

THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Exploring Strategies and Challenges to Improve Well-Being of Software Engineers

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*“Contrariwise, if it was so, it might be; and if it were so, it would
be; but as it isn’t, it ain’t. That’s logic.”*
- LC

Abstract

Context: Computer professionals, such as software developers, frequently experience stress due to numerous deadlines and the pressure to deliver. Their education should equip them with strategies to maintain long-term well-being and counteract the detrimental impacts of stress. Additionally, the intricate relationship between the psychological well-being of software engineers and the complex programs they create underscores the pressing necessity to prioritise mental health, particularly in high-stakes software development fields.

Objective: This research aims to evaluate the benefits of neuroplasticity practices on computer workers. By exploring strategies and challenges, we seek to uncover their benefits and usefulness in enhancing well-being and resilience. This leads to more efficiency and effectiveness, decreased burnout rates, and lower risk of depression.

Method: This research used different empirical methodologies to collect data, such as the design and implementation of two different interventions, interviews, and surveys. The data was analysed using thematic analysis and constructive grounded theory for the qualitative data and descriptive, frequentist and Bayesian statistics for the quantitative one.

Findings: The results of the two interventions showed positive results, mainly in the qualitative data. Participants reported a positive experience of enhanced well-being and relaxation. Regarding the quantitative data, the participants' assessments of how frequently they felt upbeat improved, as evidenced by our findings. We proposed a theory that explains how the fundamental principles, elements, dimensions, and complex interconnections that contribute to well-being synergistically shape their lives and work experiences. Finally, we tested a pilot method to integrate neuroplasticity practices into education.

Conclusion: This research found that integrating neuroplasticity practises to increase resilience and well-being among computer workers was effective among our participants. Additionally, a thorough theory explaining the complex factors influencing well-being and resilience was proposed. Finally, we proposed a pilot methodology to incorporate neuroplasticity practises into education.

Keywords

Well-being, Resilience, Neuroplasticity, Computer workers, Individual sustainability

Acknowledgment

A mi mamá, and all the minds that have accompanied me, inspired, supported, listened, challenged, and motivated me, thank you all.

List of Publications

Appended publications

This thesis is based on the following publications:

- [A] B. Penzenstadler, R. Torkar, C. Martinez “Take a deep breath: Benefits of neuroplasticity practices for software developers and computer workers in a family of experiments”
International Journal Empirical Software Engineering (EMSE), 2022 .
- [B] C. Martinez, B. Penzenstadler “Improved Wellbeing and Resilience via Breathwork Interventions for Computer Workers”
In submission to Journal Scientific Reports.
- [C] C. Martinez, B. Penzenstadler “Breathewell Grounded Theory: Self-discovery and Personal Growth in Computer Workers through Well-Being Practices”
In submission to Journal Frontiers in Psychology.
- [D] C. Martinez, B. Penzenstadler “Piloting a well-being and resilience intervention in a course on digitalization for sustainability”
Fifth International Workshop on ICT for Sustainable Education (ICT4SEdu), 2023.

Research Contribution

In this section, I describe my contributions to the appended papers.

In Paper A, I performed and wrote the qualitative analysis and cleaned and prepared the database for the quantitative analysis.

In Paper B, I did the analysis and wrote the whole paper.

In Paper C, I led the third round of the implemented course, I also led the team to perform the data analysis and wrote most of the paper.

In Paper D, I collaborate on the design of the data collection instruments, I did the qualitative and quantitative analysis and wrote most of the paper.

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Chapter 1

Introduction

In the ever-evolving landscape of technology-driven workplaces, the well-being of computer workers, referring to individuals whose occupation primarily involves tasks related to working with computers and technology, has garnered increasing attention as a critical facet of individual and organisational success. This encompassing term includes software engineers, programmers, IT professionals, data analysts, digital designers, and others who extensively utilise computers in their job roles. These individuals often engage in coding, software development, data analysis, digital design, and other computer-centric activities. Similarly, physical, mental, and emotional resilience is required to make wise decisions under duress, maintain health, and have a high quality of life [1]. This escalating focus stems from recognising that the demands of the modern professional environment, particularly among software engineers and other computer professionals, often lead to accelerated and stress-laden lives. This has a detrimental impact on their well-being and overall job satisfaction, as highlighted by research conducted by Ostberg et al. [2] and Graziotin et al. [3].

The emergence of the global pandemic further exacerbated these challenges, causing disruptions that rippled across productivity and well-being, as evidenced by Ralph et al. [4]. A striking example is the sudden shift to remote work during crisis periods, which typically correlates with decreased motivation, productivity, and commitment, as identified by Donnelly and Proctor Thomson [5]. Their research focused on post-disaster home-based telework (HbTW) experiences of over 240 public sector workers and managers following earthquakes in Christchurch, New Zealand. They found significant variations in experiences and perceptions of HbTW. This variance underscores their pivotal role, particularly in pandemic-induced complexities, where maintaining control becomes even more critical.

As contemporary studies have fervently investigated the intricate relationship between stress and cognitive task performance, exemplified by the research of Medvedyk [6], Marek [7], and Akula and Cusick [8], a more comprehensive understanding of stress's implications has begun to unfold. Amin et al. [9] found that occupational stress can detrimentally affect knowledge exchange, hampering software systems' development.

Noteworthy is the phenomenon of the “Great Resignation” witnessed in





2022, which saw a substantial exodus of employees from the technology and healthcare sectors due to heightened workloads and burnout rates, underscoring the urgency of addressing well-being issues [10].

Among computer workers, software engineers stand out with worrying data. Startling data show the increased probability of employee suicide among software developers in the United States [11]. Meanwhile, in the United Kingdom, an alarming 83 per cent of respondents reported frequent burnout at work, emphasising the widespread nature of this issue [12].

Claes [13] delves into the work patterns and indicators of overload software developers face, a concern closely tied to the potential for burnout resulting from prolonged work demands. By examining the shift of Mozilla Firefox to rapid release cycles, the research brings to light more sustainable patterns, notably reflecting decreased activity during weekends and outside office hours. Comparatively, these positive trends are emphasised when contrasted with the work patterns of Firefox OS. The study aligns with Fucci et al. [14], who identified that software developers frequently extend their working hours significantly to fulfil project deadlines, further emphasising the significance of analysing and addressing work-related challenges in this field. Akula and Cusick [8] evaluated the effects of stress on software quality.

Furthermore, the mental well-being of software engineers plays a pivotal role in determining the quality of the code they produce and their adherence to established processes [3]. This dynamic interaction between mental health and professional output yields far-reaching consequences, particularly in products and systems used in high-risk industries such as healthcare. When software engineers grapple with compromised mental well-being, it can directly translate into suboptimal code quality and deviations from essential protocols.

The complex relationship between the psychological state of software engineers and the complex code they write highlights the urgent need to treat mental health within the software development framework, particularly in domains where the stakes are extraordinarily high.

Considering contemporary studies that explore the benefits of neuroplasticity practices for well-being, and inspired by the findings of Bernardez et al. [15,16] showcasing how mindfulness positively impacts cognitive tasks, this study delves into the potential advantages of integrating neuroplasticity practices, specifically breathwork, for computer professionals. The brain's adaptability through neuroplasticity supports the notion that such practices can positively influence mental health, resilience, and cognitive performance. Breathwork was selected due to its accessibility and potential benefits for stress reduction and cognitive enhancement, as clarified in the preceding elaboration.

This thesis aimed to explore and analyse the advantages and applicability of neuroplasticity practices, specifically breathwork, for computer workers to improve and enhance well-being and resilience, resulting in more effectiveness and efficiency, lower burnout rates, and reduced risk of depression.

1.1 Research Focus

The goal was to evaluate the benefits and usefulness of neuroplasticity practices for computer workers to increase well-being and resilience, leading to more



efficiency and effectiveness, decreased burnout rates, and lower risk of depression. The research project used a quasi-experiment method, where we designed, implemented and measured the impact of two intervention programmes.

To reach this goal, we formulated the following research questions:

RQ1. How to measure the effectiveness of a neuroplasticity practice in terms of effects on well-being and resilience?

RQ1 aimed to explore a specific methodology and tools to determine whether a neuroplasticity practice positively impacts computer workers' well-being and resilience. It has two focuses; first, we wanted to comprehend how well-being and resilience of computer workers can be improved by a specific neuroplasticity practice such as breathwork. Secondly, the ultimate goal was to propose a procedure for assessing the impact of the neuroplasticity practice. Our purpose was to find suitable methods, instruments, and research plans for evaluating the practice's quantitative and qualitative effects on well-being and resilience.



RQ2. What are the benefits and challenges of implementing breathwork interventions among computer workers, and how do these interventions affect their overall efficiency, productivity, and susceptibility to burnout and depression?

This RQ's goal was to investigate in-depth computer workers' experiences of practising breathwork exercises to improve their well-being. It aimed to comprehend our programme participants' viewpoints on the advantages and difficulties of this practice. We wanted to get insightful information about the practical use of a breathing method for stress reduction. The foundation for long-term improvements in resilience and well-being, essential components of personal sustainability, was another goal we had in mind with this question.

RQ3. What are the key principles, components, dimensions, and interactions that contribute to computer workers' well-being, and how do these factors interrelate to shape their experiences?

We sought to examine and clarify the fundamental ideas, essential elements, significant factors, and complex interconnections that collectively support the well-being of computer professionals. This RQ helped us to uncover the interrelationships among these factors, giving a thorough grasp of how they operate together to shape individuals' experiences while cultivating well-being and resilience. We aimed to propose a theory based on the findings.

RQ4. To what effect and why to integrate neuroplasticity practices effectively into computer work education and practice to enhance individual well-being, resilience and mental health?

This RQ aimed to lay the groundwork for the significance of including sustainability capabilities in computing education. To achieve it, we designed and implemented a course titled "Digitalization in a Changing World" to emphasise the critical importance of personal well-being and resilience as a precondition for creating IT solutions that align with the Sustainable Development Goals. We sought to highlight the transformative potential of fostering these features inside the academic curriculum, particularly in the IT disciplines.



To answer the above RQs, four papers are included in this thesis: A, B, C and D. All papers employed empirical methodologies for data collection, with a specific focus on the utilisation of two meticulously customised intervention programs. Similarly, we used various data analysis methods to understand holistically deeply. Figure 1.1 presents an overview of this thesis mapping the RQs, papers and methodologies used.

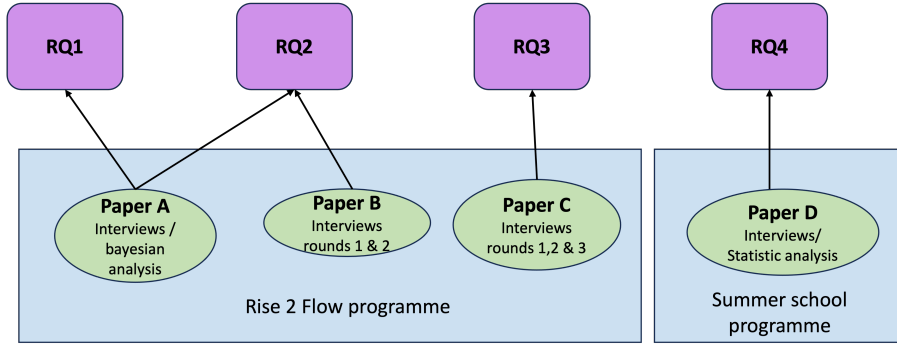


Figure 1.1: Thesis Overview



1.2 Background

The context for the various theoretical perspectives and ideas that influenced this study is fully laid out in the lines that follow. The main concepts of this thesis are presented in Table 1.1

Concept	Definition
Attention	The behavioural and cognitive process of selectively concentrating on a discrete aspect of information [17]
Attention capacity	Amount of cognitive resources available within a person [18]
Awareness	The quality or state of being aware, knowledge and understanding that something is happening or exists [19]
Mindfulness	A state of consciousness, the practice of purposely bringing one's attention in the present moment without evaluation [20]
Mindfulness Attention Awareness	Present-centered attention-awareness [21, p. 824]
Neuroplasticity	Ability of the nervous system to respond to intrinsic or extrinsic stimuli by reorganizing its structure, function and connections [22, p. 1591]
Resilience	Positive adaptation, or the ability to maintain or regain mental health, despite experiencing adversity [1]
Self efficacy	People's beliefs about their capabilities to produce effects. [23]
Stress	Non-specific response of the body to a demand [24]
Well-being	What is non-instrumentally or ultimately good for a person [25]



Table 1.1: Summary of the most important terms relevant to the thesis.

1.2.1 Well-being

It has long been believed that promoting well-being is crucial to creating prosperous and healthy societies. There are various definitions, but they all share one thing: well-being is not binary but rather a continuum [26]. Furthermore, there are many components and dimensions that makeup well-being. For instance, from the hedonic (i.e., pleasure) and eudaimonic (i.e., purposes) conceptualisations perspective, cognitive, affective, and behavioural aspects influence well-being [27]. Similar to this, other conceptualisations included a variety of aspects, especially social ones [28,29]. Since each variable is prone to alter over time, mental well-being is a relatively mutable condition [26].

There are various techniques to assess well-being, just as numerous conceptions of what it is. One of those measures is the people's subjective one, which includes aspects like how individuals view and experience life. The term used to describe this approach to assessing perceptions and experiences is subjective well-being (SWB). Diener [30] defines it as 'a person feeling and thinking his or her life is desirable regardless of how others see it', emphasising its feeling and thinking aspects. The affective and emotional component is the feeling, and higher SWB is fueled by pleasant emotions outweighing negative ones. The thinking dimension comprises the evaluative and cognitive aspects where higher SWB is achieved through evaluating individuals' lives mostly favourably [31].



1.2.2 Resilience

Research on resilience has been ongoing for a while. This has led to various resilience definitions, models, and theories. A common aspect among these definitions, models, and theories is that resilience is not a one-dimensional construct. Another important aspect is that most models and theories are based on populations with risk factors. Thus, the clinical population has served as the foundation for resilience theories, as demonstrated by research that focused on people who must deal with potentially traumatic experiences, as noted by Fletcher [32] and Mancini [33]. Contrary to populations that have been "forced" and exposed to traumatic experiences, the findings of these theories may be difficult to apply to people who are not directly in traumatic situations but in heavy demand for cognitive processes. Such is the case of computer workers. To encourage healthy coping mechanisms and reduce poor coping and stress reactions, it is essential to understand how to improve resilience in specific groups.



For the purposes of this study, we used Herrman's definition of resilience as as positive adaptation, or the ability to maintain or regain mental health, despite experiencing adversity [1].

1.2.3 Mindfulness, Attention, Awareness

Mindfulness is defined, for the purpose of this study, as a state of consciousness, the practice of purposely bringing one's attention in the present moment without evaluation [20]. Mindfulness-based practices have been researched since 1979. Kabat-Zinn has contributed by developing a programme aimed at reducing stress that has been replicated successfully all over the world. The results

have proven to be efficient in increasing immune system response and having a positive effect on emotionally stressful situations [34].

Attention, on the other hand, is understood as the behavioural and cognitive process of selectively concentrating on a discrete aspect of information [17]. According to Westen [35], consciousness includes both awareness and attention. Brown created a scale to examine empirical links between well-being and mindfulness. This scale, at the same time, focused on the presence or absence of awareness and attention to what is occurring in the present. Hence, Brown defines, in turn, mindfulness attention awareness as one single concept explained as being conscious of being mindful [21].



1.2.4 Breathing Practices



Breathwork encompasses a range of methods involving the regulation of breath, focusing on promoting mental, emotional, and physical well-being [36]. By manipulating breathing patterns, individuals can rapidly alter the communication between the respiratory system and brain centres responsible for behaviour, cognition, and emotion [37]. Additionally, breathing rhythms can harmonise brainwave activities; deliberate slow breathing synchronises with brain electrical patterns, fostering improved inter-regional brain communication [38].

Researchers and educators have observed favourable outcomes resulting from breathwork practices, leading to its popularity in Western contexts. Stanislav Grof identified and named a specific breathwork technique called Holotropic Breathwork, which induces effects similar to LSD consumption. Similarly, Leonard Orr coined the Rebirth Breath pattern following a transformative encounter in a sensory deprivation tank. These methods involve continuous in-breath and out-breath sequences, stimulating the body energetically and potentially triggering cognitive and emotional experiences [39].

Among the practised breathwork techniques, Pranayama is chosen for these studies. Rooted in the Vedic scriptures and the traditions of Ayurveda and Yoga, pranayama combines “prana” (life force) and “ayama” (extension), signifying practices that harness and amplify an individual’s life force energy. This technique aligns with the holistic principles of Ayurveda and Yoga, focusing on the synergy between body, mind, and spirit.

This choice finds robust support in the work of Joshi et al. [40], where a 6-week pranayama course exhibited notable enhancements in ventilatory functions. This encompassed reduced respiratory rates, heightened forced vital capacity, and improved metrics such as maximum voluntary ventilation, peak expiratory flow rate, and breath-holding capacity. Moreover, Pranayama showcases a spectrum of health benefits, including stress reduction and positive impacts on cardiovascular health [41], along with significant improvements in respiratory functioning [42] and cognitive abilities [43]. These multifaceted advantages underscore Pranayama’s potential to holistically enhance well-being, resonating strongly with our study’s aim to explore how this technique can contribute to computer professionals’ overall health and resilience.

1.2.5 Benefits of Breathing Exercises from a Neuroscience and Empirical Perspective

The parasympathetic nervous system depends heavily on the vagus nerve, the biggest cranial nerve in the human body [44]. During stress, our nervous system activates the fight-or-flight response, triggered by the release of epinephrine from the adrenal medulla, situated near the kidneys [45]. To expedite recovery from stress, whether physical, mental, or emotional, it becomes crucial to enhance the function of the vagus nerve [46]. Breathing exercises such as extending, slowing and holding respiration, all regarded as vagal movements on their own, stimulate the vagus nerve [47]. This lays the groundwork for responding to life from a resourced place rather than going into fight-or-flight mode.



The effectiveness of breathing exercises is shown in several studies. For example, numerous investigations have been conducted concerning the Sudarshan Kriya breathing technique taught by The Art of Living¹ organisation. For instance, Seppälä et al. [48] examine the deteriorating mental health on U.S. university campuses and explore three interventions: Sudarshan Kriya breathing (“SKY”; N = 29), Foundations of Emotional Intelligence (“EI”; N = 21), and Mindfulness-Based Stress Reduction (“MBSR”; N = 34). Notably, SKY displays the most significant impact, positively influencing six areas: depression, stress, mental health, mindfulness, positive affect, and social connectedness. Similarly, Sharma et al. [49] investigate the same SKY practice and discover favourable immunological, biochemical, and physiological effects on health (N = 42). Walker and Pacik [50] demonstrate a reduction in Post-Traumatic Stress Disorder cases among Military Veterans. Additionally, Brown and Gerbarg [51] report its successful utilisation in managing stress, anxiety, and depression. Collectively, this set of experiments contributes essential empirical assessment for a related technique, serving as both comparative data and supportive research affirming the broad benefits of breathing practices.



1.2.6 Stress in Software Development and IT Work

The use of information and communication technologies (ICTs) in the workplace today has increased workload requirements and created a noticeable sense of urgency [52]. This change has been associated with the emergence of a digital work culture, where the use of ICTs promotes the assumption that tasks must be completed swiftly and with prompt responses. People frequently feel pressured, if not obligated, to work faster to meet these shifting demands.

Research by Ayyagari et al. [52] and others has demonstrated that computerising office work environments is connected with increased employee stress levels; therefore, this change in work dynamics has not been without consequences.

Previous research has looked at the detrimental effects of stress from various perspectives. Owing to their propensity for working late due to project deadlines, Fucci et al. investigated the effects of all-nighters on software engineers and found that stress affected the quality of their sleep [8, 14].

There is little doubt that issues related to sleep deprivation and irregular circadian rhythms have a detrimental influence on one’s health, as evidenced

¹<https://www.artofliving.org>



by the harmful metabolic effects [53]) and the likelihood of acquiring life-threatening diseases [54, 55]. Last, Penzenstadler et al. [39] investigated the advantages of improving sleep quality and reducing the latent repercussions on physical and mental health.

Another viewpoint is the impact of stress on cognitive task performance; Akula and Cusick examined the impact of stress on software quality [8]. On the other side, Amin et al. investigated the harmful effects of stress on knowledge sharing, specifically in global development settings, leading to negative consequences on software system development [9].

1.2.7 Related Work

According to Graziotin et al. [3] investigation of developer happiness, unhappiness negatively affects the developers' mental health, the software development process, and the final products. To examine variations in the perception of positive and negative affect in experience episodes, they employ the Scale of Positive and Negative Experience (SPANE). However, it is essential to approach this instrument and its findings with caution due to the inherent limitations of self-reported measures. Such measures may introduce response biases and may not capture the full complexity of the developer experience. Additionally, as this study did, sampling from GitHub could lead to an over-representation of open-source developers in the sample, introducing self-selection bias and impacting the generalisability of the results. This thesis similarly utilised the SPANE instrument in our studies, and these considerations regarding self-reported measures and potential sampling biases are crucial for a comprehensive understanding of the findings.

Research by Bernardez et al. [15, 16], demonstrates how mindfulness greatly increases the effectiveness and efficiency of conceptual modelling. Notably, the authors argue that this benefit might be mainly for introverts, a group they suggest dominates the software industry [56]. It is essential to clarify that this assertion is based on their study and perspective rather than a universal fact. Moreover, it is crucial to consider the methodological aspects, such as the small sample size and the representativeness of the software industry.

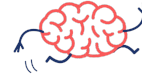
In two researches, Rieken et al. [57] study the connection between diverse thinking, creativity, and mindfulness, particularly among engineering students and recent engineering graduates. In the first, they examined the effects of a 15-minute mindfulness meditation on 92 Stanford University engineering students' performance in divergent thinking. According to earlier research, one meditation can enhance idea development in broad student populations. The divergent thinking activities were more successful for engineering students who reported increased baseline awareness. A single, 15-minute mindfulness practice improved the originality of ideas generated by students for the idea generation assignment. However, it had no noticeable effect on the number of ideas they generated for either the idea generation task or the engineering design task.



The second study measures baseline mindfulness and self-confidence in one's capacity for innovation by analysing survey data from 1400 engineering students and recent graduates from across the U.S. from the longitudinal Engineering Majors Survey [58]. A mindful mindset was the largest predictor

of innovation self-efficacy, and baseline mindfulness predicted innovation self-efficacy across the engineering group. This implies that the more crucial factor is the attentional attitude, or whether someone possesses the “beginner’s mind” mentality, typically called being open-minded, curious, and kind. However, the research’s reliance on surveys and self-assessment measures may introduce response biases and limit the depth of insights into these complex phenomena.

1.3 Research Methodology



This thesis has used two interventions as a starting point to collect data. Two programmes, Rise 2 Flow (R2F) and a one-month intervention as part of a summer school programme named “Digitalization in a Changing World”, were designed, implemented and measured their impact from a quantitative and qualitative perspective. For the quantitative analysis, we used descriptive, Bayesian and frequentist statistics. We used thematic analysis by Braun and Clark [59] and constructive grounded theory by Charmaz [60] for the qualitative analysis. See Figure 1.1 for an overview of the data analysis methodologies.

The following lines describe the two programmes and the data collection methods.

1.3.1 Rise 2 Flow Programme

We implemented three rounds of the Rise 2 Flow (R2F) program, which is a program aimed to help build mental and emotional resilience and increase well-being. It is based on Pranayama, a specific yogic breathing practice that has an effect on the nervous system. The technique is a three-part breath through the mouth that is practised laying down. Sessions were guided by a certified facilitator.

The first iteration lasted twelve weeks, the second iteration eight weeks, and the last twelve weeks again. The intervention was tailored to start on Monday with an email about the week’s topic in self-development, some questions to reflect on during the coming days and a reminder to do journaling. In the first and third iterations, the topics were Time Management, Physical Energy, Presence, Recovery, Confidence, Decisions, Listening, Feedback, Negotiation, Creativity, Prevention, and Connection. In the second one, we used the first eight of that list. Then, on Thursday, we gathered online for the session, which started with a presentation on the topic, followed by participants’ reflections and then the breathing practice, finishing with a short meditation session and after-meditation care advice. Finally, at the end of the week, participants received another email with links to the session’s recording, the weekly survey and reminders about journaling. Figure 1.2 shows an overview of the programme.

All the sessions were online. We recorded the sessions and made them available for home practice for individuals who could not attend the live sessions later in the week.

To recruit participants, we used several mailing lists, online and university networks, posters, and the personal and professional networks of two authors. We invited IT workers and software developers with at 70% of their work in front of a screen, including IT practitioners, IT researchers, IT consultants, faculty, and students. Participants were from Argentina, Austria, Bangladesh,



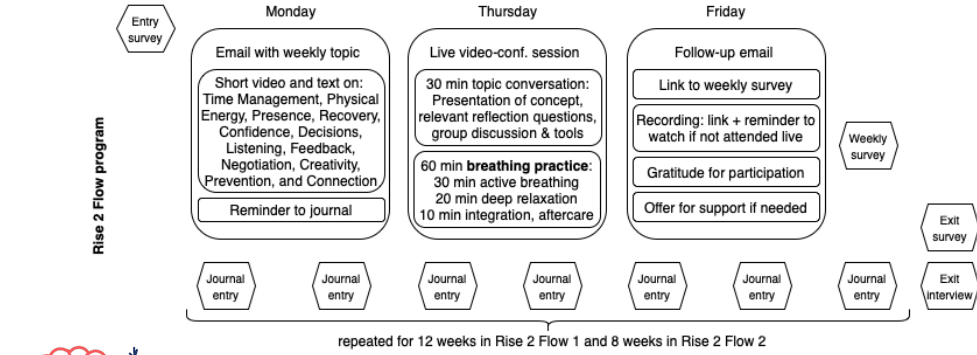


Figure 1.2: Overview of R2F programme

Brazil, Canada, Costa Rica, Denmark, Ecuador, Finland, France, Germany, India, Iran, Ireland, Italy, Netherlands, Mexico, Poland, Portugal, Saudi Arabia, Spain, Sweden, Switzerland, UK, US, and Venezuela. For the details about numbers, please see Paper A, B and C. The general overview of our sample was for the first round of R2F; we started with 87 participants filling in the entry survey and 14 giving interviews. For the second round, we got 14 interviews out of the 101 participants that sent an entry survey. Finally, in the third round, we interviewed 15 participants out of the 49 that participated.

1.3.2 Data Collection for R2F

We collected qualitative and quantitative data from R2F. To gather quantitative data, we applied an entry and exit survey formed by psychometric tools such as the Mindfulness Attention Awareness Scale (MAAS), Scale of Positive and Negative Experience (SPANE), Psychological Well-Being (PWB), Positive Thinking (PTS), Perceived Productivity (HPQ), Self-efficacy, and demographic data. Similarly, we applied a weekly survey, the 5-item World Health Organization Well-Being Index (WHO-5). Participants were also asked to write a daily journal; this tool gathered qualitative data. We gave them three items to start with the journal; we asked them what practice they did, to rate their day from 1 to 10, and to write 100 words about their day. The quantitative analysis's (a temporal analysis) goal was to examine how responses vary over time. There are three ways this was done:

- [A] Temporal analysis for each instrument at t_0 vs. t_1 , i.e., entry vs. exit.
- [B] Temporal analysis of daily trends.
- [C] Temporal analysis of weekly trends.

We employed dummy variable regression estimators (DVRE) in the last case. The time variable t is encoded using the DVRE technique dummy, which also sets an index of 0/1 with $t_0 = 0$ and $t_1 = 1$.

Finally, to obtain purely qualitative data, we applied in-depth semi-structured interviews in the three rounds. However, for Paper B we only used interviews for rounds one and two. Later, we ran a third round of R2F. For Paper C,



we analysed the interviews of three programme rounds. Figure 1.3 shows an overview of the instruments to collect data in the R2F programme.

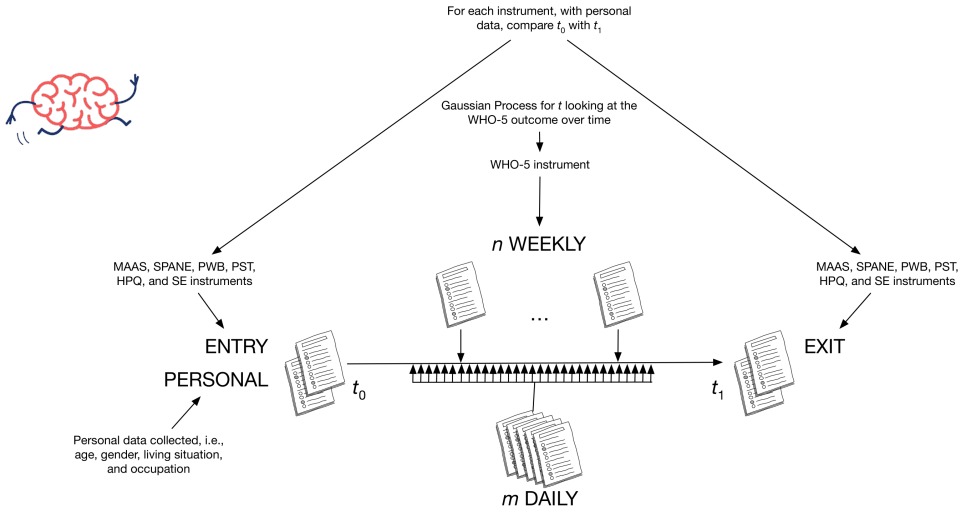


Figure 1.3: An overview of instruments used in R2F. Note that the above was executed once for each run of the programme.

1.3.3 The Summer School Programme

The course "Digitalisation in a Changing World" is offered by the International Summer School for Sustainability in Gothenburg, Sweden for one month. This course consistently garners participation from a diverse and international student cohort, encompassing a broad spectrum of educational backgrounds ranging from first-year Bachelor's students to those in their final year of Master's studies. The student body hails from various corners of the globe, representing countries such as Sweden, Germany, the UK, Austria, China, Japan, Thailand, South Africa, Russia, the US, and Australia. Since this course offers a diverse, controlled, and interdisciplinary environment, we decided to implement our pilot study in this setting. This is an ideal scenario for running a pilot study on well-being interventions, which can later be adapted and tested on computer workers in real-world employment settings. The course attracts various international students with differing education levels and backgrounds. This diversity allows for a more comprehensive examination of well-being factors since it mirrors the diversity found in computer workers. The pilot study can collect data from students at various stages of their academic journeys, which may parallel the career stages of computer workers. The sample was 25 students who completed the entry and exit survey.

During the summer school, students practised one of four well-being modalities we implemented—meditation, yoga positions, breathwork, or nature walks—for at least 10 to 20 minutes each day. To observe a potential effect over the course practice, students were encouraged to select a modality they did not routinely use. At the beginning of the course, there was a combined

live practice with the entire group when instruction and guidance were given for each modality. Students could also access further guidance through audio or video and continue the selected practice independently. We encourage students to write a reflective journal detailing their emotions and ideas sparked by the day's events during the course.



1.3.4 Data Collection for The Summer School Programme

To collect quantitative data, we designed a survey formed by the following tools: The self-report Emotional Intelligence Test (SSEIT), Resilience Scale (RS-14), Short Self-Regulation Questionnaire (SRQ), Self-Transcendence Scale (STS) and the Mystical Experience Questionnaire (MEQ). We applied as an entry and exit survey. To collect qualitative data, we applied semi-structured interviews at the end of the programme.

The use of different psychometric instruments in the two courses on well-being arises from a deliberate research strategy aimed at a comprehensive exploration. In the initial intervention, we opted for instruments that would provide a fundamental understanding of specific facets of well-being. However, in the subsequent intervention, the selection of instruments was guided by the intention of delving into the construct of resilience. Consequently, this decision led to the inclusion of instruments that covered a broader spectrum of resilience dimensions, allowing a more comprehensive assessment of the well-being of the participants. This methodological variation allowed us to progressively improve the measurement approach to improve the depth of understanding of well-being and resilience.

1.4 Research Results


This section presents the results and answers the research questions based on the studies contained in this thesis.

RQ1. How to measure the effectiveness of a neuroplasticity practice in terms of effects on well-being and resilience? This question aimed to ascertain whether a neuroplasticity practice, particularly breathwork, has a good impact on the resilience and well-being of computer professionals. First, we sought to understand how a particular neuroplasticity practice like breathwork can enhance the resilience and well-being of computer professionals. The second objective was to suggest a method for evaluating the effects of the neuroplasticity practice. We aimed to identify appropriate techniques, tools, and research strategies for assessing the practice's quantitative and qualitative benefits on resilience and well-being.

To achieve our goals, we designed and implemented the R2F program. We use the quantitative and qualitative results of the first two iterations.

Table 1.2 shows the summary of quantitative findings per psychometric instrument. It also shows how the qualitative data link and support quantitative results.

See Paper A for detailed results and interpretation. In this section, I want to grab the attention to the daily and weekly surveys. This is crucial since the



Phrasing	Quantitative	Qualitat.
Does the intervention bring about change in the participants Mindfulness Attention Awareness?	negative (MAAS)	positive
How did the daily perceptions of life experience progress over time?	inconclusive (daily)	positive
Is there change in the participants' perceptions of positive and negative experiences? If so, how are they affected?	supported (SPANE)	positive
Is there change in their psychological well-being? If so, how is it affected?	supported (PWB)	positive
Is there change with regard to positive thinking? If so, how is it affected?	supported (PTS)	positive
How does the well-being fluctuate and vary over the course of the intervention?	inconclusive (weekly)	positive
Does the intervention lead to change in the participants perceived productivity? If so, how is it affected?	inconclusive	positive
Does the intervention lead to change in the participants' self-efficacy? If so, how is it affected?	supported	positive




Table 1.2: Overview of the quantitative and qualitative results.

findings from these surveys remained inconclusive, emphasising the need for a closer examination and understanding of the data they present. Results of the daily survey are shown in Figure 1.4. Participants rated their days from 1 (very poor) to 10 (absolutely excellent). The visual overview shows an upward trend for about two-thirds of the intervention before it goes back down towards the finish. We could not declare a significant trend because of the ambiguity across time. The reversal of the tendency was significant enough to be investigated even though it still showed an overall improvement from start to finish. We identify two effects as the cause of the observed small drop towards the end: 1) The study's end is in sight as the intervention's novelty wears off. 2) After some practice, a plateau effect manifests as a lower rating of items. The interviews later supported these hypotheses.

For the weekly survey (see appendix A.2.5), we saw that there had been improvement with a clear pattern of variation and a positive tendency. All five of the weekly survey's items displayed a similarly curved curve, with an increase through the first two-thirds, a peak, and then a decline. Overall, though not necessarily significantly, the ratings were nevertheless higher towards the conclusion than at the beginning. Although there was a good tendency for Q1, Q2, and Q4, it was challenging to draw any firm conclusions due to the ambiguity. This was more true for Q3 and Q5 than for Q1 as shown in Figure 1.5.

Compiling the participants' comments shows how they gradually understood the changes over the course's several weeks. They discussed how their perspectives had changed and gave examples of brief encounters that they had

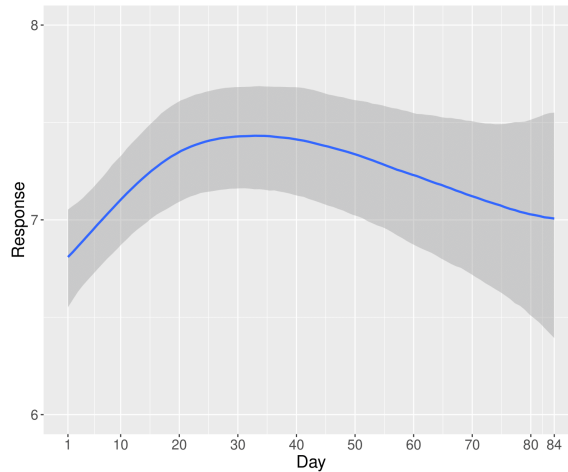


Figure 1.4: Trend for daily survey ($N = 1646$). The blue line indicates the median while the band signifies the 95% credible interval. On the vertical axis we have the response on Likert scale (1–10), while the horizontal axis indicates the day. Even though an initial positive trend is visible, due to the uncertainty (especially in the later part of the study) one cannot draw any conclusions.

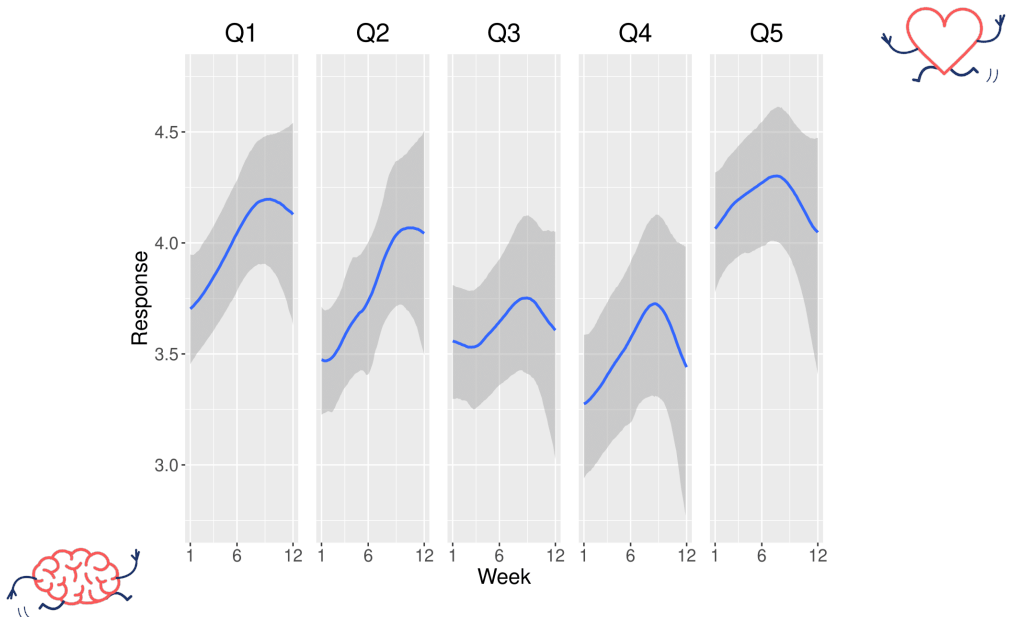


Figure 1.5: Trends per question for weekly survey ($N = 456$). The blue line indicates the median while the band signifies the 95% credible interval. On the vertical axis we have the response on Likert scale (1–6), while the horizontal axis indicates the week. In particular for Q1 and Q2 one can see a positive trend. Due to the uncertainty no conclusions can be drawn. For Q3–Q5 this is even more so the case.

interpreted differently. They are better able to recognise and manage their moods and emotions. They also spoke about how their emotions fluctuated. They experience a greater sense of serenity, calmness, and emotional control.

The weekly topics content also influenced the variations in well-being. “Pick three things that are essential to you,” for instance, one participant said they were able to recognise the care they show others but not themselves by adopting this practice. The last gains mentioned were the ability to sleep more, be less emotionally taxed overall, rest, and better handle stress.

The quantitative and qualitative findings suggest that the intervention may enhance participants’ mindfulness, attention awareness, well-being, and self-efficacy. Breathwork raises awareness on a neurological and subconscious level, while topic presentations, group discussions, and individual practice with suggested tools raise awareness on a cerebral and rational level. To explain the unfavourable shift in the quantitative data and the differences compared to the qualitative results, we discovered evidence that suggests participants had gotten much more alert. Increased awareness may cause more critical self-evaluation; for additional information on problems with self-awareness assessment, see Fletcher and Bailey (2003).



There were no reports of unfavourable or undesirable effects, most likely due to participants who did not experience the anticipated results ceasing to report; nonetheless, we cannot determine the exact cause. We are transparent in our analysis of what was present since we cannot report on information we do not have. People who did not experience the intended benefits nevertheless discontinued the programme, along with those who experienced urgent additional issues, were among those who did.



This study examines breathing, likely the easiest technique to control and heal the neural system. The breathing technique can also be used independently for a few minutes of reset in any scenario, even though the study concentrates on a specific framing as intervention (the entire with the breathing and reflection practice for certain topics). Participants receive instruction that fosters short- and long-term rehabilitation while enhancing resilience.

To conclude, this study could have three different effects: First, to educate and increase awareness in the research community and practice. Second, to train new cohorts of software engineers and software engineering researchers and educators in restorative practises. Third, to create specialised programmes for businesses and higher education that teach these techniques and frame them as science-based while still focusing on the embodiment component to increase self-connection.

RQ2. What are the benefits and challenges of implementing breathwork interventions among computer workers, and how do these interventions affect their overall efficiency, productivity, and susceptibility to burnout and depression?

The purpose of this RQ was to thoroughly examine the benefits of breathwork on the well-being of computer professionals from a purely qualitative perspective based on participants’ experiences. More details can be read in the qualitative part of **Paper A** and **Paper B**. This study aimed to explore participants’ perspectives on the benefits and challenges of our programme. We were interested in learning more about the practical application of a breathing

technique for stress reduction. We applied in-depth semi-structured interviews, we analysed the collected data using thematic analysis. The themes we obtained are shown in Figure 1.6

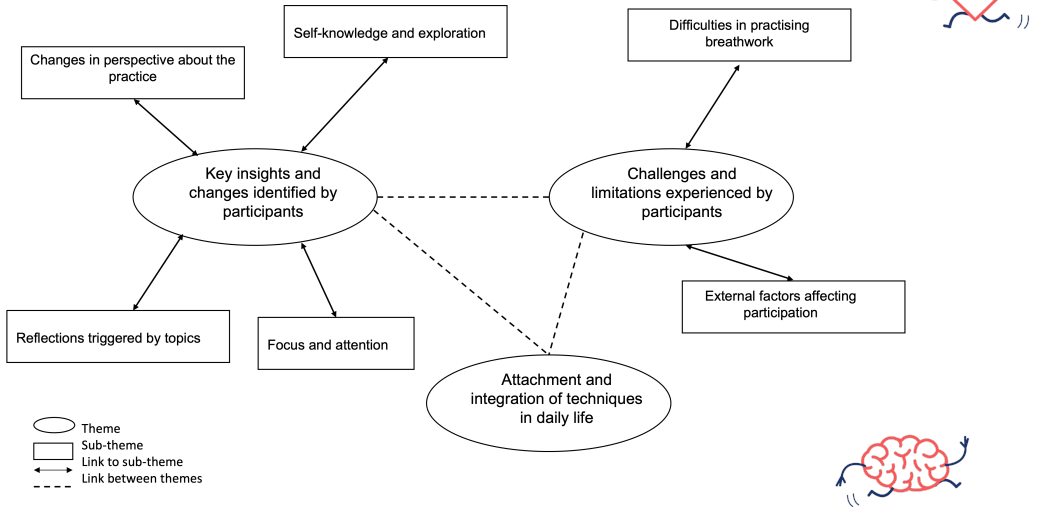


Figure 1.6: Themes paper B.

Findings showed that the programme’s participants reported feeling more at ease, noticing changes due to breathing exercises, and generally describing their whole experience as pleasant. Other areas affected by these changes include employment, interpersonal relationships, stress management, and work-life balance.

Higher and fundamental cognitive functions are both positively impacted. Many of the duties performed by software engineers in the IT industry involve coding, testing, decoding, and other similar tasks, and stress directly impacts both productivity and wellbeing [61]. According to Donald [62], greater employee productivity is highly correlated with improved psychological well-being. Similarly, numerous research studies have demonstrated a positive correlation between well-being and productivity and a negative correlation between emotional weariness and productivity [63–66].

Their increased well-being and relaxation positively impacted their productivity. In addition to the previous and returning to the field of IT, as Beck’s theory says, these changes also affect interpersonal interactions, decision-making, behaviour, and as a result, the state of mind. Positive changes in behaviour and welfare are more than necessary given the work environment, the ordinary circumstances in this sector, and the nature of the activities software developers, engage in. There is enough data to conclude that stress negatively affects well-being and productivity. According to our research, doing breathwork positively impacts well-being by promoting greater relaxation. In general, the ability to handle stressors rather than the presence of stressors influences productivity [62]. Programmes that help people build coping mechanisms are thus one of the promising ways to go forward.

This study shows both the short-term benefits of breathwork for computer employees, especially those in the IT industry and the long-term advantages of

incorporating it into daily life. Our findings close the empirical evidence gap for the use and effects of breathwork in stress reduction, well-being enhancement, and resilience. By doing so, we establish the groundwork for a more thorough evaluation of the advantages of restorative practises, specifically in knowledge work and IT development. Given that mental health has become a more pressing issue over the past two years, the information presented may be utilised as empirical motivation to encourage a broader population of computer workers to care for their well-being and resilience, whether in universities or workplaces.



RQ3. What are the key components and their interrelationships that contribute to the overall well-being of computer workers, and how does the use of breathwork as a stress reliever intersect with these factors?

With this RQ, we set out to investigate and make sense of the underlying concepts, crucial components, important elements, and intricate relationships that jointly support the well-being of IT workers using breathwork as a stress-relief technique. The goal was to provide a clear understanding of how all of these elements work together to shape people's experiences while fostering resilience. As a result, we present Breathewell Grounded Theory in **Paper C**. Figure 1.7 shows the elements of this theory and their relationships between them.



We use Constructive Grounded Theory to analyse the data from the three rounds of the R2F program. The result of this analysis was several concepts and their interrelationships that explain how the path of the program participants was to strengthen their well-being and resilience.

The concepts were:

Intentional Actions. It explains how intentional practices are interconnected and how they contribute to a general sense of agency, participants believed intentional action could promote well-being by encouraging thoughtful practices and deliberate decisions. They also emphasised how effectively it provides a sense of direction and purpose.

Consciousness Expansion refers to a process or practice that aims to broaden an individual's awareness and experience of different states of consciousness beyond their ordinary waking state. Participants described going through various states of consciousness, including deep states of meditation. Some participants also report a sensation of falling asleep.

Emotional Exploration. Understanding, controlling, and using emotions for personal development and empowerment were all parts of the participants' emotional exploration journey. Exploring emotional states, increasing awareness, and resolving the interaction of feelings, ideas, and bodily sensations were all part of this process. Additionally, this journey involved acknowledging feelings and thoughts as messengers. Participants opted to let those thoughts pass without trying to repress or react to them, even if they were labelled negatively. Participants could actively analyse their emotional states while observing them, developing their emotional consciousness.

Self-Reflection and Discovery. It had a dual purpose, serving as a byproduct of growing consciousness and a tool for better comprehending how things work inside. Reflective journaling was the tool that helped participants

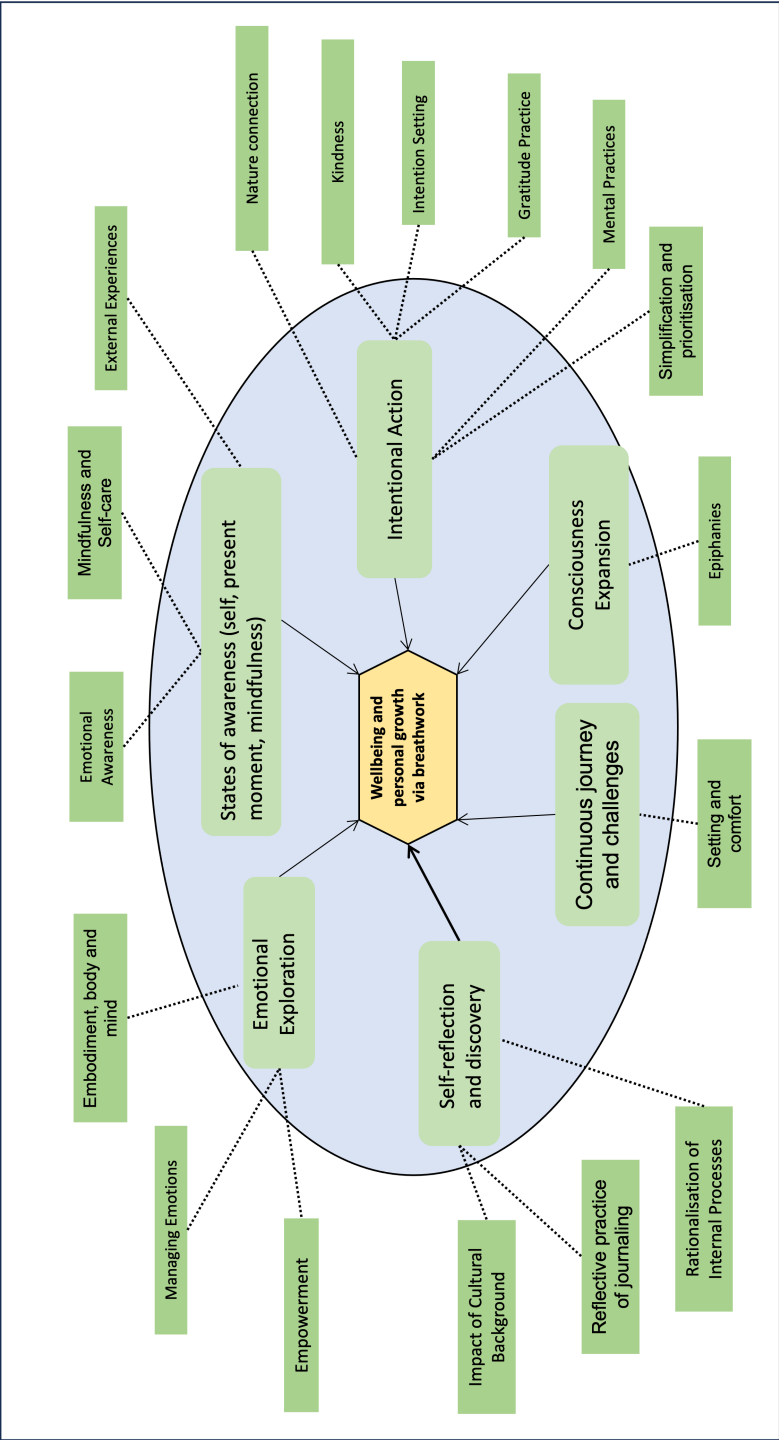
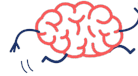


Figure 1.7: Overview of Breathewell Grounded Theory.



to reflect deeper.

Mindfulness and Present Moment Awareness. Mindfulness refers to being fully engaged in the present moment, achieved through practices like breathwork and reflective journaling. It allows participants to enhance their awareness, observe their emotions, and manage them effectively. Present moment awareness pertains to the intentional focus on the current experience, enabling individuals to appreciate small details, practice self-care, and find empowerment through connection with the immediate environment and their well-being.

Finally, we explain that breathwork is a **continuous journey with challenges** rather than a temporary fix for building and enhancing well-being. Maintaining and enhancing the benefits takes effort and consistency, which must be ingrained into daily or weekly routines and lives. The difficulties encountered along the route are essential factors in shaping the journey's trajectory of exploration, self-discovery, and development. As they begin their path towards wellness, participants could experience resistance, discomfort, plateaus, and even setbacks. These difficulties also present chances to face constraints and go beyond one's comfort zone, strengthening one's resilience and fostering personal development.

It is crucial to have a well-defined theory of well-being that is suited specifically to computer professionals for several reasons:

- Preventing burnout and stress: Because of elements including high workloads, continual connectivity, and digital demands, computer professionals are frequently prone to burnout. The early detection of burnout and stress symptoms can be facilitated by a well-developed theory of well-being, which also offers management and prevention techniques.
- Targeted interventions: Every profession has its own distinct set of difficulties and stressors. A theory of well-being tailored for computer workers can assist in identifying and resolving the particular problems they experience, including isolation, excessive screen time, sedentary behaviour, and digital eye strain. Interventions that are specifically designed to address these issues can improve general well-being.
- Customised support: Computer professionals frequently have particular social and psychological issues relating to their jobs, such as difficulties with remote work, virtual teams, and digital communication fatigue. A well-being theory can offer individualised support to aid people in navigating these experiences more successfully.

In conclusion, the theory presented in this study offers a valuable framework for enhancing specific aspects of computer workers' well-being, particularly in stress management through breathwork. While this theory represents a significant step forward in understanding and addressing key challenges they face, it is essential to acknowledge its limitations. This theory primarily focuses on a specific dimension of well-being related to stress relief through breathwork and may not encompass the entirety of computer workers' multifaceted well-being needs. Nonetheless, it serves as a promising foundation for further research and developments, ultimately contributing to a more comprehensive understanding and enhancement of their overall well-being. Organisations may build a healthier and more productive work environment that ultimately benefits both employees and employers by recognising the particular needs of



this group.



RQ4. To what effect and why to integrate neuroplasticity practices effectively into computer work education and practice to enhance individual well-being, resilience and mental health?

This RQ set out to establish the importance of incorporating sustainability skills into computing education.

To do this, we integrate neuroplasticity practices in the course “Digitalization in a changing world” and explore the impact on the well-being of students. We sought to highlight the crucial need for individual resilience and well-being as a prerequisite for developing IT solutions that align with the Sustainable Development Goals. The complete study can be found in **Paper D**. We aimed to highlight how these traits may be encouraged within the academic curriculum, especially in IT.

We collected and analysed quantitative and qualitative data. Thirty-two participants were initially enrolled; however, twenty-five submitted their exit surveys in full, providing all the necessary data for the quantitative analysis. We acknowledge that our sample size threatens the validity of our findings; hence, we further enriched our understanding of the participants’ experiences with qualitative data. Additionally, we plan to replicate this study with a larger population in future research. The box plots of the five scales that made up the survey are shown in Figure 1.8 and 1.9 . There is a difference between the entry and exit survey medians. All of the scales have increased, according to the exit survey plots.

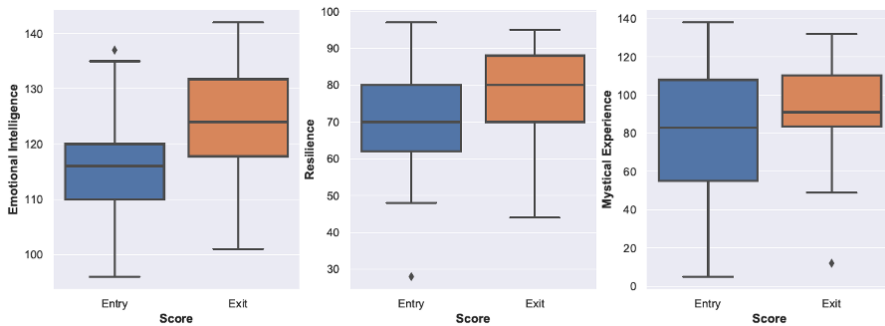


Figure 1.8: Entry and exit medians response.

The survey’s findings indicate a modest modification in each test and questionnaire. Given that the trial only lasted four weeks, this result is predictable. The context of the participants was also important. As several of them stated, they were travelling and seeking new experiences while in a strange country. As a result, assessing the effects of various external influences on the outcomes was impossible.

Concerning the qualitative data, interviewees commented on recognising changes following the study. They experienced favourable mood improvements, a general sense of calmness, increased attention, and even some physical pain relief. Similarly, most participants expressed a desire to keep up the practice following the training.



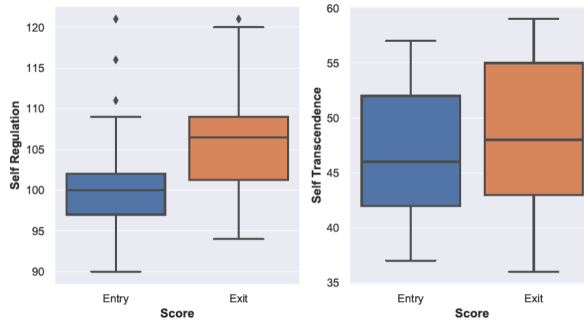


Figure 1.9: Entry and exit medians response.

Another prevalent aspect was that many students claimed that doing the elected practice with the group led to beneficial effects, including feeling welcomed, being a valuable part of a group, and sharing significant experiences with their classmates. Our previous study [39] likewise recorded the favourable effects of participation in this kind of group activity. Others said they would hunt for locations to continue the practice in a group. The decision to continue the well-being practice afterwards may have been influenced by the participants' positive experiences of performing it as a group and in a secure environment.

The implications of these findings are significant for inspiring people to practise behaviours and learn skills that support emotional intelligence, mystical experiences, self-transcendence, and self-regulation. Individuals can concentrate on improving those areas and possibly reap higher rewards in terms of their general well-being by learning the components linked to these constructions.

The intervention in this study was brief, and it is possible that it wasn't long enough to cause appreciable changes in the assessed constructs. This shows that in order to notice significant changes, more extended sessions or repeated interventions may be required.

1.5 Limitations and Threats to Validity

This research used quantitative and qualitative methodologies; this section presents threats and biases encountered during our studies. We acknowledge the need for careful interpretation and more study to guarantee the validity and applicability of the results.

Sampling Bias: A variety of personal and online networks, such as the global personal network of one of the papers' authors, academic networks, mailing lists, online spaces, and social media platforms, were used to find participants for the three rounds of R2F. Due to the number of broadcasting channels used, it is not a conventional convenience sample, but it can be viewed as an extension of one [67]. All of these networks, however, were built based initially on ties to the authors, which could lead to sample bias. We did our best to lessen this threat by asking for re-posting and spreading the invitation to join the several hundred emails and posts sent out to recruit people through their provided routes.

Self-selection Bias: Those drawn to studies like R2F are probably not a representative sample of the study population as a whole. We want to learn more about that element by repeating the experiment and learning more about the participants through the surveys and follow-up interviews.

Response Bias: We followed the advice of Dillman et al. [68] and employed standard validated instruments in our survey that, to the extent possible, prevent response bias. For example, we asked content questions before demographic questions. Because the participants got to know the authors, some response bias may still exist in the free-text responses they provided. By informing participants upon sign-up that their data would be anonymised before analysis, we were able to reduce this risk.

Measurement Validity: Participants growing weary while responding to the various questions on the entry/exit survey may compromise measurement validity. The poll may be finished in ten minutes, according to our pretests.

Internal validity: It might be challenging to separate the effects of group discussions and breathwork sessions when combined. Internal validity is threatened since it is difficult to determine how much the community component contributes to the beneficial benefits of breathwork. Comparing the results of breathwork to those of topic conversations raises another validity issue. Although most participants valued both elements, some preferred one over the other, which might have affected programme outcomes. Topics seem to have less of an effect and are less important than breathwork. Due to several difficulties, we did not include a control group. In the initial pilot phase, attempts to establish one yielded no responses. A possible alternative is to utilise a waitlist method similar to what was employed by Bernárdez et al. (2018). However, this approach carries several biases. For instance, participants self-select and tend to have a positive bias towards the intervention compared to a randomly selected control group. Additionally, they might be influenced or prepared for surveys once they engage in the intervention. As a result, this approach's suitability is controversial, even in medical studies.



Self-report bias and generalisability: The qualitative analysis, mainly based on interviews, may introduce self-report biases in participant responses. People could show themselves in a better light, downplay unpleasant memories, or accidentally leave out particular difficulties. The accuracy of the data that was gathered may be impacted by this bias. Our data is also limited in that it only includes participants who agreed to be interviewed and discuss their experiences, which may underrepresent the group. Participants who did not see improvements might have decided against participating in interviews because they would have nothing to say.

Researcher Bias and Reflexivity: Because our chosen qualitative analysis methodologies involve the researcher in an active and interpretative role, researcher bias may affect the coding and interpretation of the data. Preconceived ideas, assumptions, and viewpoints of the researcher could unintentionally influence the analytic process, producing a biased portrayal of participants' experiences. We continuously reflected and discussed openly within the research team to lessen this threat.

1.6 Conclusions

This thesis aimed to evaluate the benefits and usefulness of neuroplasticity practices for computer workers to increase well-being and resilience, leading to more efficiency and effectiveness, decreased burnout rates, and lower risk of depression. To achieve this goal, we used a quasi-experiment design implementing two programmes having computer workers and students as participants.

In Paper A, we collected qualitative and quantitative data before, during and after the R2F programme. Results indicate that the intervention helped improve participants' mindfulness, well-being, and self-efficacy. Similarly, the evidence showed an increase in well-being and resilience. Further, we proposed and tested instruments to measure the effectiveness of the course, with this we answered our RQ1.

In Paper B, we used in-depth semi-structured interviews from rounds one and two to gather data. By diving more profound into the participants' experiences using a neuroplasticity practice, we sought to answer RQ2. Participants spoke highly of their improved well-being and relaxation. This paper's findings are first-hand accounts of using a breathing method that may be used to lower stress levels. Further, in the long term, it may establish the groundwork for personal sustainability by improving well-being and resilience.

For Paper C, we ran one more round of the R2F programme and also did another round of interviews. We used constructive grounded theory to analyse the collected data. The result of this paper was the Breathewell theory which presents and elaborates on the key principles, components, dimensions, and interactions that contribute to computer workers' well-being. This theory also explains how these factors influence computer workers' experiences when working to enhance their well-being and resilience.

Lastly, in Paper D, we explored other neuroplasticity practices in an educational setting. We implemented a pilot study asking students to explore a well-being practice and reflect on their daily state. The students' survey and interview responses show that these practices improve their resilience and general well-being. We stood out the need to include mental and emotional health in software engineering university curricula.

1.7 Future Work



Using our results as a starting point, we are able to identify points that will complement the state of our research so far. We detected areas that need further exploration to make our overall results more robust.

The next step is to explore the factors that contribute to the well-being of software developers at the individual, managerial/peer, and company levels. For this, we are already running interviews in partnership with Software companies. Further, we plan to develop and apply a survey based on the findings we get from the interviews.

Moreover, we also want to expand our pilot study to a larger population, allowing us to analyse and compare modalities. With these results, we could offer a better overview of how to integrate these practices into the university curriculum and if any modality would suit this specific environment better.

Further, we can also create a comprehensive framework that unifies neuroplasticity practices, well-being principles, and cognitive enhancement techniques into a holistic approach for computer work education and practice.

Furthermore, we seek to expand our comprehension of the topic by exploring the effects of neuroplasticity practices on brain wave patterns. We plan to use electroencephalography (EEG) equipment to aid this investigation. We aim to gather real-time neurophysiological responses and identify potential correlations between brain modulations and the psychological advantages individuals report.

Finally, we would like to develop a specialised instrument to measure the impact of neuroplasticity practices in the context of software engineers to quantify the effects resulting from neuroplasticity practises. We aimed to propose a tool with multidimensional metrics that consider emotional, cognitive and performance parameters. The final goal is to develop a more in-depth understanding of how neuroplasticity practises interact with the unique requirements of software development, thus contributing to the cultivation of tactics that support these professionals' mental health and resilience.

