feeling stressed or fatigued, I would think about using this virtual reality intervention.
    a. 1 (Not at all true), 2, 3, 4 (Somewhat true), 5, 6, 7 (Very true)
5. Please select the appropriate number to indicate how true the following statement is for you *in general:* I would use this virtual reality breathing intervention (that I experienced today) again in the future one or more times per week.
    a. 1 (Not at all true), 2, 3, 4 (Somewhat true), 5, 6, 7 (Very true)

Appendix H

Feedback on Tailoring

1. In what (other) ways would you prefer the breathing exercise to adapt to you specifically? Examples could be adapting to your personal breathing rate, selecting the voice (gender) and volume sound of the audio instructions, or the way that the tree looks.
2. Do you believe that this breathing exercise within VR is relevant and would be beneficial for you specifically? Why/why not?
3. What aspects of the intervention would motivate you to continue using it?
4. What aspects of the intervention would discourage you from continuing to use it?

Appendix I

Coding for thematic analysis of the post-intervention interviews, findings from all participants in both groups.

Mental States			
Code	**Definition**	**Frequency**	**Quote**
Calmness	Explicit mention of feeling calm or relaxed due to certain variables within the intervention as a whole.	Control (n=4) Experimental (n=5)	“It was very soothing, very relaxing. It was therapeutic.” (P300)
Code	**Definition**	**Frequency**	**Quote**
Subjective vitality	Explicit mention of feeling alive or energetic due to certain variables within the intervention as a whole.	Control (n=2) Experimental (n=2)	“It helps you focus again and it takes away a bit of the tiredness, makes you feel alive." (P865)
Code	**Definition**	**Frequency**	**Quote**
Stress	Explicit mention of feeling stressed due to certain variables within the intervention as a whole.	Control (n=1) Experimental (n=2)	“Trying to keep exhaling even when you don't really have the air to exhale anymore just made me feel, um, well, worse because that is really stressing [me] out because, like, you can't breathe.“ (P940)
Customisation			
Code	**Definition**	**Frequency**	**Quote**
Customisation of Guidance Elements	Reference to liking or disliking certain formats of guidance, and wanting to select or remove forms of	Control (n=9)	“I think I would have liked the opportunity to remove some visual aspects. I found that having both the bubble or the

	guidance, such as the bubble, audio, or addition of other guidance elements.	Experimental (n=11)	circle and the tree, uh, was a bit confusing. I didn't really know what to look at. So for me personally, it would have been nice to be able to edit out one of them." (P139)
Code	**Definition**	**Frequency**	**Quote**
Customisation of Environment	Desire for more customisable options for the visuals of or variables within the environment to increase relevance and motivation.	Control (n=9) Experimental (n=4)	"I want to grow [a] different kind of tree...probably also [a] different natural setting like at the beach with the sea." (P365)
Code	**Definition**	**Frequency**	**Quote**
Customisation of breathing exercise	Preference for having the option to select different types of breathing exercises, rhythms, or duration of the breathing exercise.	Control (n=3) Experimental (n=2)	"I know those apps you can sort of like set like how much time you want to have it in each session. And I think it might be good." (P302)
Engagement			
Code	**Definition**	**Frequency**	**Quote**
VR as a Hindrance and Facilitator	Mention of decreased relevance or benefit due to VR being inaccessible, expensive, or difficult to set-up. Also mentioning preference for closing one's eyes during breathing exercises or preference for	Control (n=14) Experimental (n=12)	**"**I would rather just sit in an actual naturistic place rather than like, yeah, just kind of televise it through technology." (P692)

	being in an actual forest/nature setting.		
Code	**Definition**	**Frequency**	**Quote**
Interactive Visual Reinforcement	Mention of the storyline of breathing a tree back to life, and the visual changes within the tree guiding the user by providing a sense of interaction with the environment, or a sense that one's breathing efforts are reflected within the tree.	Control (n=13) Experimental (n=12)	"I definitely like the tree and that I, that it's more engaging than like normal breathing exercises...the whole environment, that it feels like you're doing something with your breathing, and that makes it more conscious to me like that my breathing is making me like feeling more alive kind of." (P506)
Impact of Tailoring on User			
Code	**Definition**	**Frequency**	**Quote**
Difficulty Level	Perception of the alignment or misalignment of the breathing exercise with user skill level and experience with breathing exercises.	Control (n=11) Experimental (n=13)	"For me it was a little bit hard, uh, for a couple of minutes to keep that pace. It was I was a bit out of out of rhythm. And then that distracted me a little bit... it was a little bit too slow." (P643)
Code	**Definition**	**Frequency**	**Quote**
Adaptation	A desire for the VRE to adjust to their breathing rate, heart rate, or other biomarkers.	Control (n=12) Experimental (n=5)	"Something you can monitor, like with heart rate or with anything else. So the tree also kind of acknowledges when you're a bit behind on the

			exercise and maybe it waits up or it's asked you to maybe exhale one second slower or something, maybe something like that." (P470)