Delft University of Technology

Motivating, your way.

Tailoring your fitness journey.

Ramya Praneetha Ghantasala

TU Delft

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by

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Abstract

A significant cardiovascular health risk is insufficient physical activity. The World Health Organization recommends 150 minutes of strenuous physical activity every week. Inadequate physical activity increases the risk of chronic diseases and other health conditions like cholesterol and obesity. This thesis researches the role of data monitoring as a persuasion strategy in monitoring a user's progress in their journey to becoming more physically active and how it can be leveraged to decrease the risk of cardiovascular diseases. Specifically, the focus of the thesis is to determine the effectiveness of expert-generated tailored messages to motivate a user in their physical activity behaviour. We designed the content of the messages by adapting an existing ontology for tailoring motivational messages in the context of physical activity. Messages were then generated by experts through a scenario-based feedback generation process, where the scenarios were tailored to a user's mood, self-efficacy and progress. The design of these tailored messages was tested against generic messages to determine which type of message was more motivating to the user. An experiment was conducted by recruiting crowd workers who were asked to rate the motivational levels of the two message types with respect to a given scenario. The results of the experiment supported the initial hypothesis that messages tailored to mood, self-efficacy and progress are more motivating than generic messages. Additionally, we have shown a systematic and reproducible way to obtain motivating messages. We have also provided a dataset of motivational messages that can be used during various stages of a user's physical activity intervention, along with a set of scenarios representing different levels of a user's state (mood, self-efficacy and progress).

The cover image is a word cloud of the themes arising from the factors that motivate people. The back cover is a word cloud of the themes based on the factors that demotivate people.

Acknowledgements

"For we put the thought of all that we love into all that we make."

This journey started on 27th November 2020, and it has been a long and arduous road since then. It would be remiss of me to not mention the people without whom this undertaking would have been impossible.

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And like how Frodo couldn't have finished his journey to Mount Doom without Sam, I wouldn't have been able to complete my thesis without my friends (and no, it is not an exaggeration at all, stop rolling your eyes). Thank you to my boondoggles for being my sounding board and for your entirely unbiased and objective opinions during my rants. I love you all; you are my anchors. Thank you to my friends here for all your support and for helping me navigate the intricacies of a brand new system. I would have been lost in the ways of this place many more times if not for you. Most importantly, I'm eternally grateful to my flatmates for preserving my sanity during this thesis. Our game nights and movie nights gave me the much-needed distraction from my work. And even though our principles of entertainment are poles apart, seeing you all cringe at the bad movies I make you watch is not something I'd trade for anything in the world. I love you guys, you make me want to be a better version of myself. And let's please finally play D&D, we've been prepping for a year now. Special thanks to my closest friend, who ensured I was a functional human being outside of work and for being the strength I needed during these two years. I honestly do not know how I would have coped without you. Cheers!

Ramya Praneetha Ghantasala
Rijswijk, March 2022

Contents

1 Introduction

> What lies in our power to do, lies in our power not to do.
>
> *Aristotle*

Imagine a person called Smoky McPufferson, a 37-year-old man who works a desk job, leads a sedentary lifestyle and smokes five packs of cigarettes every day. One fateful day, the elevator in Smoky's workplace broke down, and he had to climb seven floors to his office. By the time he reached the second floor, he had started feeling out of breath and felt like his lungs were on fire. Smoky realized the damage his lifestyle was wreaking on his body and resolved to adopt a healthier lifestyle. He read articles and motivational messages on the internet to motivate himself to be physically active. The downside to this was that the platitudes he was reading would make him feel worse on the days he was feeling bad about his progress. One day, he had a stressful situation at work and figured one tiny cigarette would not cause any harm. He skipped running that day because he believed that not much harm would come from skipping one day. Before he knew it, he was back in his old routine and would not be motivated to change until the subsequent elevator breakdown, or worse, he experienced a fatal health scare. Smoky's relapse could probably have been prevented if he could relate to the messages he was reading, or if the messages made him feel better when he was feeling low or reminded him of how far he had come in the journey when he would feel like he could not work out.

1.1. Background

According to a study by Yusuf et al. [1], over 70% of cardiovascular diseases cases were caused by modifiable risk factors - behaviour or lifestyle-related factors that a person can take measures to change. Smoking and physical inactivity are established as modifiable risk factors for cardiovascular diseases (CVDs) [1–3]. Physically inactive people are at a higher risk of CVDs, and any physical activity protects against such risks [4]. Changing entrenched behaviour has associated hurdles, and relapses when trying to change behaviours are expected. Possible causes for such relapses are lack of support, resources, money or guided programs [5, 6]. Additionally, lack of tailored information or feedback may leave the person wondering if they are even making progress in their behaviour change [7]. This thesis aims to research how user monitoring can motivate an individual in their journey towards a healthier lifestyle.

This thesis is part of the Perfect Fit project, which aims to reduce the risk of CVDs by aiding in smoking cessation and improving physical activity. The Perfect Fit project focuses on low socio-economic status (SES) populations. The project aims to provide an affordable and tailored solution through an application that users can download and use on their smartphones. In the context of the Perfect Fit project, if a user has downloaded the application, it is safe to assume that they have the intention to quit smoking and improve their physical activity. Per the transtheoretical model [8], the user has passed the pre-contemplation and the contemplation stage, and other components of the app will guide the user in the preparation phase. Thus, the data monitoring aspect of the application is concerned with the action and maintenance stages of the habit, which ties in directly with the user's progress. The scope of this thesis is to leverage user monitoring to motivate the user.

1.2. Motivation

1.2.1. Societal Issue

To reduce the risk of CVDs, Smoky has to focus on changing the two lifestyle choices: smoking and physical inactivity. Smoky is not the only person to fall prey to the allure of cigarette smoking. Tobacco is one of the most addictive, and consequently, one of the most abused substances globally [9]. Eight million people die every year due to smoking-related causes, of which seven million are the direct result of tobacco consumption while the rest are due to exposure to second-hand smoke [10]. It is estimated that around 1 billion people could die from tobacco usage in the 21st century [11]. Tobacco contains carcinogens that put users at an increased risk of cancer of the head, mouth, neck, along with other illnesses like heart disease, stroke, lung diseases and diabetes, to name a few. Along with physical ailments, smoking is often associated with depression, anxiety, stress, and an overall reduction in their quality of life [12]. This is by no means an exhaustive list of all the harmful effects caused by smoking but indicates the magnitude of the smoking epidemic the world is currently facing.

Smoky's second risk factor, physical inactivity, stems from his sedentary lifestyle. The World Health Organization recommends 150 minutes of strenuous physical activity every week. Insufficient physical activity increases the risk of chronic diseases, and other health conditions like cholesterol and obesity [13]. Regular physical exercise also helps in the prevention of many illnesses caused by smoking, such as cardiovascular disease, diabetes, cancer, hypertension, depression and most importantly, premature death [14]. Apart from these benefits, physical activity also helps people deal with the after-effects of quitting smoking by regulating nicotine withdrawal symptoms [15, 16]. Additionally, physical activity has been shown to be a powerful intervention for smoking cessation, leading to improvements in both physical and mental health [17, 18]. Studies show that physical activity in smokers is inversely proportional to their smoking behaviour [19], thus if a smoker changes their lifestyle to be more active, their smoking habits tend to decline.

1.2.2. Current Situation

In order to protect against CVDs, physical activity should be encouraged. Physical activity-based smoking cessation programs have demonstrated efficacy in the past [17, 20]. Being physically active is a habit and should be inculcated in one's routine. That being said, any form of behaviour change is by no means an easy journey. In the case of smoking cessation, there are applications available on the internet claiming to help people with smoking cessation. However, the majority of these applications are not grounded in the theory of behaviour change and are hence not as effective as interventions with a theory-backed foundation [21, 22].

Moreover, there is substantial evidence that suggests that smokers who try to quit on their own without the help of external interventions are likely to fail [23]. A reliable and sustainable way to successfully give up smoking is through behavioural intervention programs [24]. Generic self-help material may encourage more people to give up smoking, but its effects in maintaining the habit are minor [25]. An answer to counter this inadequacy is personalization. Personalized interventions, also known as tailored interventions, are believed to be more effective than presenting standard information to improve health behaviours, including smoking cessation and physical activity [26–29]. The secret behind the effectiveness of tailored persuasion lies in the fact that people remember information pertinent to them better than they remember information that could apply to anyone [30].

In the past, interventions were tailored by targeting sub-sections of the population based on socio-demographic factors like age, sex, and socio-economic status [31]. However, such interventions still fail to account for other differences in these population groups. Until a few years ago, tailored interventions were delivered via physical materials such as pamphlets, leaflets and information booklets, and targeted population groups. As computers became more sophisticated, interventions could be targeted at a single person through the use of computer-driven algorithms by processing their data and providing personalized feedback specific to an individual's needs [32]. Such computer-tailored interventions have been on the rise due to their sophistication and ease of delivery. With the prevalence of smartphones and computers in today's digital age, delivery of computer-tailored interventions through an internet-enabled ubiquitous device such as a smartphone would increase the reach and availability, and consequently, the effectiveness of such programs [33, 34].

1.2.3. Limitations

If the solutions for existing physical activity or smoking cessation interventions were perfect, people like Smoky would not have any trouble quitting smoking or being active. Possible barriers to successful smoking cessation could be financial hurdles, lack of tailored interventions and inadequate assistance during a smoking cessation program [35]. Though computer-tailored interventions can personalise solutions unique to a person's needs, there are not many physical activity-based smoking cessation programs that take advantage of this fact [36]. Another significant drawback of the current applications is the lack of behaviour change principles in their design [36, 37]. Factors such as feedback and reinforcing positive change are critical in promoting positive behaviour change during an intervention as evidenced by studies [38–41], and theories such as socio-cognitive theory [42] and goal-setting theory [43]. Giving users progress feedback makes them keep a positive mindset about physical activity [44], which consequently affects their engagement with working out and other health behaviour outcomes [45]. Despite overwhelming evidence supporting the role of tailored feedback in interventions, there is limited research into incorporating it with technology to help users in their behaviour change [46].

1.2.4. Technological Vision

Exploiting the opportunities provided by the limitations described in the previous paragraph, a better physical activity or smoking cessation intervention can be built. An area that can be improved upon is personalisation [36]. Tailored interventions delivered through the web can be made interactive while also incorporating different modalities like email, push notifications, in-app games and daily reminders to enhance user experience.

Furthermore, data gathering has become more accessible through the use of smartphones. Functionalities like pedometer, accelerometer, GPS tracker, and more have automated data collection with minimal interference from the user. Self-monitoring has been demonstrated to be a useful strategy to increase self-efficacy for physical activity programs [47]. Monitoring data observations such as step count, kilometres run, and duration of high-intensity workouts is crucial to keep track of the amount of physical activity done by a person. Data in apps for smoking cessation and physical activity is often presented as raw facts and figures, with little to no context to the goal the user wants to achieve. The lack of context diminishes the role of the user's progress as a potential means of motivation. The data gathered from the observations mentioned above can be analysed to provide insights to the user. In this way, given the data, feedback can be adapted for the user in the context of their goals, acting as a potential persuasive strategy. Therefore, the system can learn what feedback works for a particular user and tailor the program to each user.

1.3. Research Question

From the discussion laid out in this chapter, we arrive at the following research question:

RQ: How can user monitoring be effectively used to motivate people in a physical activity intervention?

Monitoring here refers to the observation of variables pertaining to the user. For instance, variables like self-reported workouts, mood, self-efficacy, number of instances of nicotine cravings indicate a user's journey towards a better lifestyle. To answer this research question satisfactorily, requirement gathering through literature review and expert interviews is done to lay a robust theoretical foundation. Based on the literature gathered, a design is proposed, following which, we build an experiment to evaluate the validity of the design proposed. Thus, the following sub-questions arise.

SRQ: What are the requirements of using user monitoring to motivate people in a physical activity intervention?

The requirements of user monitoring to motivate people need to be extracted from existing literature and the Perfect Fit project requirements. This includes questions such as: what data needs to be monitored, how will this data be monitored, used and processed, what motivational strategies are most effective. The answers to these questions are condensed into a set of requirements.

SRQ: What is the design proposed to motivate people in a physical activity intervention?

Based on the requirements gathered in the previous sub-question, a design is proposed for a system that increases users' motivation in smoking cessation or physical activity intervention.

SRQ: What is the effectiveness of the system to motivate people in a physical activity intervention?

The proposed design is studied in an experimental setting to test its effectiveness. The obtained data is analysed and interpreted, followed by a discussion of the experiment's limitations.

1.4. Approach

The first sub-research question was answered through a thorough literature review to build a theoretical foundation for requirement elicitation. Additional requirements were gathered from a panel of experts and the Perfect Fit project members. This is explained in detail in Chapter 2. The second sub-research question was answered by incorporating the requirements gathered into a scenario-based design strategy to simulate the application's hypothetical user. Chapter 3 gives an in-depth explanation about the design choices of the application. Finally, the design was evaluated in an experimental setting, the results of which are explained and discussed in Chapter 4. Lastly, the research work presented in the entirety of this thesis is discussed in Chapter 5, which also serves as the conclusion for this thesis.

2

Foundation

The first step to answer the first sub-research question -

> *What are the requirements of using user monitoring to motivate people in a physical activity intervention?*

- is to establish a theoretical foundation based on background research of existing literature. The literature study reviews existing related knowledge in the field of persuasion, smoking cessation and improving physical activity. Figure 2.1 shows how the requirements elicited are used in later chapters.

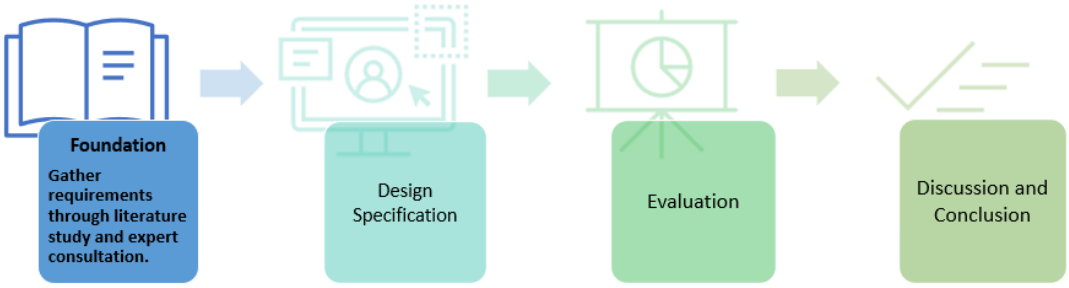

Figure 2.1: The current chapter provides the foundation for the thesis.

Experts from the bio-medical sensors and psychology fields were interviewed to obtain their inputs on the design of the system, supplementing the literature study. A scenario-based requirement elicitation was conducted with three expert psychologists presented with three scenarios and three samples of conversation between a virtual coach and the user for each of the scenarios. The experts discussed the most effective way to motivate users given the scenarios. This discussion with experts helped us better understand the concerns to be taken into consideration for the design of the system. In addition, an expert on sensors for physical activity/biomedical sensors and systems was interviewed regarding the safety of the users while doing the physical activity, specifically walking and running. The general themes of the discussion were user safety and user feedback. A summary of the expert consultation discussion is presented in Appendix C. The final requirements elicited were focused on tailoring to user state variables, providing feedback to the user, and motivating the user in their intervention.

2.1. Persuasion in Health Behavioural Change: A Brief Overview

According to the IDEAS (Integrate, DEsign, Assess and Share) framework described by Mummah et al. [48] for effective digital interventions, a critical phase of system design is to ground the design in behaviour change theory. Behavioural theory-centred tools are also effective in increasing users' adherence to a program [49]. This section describes the theoretical elements on which the data monitoring system is based.

2.1.1. Persuasive Technologies

Persuasive technologies are defined as interactive systems explicitly designed to influence their users to modify their attitude, or behaviour [50]. Human-computer interaction is a primary component in persuasive technologies, specifically human-computer dialogue. Human-computer dialogue systems assist the user in achieving their target behaviour through providing information and feedback or integrating a social avatar such as a virtual agent [51]. Feedback is a fundamental requirement for progress. Baumel et al. [52] describes the data-driven persuasive design as a quality concept in user behaviour change. Content that adapts to the users' progress in an intervention is a critical resource in persuasive design, as it caters to an individual's specific needs [51]. A review of smoking cessation programs indicates that interventions that customize information and feedback provided to a user's progress or preferences are rare [53]. The lack of such interventions probably arises because such types of personalization would require a large amount of data, including a corpus of motivational messages and advice, and a data stream that has assessments about the user's state either by automatic detection through sensors or by self-reported information. The following section describes how this data shortage challenge can be overcome.

2.1.2. Mobile-delivered Interventions

An effective and affordable solution to the problem of data shortage is through mobile-delivered interventions. Advancements in technology have enabled smartphones to collect data about the users' state such as physiological state, social context, activity level, and behaviour patterns [54]. Mobile-delivered interventions also have numerous other advantages, including ease of delivery, cost-effectiveness, availability, scalability, ease of tailoring, ability to send time-sensitive messages, and the ability to distract the user from cravings with multi-modal interaction [55]. Therefore, since it is possible to access the data about a user's progress, tailored interventions are made feasible. In the case of smoking cessation programs, the average user engagement rates are quite low [56]. Higher rates of engagement have been shown to result in more success in smoking cessation programs [57, 58]. Based on Mohr's 'Model of Supportive Accountability' [59], the addition of human support in an intervention increases adherence to the program by developing a sense of accountability to the coach who is perceived as trustworthy, kind and having expertise. Since having human experts on-call for a physical activity-based smoking cessation program can get quite expensive, an affordable and human-like replacement for such support is conversational agents. An added benefit of the inclusion of conversational agents is that it also increases engagement with the user [60].

2.1.3. Conversational agents in health behavioural change

Conversational agents, or virtual coaches, can target large sections of the population in a cost-effective way [61]. Conversational agents provide a non-intrusive way of collecting subjective data like mood and self-efficacy to complement the objective data obtained from sensors. Such enriched and complex data can help the virtual coach be more engaging [62]. Additionally, the user is more amenable to disclosing information they perceive as shameful with a virtual coach than with another human being which can demonstrate a positive sentiment towards the virtual coach, thus fostering a sense of privacy and anonymity [63]. In the Perfect Fit project, the user will be assisted by a virtual coach who will motivate them in their intervention.

2.2. Role of Monitoring in Motivating Users

The main goal of our data monitoring system is to motivate users through their progress. From here on, we narrow our focus to motivating users in a physical activity intervention. Along with being a good alternative to replace smoking [17, 18], physical activity has also been shown to reduce smoking cravings [64]. Thereby we obtain our first requirement:

R1: The messages should be designed to motivate the user to do physical activity.

2.2.1. Tailoring

According to the Elaboration Likelihood Model, tailored interventions are relatively successful in changing users' attitudes as they increase the perceived personal relevance of the user, which results in an increased motivation to process the information presented to them [65]. Rimer et al. define tailoring as "a process of creating personalized behaviour change strategies intended for a single person based on information unique to that person by gathering and assessing data about the intended recipient through a targeted assessment" [66]. Additionally, the Elaboration Likelihood Model (ELM) establishes that information that is understood to be personally relevant increases an individual's motivation and ability to evaluate and respond to the persuasive efforts of a message [67]. Interestingly, it has been found that the appearance of personalization is more important than actual tailoring [66, 68]. Including personally relevant information like the user's name, weekly goals, and daily progress is more effective than implicit adaptive systems without any clear signs of personalization [69]. It is also critical that along with personalization, the messages delivered to the user contain convincing arguments for the user to modify their behaviour [70].

Feedback

The importance of tailoring and personalization was highlighted by experts during the consultation session, especially regarding the progress the user makes towards their goals. As evidenced by Morrison et al. [68], users can have high attrition rates in the beginning if they do not receive sufficient feedback from the system. It has been shown that feedback on goal progress acts as a self-regulator for the user in achieving their goal behaviour [71, 72]. Therefore, it can be reasoned that a user's motivation to complete their goals can be influenced by the progress they have made and the feedback given about the progress. Additionally, it is vital to reinforce a user's self-efficacy and provide positive feedback that encourages the user's progress towards their goals [68]. The concept of feedback to the user acting as motivation in promoting physical activity was emphasized during the expert consultation. According to the biomedical sensors expert, feedback is necessary for the user to measure their progress towards their goals in a physical activity intervention. Consequently, we arrive at the following requirement:

R2: The messages should provide adequate feedback about the user's progress.

User State

A survey by Ghanvatkar et al. [73] emphasized the inclusion of user state variables to create tailored content. During an intervention, a user's state, such as their mood, self-efficacy, intention, motivation, and so on, could be used in an adaptable user model that helps deliver tailored messages. People are more likely to read and remember tailored information as they perceive it to be more relevant than generic information [65]. It could be argued that a user might better relate to a message that has been tailored to their state. Thus, the following requirement arises:

R3: The messages should be tailored to the user's state during their physical activity intervention.

2.2.2. Messages delivered by a virtual coach

In the expert consultation conducted, the psychology experts had recommendations and concerns about the messages sent by the virtual coach. The primary recommendation was that the message be friendly, empathetic and positive. The messages sent by the virtual coach also need to communicate to the user that a failure during their intervention is common and normal and that the user can get past this temporary setback. In the context of a physical activity intervention, a lapse is a temporary or standalone event when the old habit re-emerges. In contrast, a relapse is reverting to the old habit/behaviour as it was before the intervention [74, 75]. This is particularly of note as it has been shown that a few types of lapses, for instance, those triggered by stress, can quickly progress into a relapse [76]. These failures can be due to improper goal setting, lack of knowledge of the goal, other external barriers. Self-reflection is an essential component of successful health behavioural change [77, 78] and helps users increase self-efficacy and set realistic goals [79, 80]. The positive behaviour of the user needs to be reinforced, and their daily successes celebrated. However, repetitive and generic messages which do not seem tailored to the user's progress can leave the user feeling dissatisfied with the virtual coach [81].

Message Content

For sustained engagement, the virtual coach needs to have empathy, understanding and acknowledge the user's emotional states [82]. Developing a rapport with the virtual coach has shown to increase a sense of self-efficacy in the user, thereby increasing adherence rates [83]. Linguistically, to mimic a human-like interaction, the

virtual coach needs to keep messages concise and make the content engaging and readable. The content of messages in successful interventions includes positive feedback, emphasis on the benefits of the intervention, how to make progress, and personalized text messages, for advice, support and distraction [55]. As one of the experts mentioned, the user should not be overwhelmed with the information. Instead, the information should be presented to the user in an easily digestible format. There is a critical focus on the content of the messages delivered by the virtual coach in these interventions. The requirement below follows from this discussion:
R4: The content of the messages should be simple and easy-to-understand.

Reproducibility
A study of existing literature revealed that even though messages are widely used to motivate users in the physical activity domain, the knowledge about how these messages are formulated or generated is limited [84]. Some studies, such as the one by Patrick et al. [85] for a text message-based weight loss intervention, split personalized messages into components: a topic, question and a tip. Kaptein et al. [86] designed messages based on six strategies tailored to the user's susceptibility to persuasion. Even though these studies are an improvement given the lack of information about designing messages, they still do not detail the process enough for the messages to be reliably reproduced for future work. The presence of datasets containing motivational messages would also ease the work for researchers who want to study these messages' effects. Instead, if someone intends to study the effects of messages, they should start by data gathering, which is time-consuming and resource-intensive. Hence, to improve reproducibility and increase transparency, the design of the message must follow a clear schema or structure, which can also help future researchers generate motivational messages. Thus, we arrive at the following requirement:
R5: The messages should follow a formal schema to help reproducibility.

Based on the literature study done, and with the help of the input from experts, requirements for the design of a user monitoring system to motivate messages were gathered. The scope of this research would be the messages sent by the virtual coach to motivate the user in promoting physical activity. Table 2.1 consolidates all the requirements described in the chapter.

	Requirements
R1	The messages should be designed to motivate the user to do physical activity.
R2	The messages should provide adequate feedback about the user's progress.
R3	The messages should be tailored to the user's state during their physical activity intervention.
R4	The content of the messages should be simple and easy-to-understand.
R5	The messages should follow a formal schema to help reproducibility.

Table 2.1: Requirements for leveraging user monitoring to increase motivation.

3

Design Specification

This chapter outlines the research and consequent design proposed intended to answer the second sub-research question:

> *What is the design proposed to motivate people in a physical activity intervention?*

It highlights the design choices that follow the requirements described in the previous chapter, as shown in Figure 3.1. An overview of the design of the system is described in Section 3.1, followed by a breakdown of each individual component of the system in the consequent sections, 3.2 and Section 3.3.

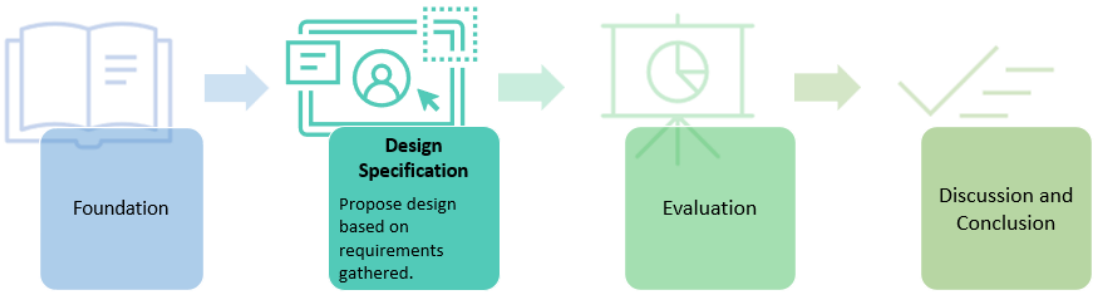

Figure 3.1: The requirements in Chapter 2 dictate the design of the system.

3.1. Overall Design Specification

Based on the discussion in Chapter 2, it can be surmised that a virtual coach needs to provide tailored and adaptive feedback to the users with respect to their progress towards their goals. The principal focus would be the motivational messages that the virtual coach sends to the user in order to motivate them. The requirements are consolidated in table 5.1.

Taking into account the requirements outlined in Chapter 2, an overall design of the system for modelling adaptive and personalised progress feedback is envisioned as depicted in Figure 3.2. Each node can be considered an area of research in itself. We aim to explore these areas in the context of this thesis. After that, areas of marginal improvements can be identified and how they can be leveraged and incorporated into our design. The first module, ontology, is elaborated on in Section 3.2, which describes what an ontology is, its advantages in designing motivational messages, and how an existing ontology was partially modified to suit the needs of the research question. After the ontology was designed, experts were recruited to write messages that motivate users to be more physically active, which is described in detail in Section 3.3. To help devise these motivational

Requirements	
R1	The messages should be designed to motivate the user to do physical activity.
R2	The messages should provide adequate feedback about the user's progress.
R3	The messages should be tailored to the user's state during their physical activity intervention.
R4	The content of the messages should be simple and easy-to-understand.
R5	The messages should follow a formal schema to help reproducibility.

Table 3.1: Consolidated list of requirements

messages, experts were asked to adhere to the formulated ontology. Additionally, hypothetical scenarios were designed with personas in varying stages of physical activity progress so the messages could be tailored to specific factors in the scenarios. After the first half of the pipeline was completed, an experiment was set up where participants rated the motivational levels of these messages, and the results were analysed to determine if the tailored messages were more effective than generic ones. The experimental setup and evaluation part will be detailed in the next chapter (Chapter 4), followed by the discussion of the results in Chapter 5.

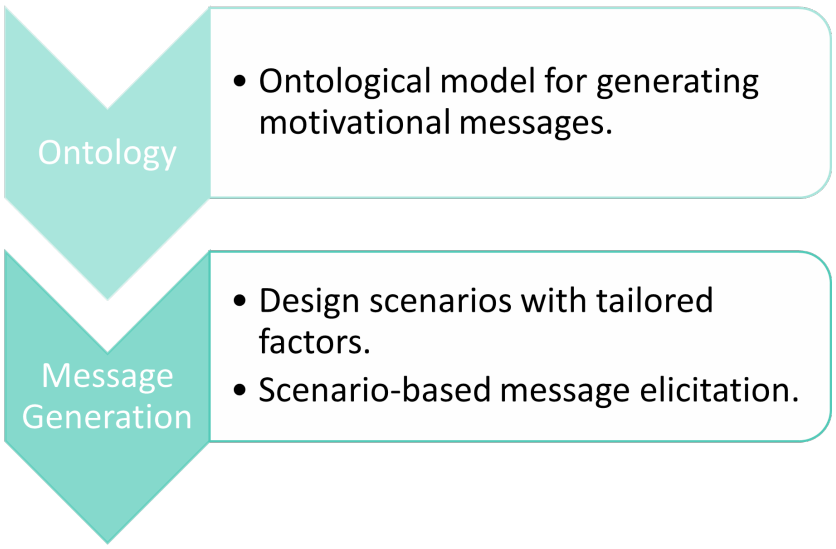

Figure 3.2: Overview of the design for personalised progress feedback.

3.2. Ontology

This section delves into the world of ontology and how it can improve motivation in a physical activity intervention.

3.2.1. What is an ontology?

According to Gruber [87], it is "a formal, explicit specification of a shared conceptualization." Simply put, an ontology is a formal representation of knowledge in a particular domain. Ontologies are effective when creating systems that drive behaviour change [88, 89]. An inter-disciplinary review by Kennedy et al. [90] of technology actively being applied in behaviour change found that out of 41 studies, five incorporated theoretically-grounded ontologies, out of which only three did so in the context of dynamic tailoring. This was still noted as an "important novel development", suggesting that using an ontology to formalize interventions for behaviour change is an up-and-coming area for research.

3.2.2. Why do we need an ontology?

The primary purpose of including an ontology in our design is to semantically model the motivational messages that were delivered to the user. These messages can be broken down into components, making it easier

for future researchers to understand and reproduce our work. An added benefit is that an ontology allows for including ”tailored” variables, particularly useful for incorporating dynamic user-related variables like mood, self-efficacy, etc. One such instance was demonstrated by Uribe et al. [91], wherein they use an ontology to model personalized messages to send medication reminders or advice to patients based on their stages of change.

Thus, with the use of an ontology, we satisfy the following requirement:

R5 - The messages should follow a formal schema to help reproducibility.

We use an existing framework for modelling tailored motivational messages described by den Akker et al. [92] used for physical activity coaching, which was further implemented as an ontology by Villalonga et al. [93]. The fundamental principles behind modelling a message in the framework described were timing (when the message was sent), intention (why the message was sent), content (what was in the message) and representation (what was the form of the message, for instance, image, text, audio, etc.). We disregard timing and representation as they are constants in the current scope of the thesis, i.e., the message is assumed to be only sent once after the user does physical activity and in text form. The framework developed by den Akker et al. was adapted to fit the requirements described in table 5.1, resulting in the ontology shown in Figure 3.3.

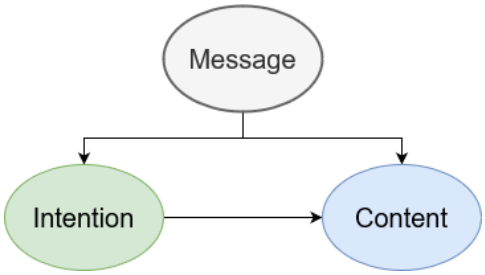

Figure 3.3: The base model of the motivational messages adapted from den Akker et al. [92]

Using the ontology for modelling motivational messages also partially address the requirement:

R1 - The messages should be designed to motivate the user to do physical activity.

An example of a motivational message generated according to the adapted model is shown in Figure 3.4. The different components of the message are described in the following section.

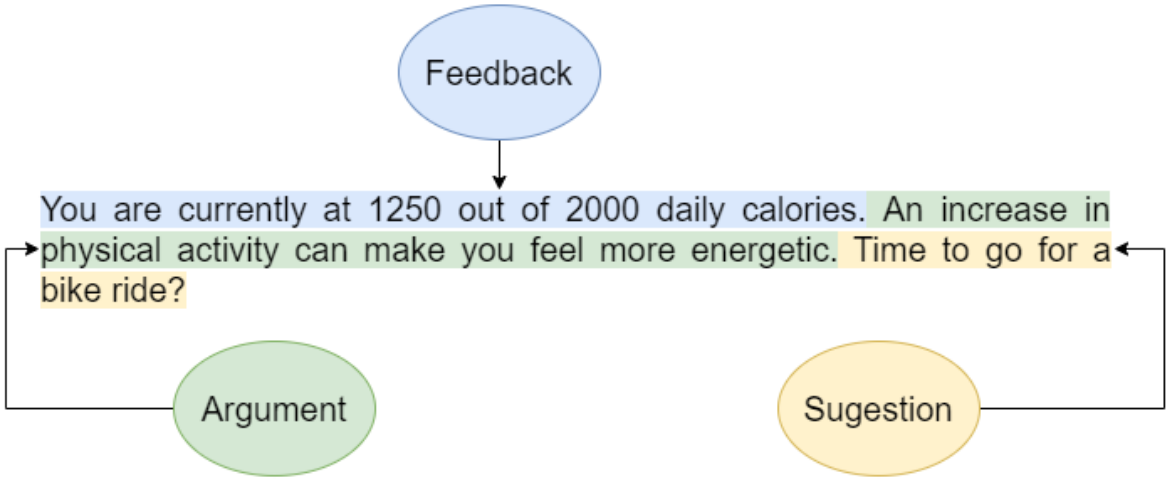

Figure 3.4: A motivational message and its different components.

The sub-components in the adapted ontology, also borrowed from den Akker et al., are described in brief below:

- **Intention** - The intent of the message is the Intention component. The intentions are of two types: primary and secondary intentions. The primary intention determines the principal intent of the message and sets its tone, while the secondary intentions shape the structure of the message according to the primary intention. An overview of the available intentions are shown in Figure 3.5 The two main types of primary intentions are:
  - **Encourage** - The encourage or positive intention, as the name suggests, encourages users to do (more) physical activity. It is typically used when users have not met their goals or have low self-efficacy.
  - **Neutral** - The neutral intention is used when users are achieving their goals and doing well. It acknowledges the user's progress and informs them to keep up the good work.

  An example of the two types of messages are shown in table 3.2.

Intention	Example
Encouraging	*"You have taken more rest. Take a walk around the block."*
Neutral	*"Your activity level is sufficient. Keep it up!"*

Table 3.2: Example of an encouraging intention and a neutral intention

The primary intention directs the secondary intention to be used in a particular message. The encourage intention has the feedback, argument and suggestion secondary intentions, while the neutral intention has the reinforcement, feedback and argument secondary intentions, as shown in Figure 3.5,

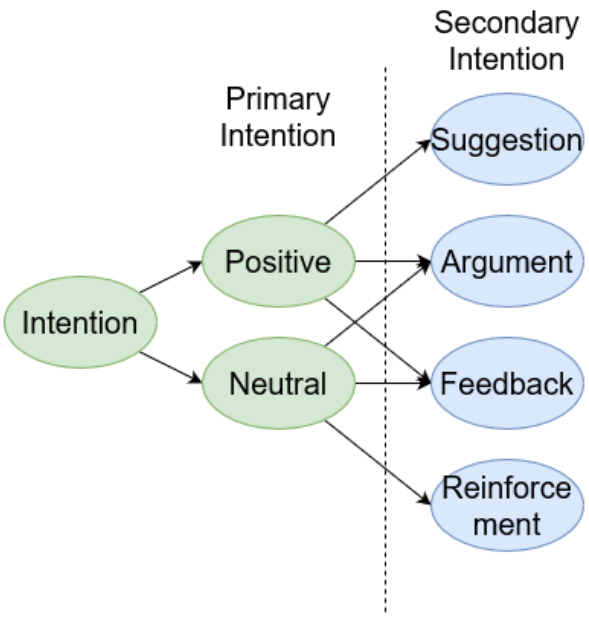

Figure 3.5: An overview of the intention model [92].

- **Content** - The **content** of the message is provided by the secondary intentions as described in table 3.3, along with examples of each secondary intention.

  The content of the message starts with feedback regarding the user's physical activity performance. The follow-up to feedback depends on the primary intention. If the primary intention is to encourage, the suggestion intention is chosen, and if the primary intention is neutral, then the reinforcement suggestion is chosen. Additionally, if the user has been meeting their goals regularly and maintaining their positive behaviour for a while, it is unnecessary to keep reminding them of arguments.

Consequently, the described components of the motivational message address the following requirements:

Secondary intention	Purpose	Example
Feedback	- Comment on the user's performance in the physical activity. - Common to both neutral and encourage intentions	*"You have worked out for 10 minutes out of your 30 minutes goal."*
Suggestion	Provides a practical option for the user to increase their activity.	*"Take a walk in the park to achieve your daily step goal."*
Reinforcement	- Inform users they are doing well, and they should continue doing so. - Commonly used with the neutral intention, can also be used to motivate users in the beginning stages of their physical activity journey.	*"You're doing a good job, keep it up."*
Argument	- Provide a reason for the user to exhibit healthy behaviour, either to educate the user about the benefits of the healthy behaviour or the negative consequences of the unhealthy behaviour. - Can be used for both encourage and neutral intention.	*"An increase in physical activity can make you feel more energetic."*

Table 3.3: Purpose of secondary intentions described by den Akker et al., along with an example each.

- **R2 - The messages should provide adequate feedback about the user's progress.**
- **R4 - The content of the messages should be simple and easy-to-understand.**

A model has been created by incorporating the relevant components of the framework for tailored messages developed by den Akker et al., as shown in Figure 3.6.

As a minor addition, the feedback component is further split into quantitative and qualitative feedback.

- **Qualitative Feedback** - Feedback about the progress of the user's journey, including performance concerning their past progress, milestone achievements, or significant change in user behaviour - "You did better than yesterday", "You have rested for more days than you have worked out."
- **Quantitative feedback** - Objective feedback about the user's performance - "You have done 7000 out of 10000 steps", "You have worked out for 10 minutes out of your 30 minutes goal."

This is to deliver better feedback content tailored to goal setting that includes information about the goal – e.g. 'You have done 7000 steps out of 10000 steps', compared to 'You have done 7000 steps' (or 'You are currently at 1250 out of 2000 daily calories'.)

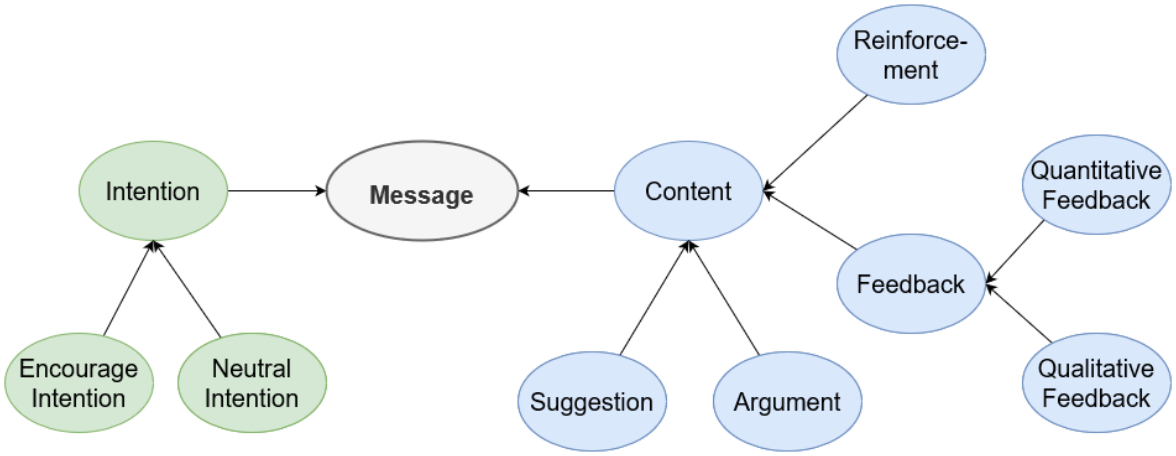

Figure 3.6: The minimal version of the ontology used for generating tailored motivational messages to improve physical activity.

3.3. Gather Data from Experts: Message Generation

The following part of the chapter describes the data gathering aspect of the design. Now that we have an ontology, we need motivational messages designed according to the ontology. The ontology prescribes tailoring the messages concerning the user's progress in their goals. This tailoring is extended by including user state variables that could be most effective for personalisation, as described in the following section. A total of three tailoring factors were identified: self-efficacy, mood and progress. Scenarios were designed with these tailored factors, and experts generated motivational messages based on these scenarios, which would later be used in our experiment.

3.3.1. Tailored factors

The rationale for the design choice of progress, mood and self-efficacy as the tailoring factors of a motivational message is described in the following section.

Self-efficacy

Self-efficacy is a critical factor in improving physical activity levels. According to the self-determination theory [94], self-efficacy or competence is defined as "feeling effective in one's ongoing interactions with the social environment and experiencing opportunities to exercise and express one's capacities". Theories commonly used in health behaviour change domain such as the self-efficacy theory [95], the self-determination theory [94] and the socio-cognitive theory [96] postulate self-efficacy as one of the principal driving factors of behaviour change. Furthermore, according to the self-determination theory, and as evidenced by studies [97, 98], self-efficacy has been linked to self-determined motivation, which has shown to be a significant predictor of physical activity.
Additionally, a study by Riet et al. [99] detected that, in the case of health behaviour change, self-efficacy regulated how the user perceives a message. As an extension, the framing of a message could be defined by the self-efficacy of the user. Therefore, the self-efficacy of the user moderates the way they absorb message content, and hence, self-efficacy can be a contributing factor in tailoring motivational messages.
In the scenarios designed, the self-efficacy of the persona is described in two levels: high and low., i.e., messages are tailored to the user based on if their self-efficacy level is low or high, for instance, in the scenario *"Tim is two weeks into a program that promotes physical activity, and he has achieved his goals every day in the program. He believes he can successfully keep going. It is also an advantage that the workouts always leave him feeling good and satisfied."*, the self-efficacy of the persona is high, while in the scenario, *"Jane has been consistently achieving her goals for a week now, and she feels pretty good about herself. However, lately, she is feeling exhausted after her workouts, and she does not think she can keep up her progress."*, the self-efficacy of the persona is low.

Mood

Mood has been an important concept in behaviour change theory, especially when it can affect how a user processes feedback regarding said behaviour [92, 100]. How a workout influences a user's mood is also relevant, as people tend not to continue doing unpleasant things or leave them feeling low or dissatisfied [97]. Additionally, it is shown that mood can be a predictor for physical activity [101].
Furthermore, the mood of the user has also been shown to influence how the user processes messages, which in turn affects the perceived motivation effect of the messages [102]. Mood is used as a resource in the processing of messages, with studies showing that users react differently to message content depending on whether they are in a positive mood or a negative mood [103, 104]. Hence, it could be argued that mood would be an effective factor in tailoring motivational messages.
In the scenarios designed, the valence part of the mood, which describes an emotion on a scale of positiveness to negativeness (or pleasantness to unpleasantness) [105], is described in three levels:

- **High valence** - *"Tim is two weeks into a program that promotes physical activity, and he has achieved his goals every day in the program. He believes he can successfully keep going. It's also an advantage that the workouts always leave him feeling good and satisfied."*
- **Neutral valence** - *"Tim is doing his physical activity every day, and he is confident he will make this a habit and incorporate active living into his lifestyle. The workouts do not have any strong impact on his mood."*
- **Low valence** - *"Tim is six weeks into a physical activity promotion program, and he has not missed his targets even for a day. However, he is getting bored of his workouts as they seem too routine and mundane. He is continuing with the physical activity sessions since he's confident he can finish his scheduled workouts, but they seem like a chore."*

Progress
Traditionally, progress feedback has mostly been limited to a numeric summary of the data [106]. Providing users with actionable feedback while providing additional information about their activity and progress will increase their intrinsic motivation and increase their adherence to the program [107].

The scale for the progress level has been borrowed from a study for smoking cessation by Sridharan et al. [108] and has been adapted to represent user's progress in the physical activity domain. Progress is categorised into five levels based on how the user is progressing with their physical activity goals.

- **First-time Success** - person achieves their physical activity goals continuously. For instance, *"Tim has started a physical activity promotion program today, and he has achieved his step count goal for the first time. He is feeling pretty good, and he believes that he can maintain his active behaviour this time."*
- **Continued Success** - person achieves their physical activity goal for the first time. For example, *"Tim is two weeks into a program that promotes physical activity, and he has achieved his goals every day in the program. He believes he can successfully keep going. It's also an advantage that the workouts always leave him feeling good and satisfied."*
- **First-time lapse** - the person does not achieve their goal for the first time. *"Jane has been achieving her goals for three days consecutively, but today she did not feel like going walking and completing her step goal and, as a result, failed her goal for the first time. She is sure this is a one-time failure, and she is optimistic about achieving her goal tomorrow."* illustrates this.
- **Continued lapse** - the person does not achieve their goals for an extended period of time. This scenario represents continued lapse, *"Jane has been doing a physical activity promotion program for about three weeks now. However, she has not met her daily goals for the past 3-4 days. She doesn't see the point in sticking with the program anymore. She feels good after a workout and is sure she'll ace her goals, but her motivation is fading away."*
- **Flip-flopper** - the person is inconsistent in achieving their physical activity goals. As an illustration, *"Jane has had a strenuous relationship with working out. She's highly confident she can get fit if she sets her mind to it, and working out also makes her feel good, but she's not dedicated to maintaining the habit. She doesn't see the harm in missing a day or two of her goals, and as a result, her progress is erratic."*

These tailored factors help address the given requirements:

- **R2 - The messages should provide adequate feedback about the user's progress.**
- **R3 - The messages should be tailored to the user's state during their physical activity intervention.**

3.3.2. Scenario-based message elicitation

Given the tailoring factors, the next step was to devise scenarios with made-up personas containing varying levels of these factors so experts could correspondingly write messages to motivate the persona. To this effect, hypothetical scenarios were designed to elicit motivational messages from the experts. Each scenario had a persona with a specific mood and self-efficacy in a particular progress level of their physical activity program. A total of 30 scenarios were created (5 progress levels * three mood valence levels * 2 self-efficacy levels), balanced on gender.

An example scenario is shown below:
"Jane did not meet her goal for the first time yesterday. She had a rough day at work and was too gloomy to work out, even though she knew she could successfully achieve her step count if she wanted to. Even though it was a first-time lapse, Jane is worried this might continue and that she'll undo all the excellent work she has put in to develop her habit."

The scenarios were rated by two independent coders (both masters students who were not involved in the project) to evaluate whether each scenario had a distinguishable mood, self-efficacy and progress level, and therefore, people who would read these scenarios, later on, would be able to identify the respective variable levels. Cohen's kappa test was performed, and the results were interpreted according to the scale developed by Landis et al. [109] There was a substantial agreement for the mood (Kappa= 0.732) and self-efficacy (Kappa= 0.733) levels in the scenarios and almost perfect agreement for progress (Kappa= 0.958) levels.

3.3.3. Expert generated messages

Two experts, a practising therapist and a medical psychologist, were recruited to generate motivational messages for the scenarios described in the section above. The experts followed the ontology described in Section 3.2 to design the messages. They were asked to consider the people in the scenarios as their clients and write the messages like they would be motivating their patients to improve their physical activity levels. Sixty scenario-based motivational messages were obtained, 30 per expert and two per scenario. Multiple messages per scenario helped with the variability of the messages, while also giving us the flexibility to choose amongst more than one message per scenario. The messages were corrected for spelling errors. An example scenario and an expert-written tailored message are shown in table 3.4. In the context of the described ontology, the first part of the tailored message, "Only one gap in your amazing activity progress." is the feedback component, while the latter part is the reinforcement component.

Scenario	Even though Tim has been meeting his goals every day, his confidence has been dropping recently. Yesterday, he did not feel motivated enough to work out, stopped his session halfway through, and therefore, didn't meet his physical activity goal. Since this is the first time he has not met his goal, he feels indifferent about it.
Tailored Message	Only one gap in your amazing activity progress. Just wanted to give you a big thumbs up for making it this far and to tell you that I am excited to see you reach your goals the rest of the week.

Table 3.4: An example of a scenario and the corresponding tailored message that an expert wrote.

3.4. Next Steps

This chapter proposed a design to frame motivational messages based on an ontology and tailored to the user's state. Hypothetical scenarios containing these user state variables were given to experts who provided messages intended to motivate the persona in the scenarios. The scenarios and messages will be used in the experiment to study the effects of generic and tailored messages. The following chapter will describe the methodology and experimental setup in greater detail.

4

Evaluation

This chapter describes the process of answering the third sub-research question,

> *"What is the effectiveness of the system to motivate people in a physical activity intervention?"*

The primary hypothesis to be tested is stated as follows:

> **H1: Motivational messages for increasing physical activity that are tailored to a user's mood, self-efficacy and progress are more motivating than non-tailored messages.**

The design specified in Chapter 3 is tested in an experimental setting to determine its effectiveness, as depicted in Figure 4.1. This chapter outlines the methodology of the experiment, described in Section 4.1. Section 4.1 covers an overview of the experimental design, followed by the materials used for the experiment, and the recruitment and characteristics of the participants. It also talks about the procedure of the experiment, the measures and data analysis used. The results of the experiment, are reported in Section 4.2, followed by a discussion of the reported results in Section 4.3.

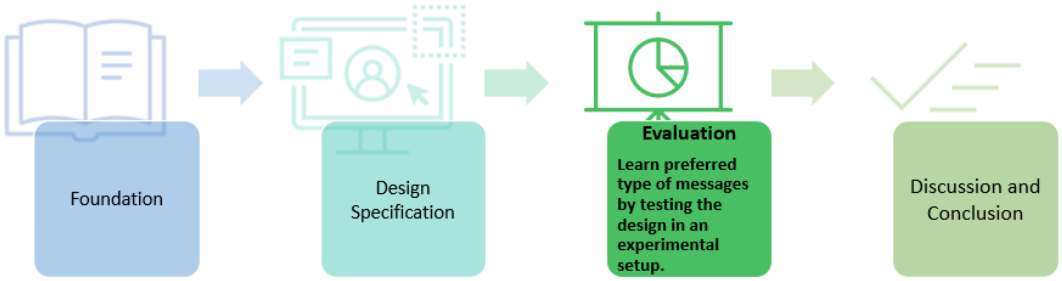

Figure 4.1: The proposed design is tested in an experiment.

4.1. Methods

The following experiment was run during December 2021-January 2022.The experiment was pre-registered on the Open Science Framework (OSF) [110], and the procedure outlined in this chapter has been approved by the Human Research Ethics committee of TU Delft with the approval number 1814.

4.1.1. Experimental Design

An experimental design was devised to evaluate the design of the messages as described in Chapter 3. The effect of messages tailored to a user's mood, self-efficacy and progress on motivation needed to be measured, to test the primary hypothesis. Figure 4.2 illustrates the conceptual model of the experiment. The aim of the experiment was to evaluate the impact of the two types of messages, tailored and generic, for a particular scenario on motivation. The control condition was established to be the generic messages written by experts, while the experimental condition was the messages tailored to progress, mood, and self-efficacy written by experts. A within-subjects design was used, and the two conditions in the within-subjects were tailored and generic messages. A single crowd worker evaluated 6 repeated measures per condition, i.e., each participant rated six generic messages and six tailored messages. To mitigate order effects and learning effects, ABBA counterbalancing was done when assigning tailored or generic messages to the crowd workers. Furthermore, the progress, mood and self-efficacy variables of the persona used in the creation of the hypothetical scenarios was counterbalanced with a modified Latin square. Interested readers are directed to Appendix A for a more thorough explanation.

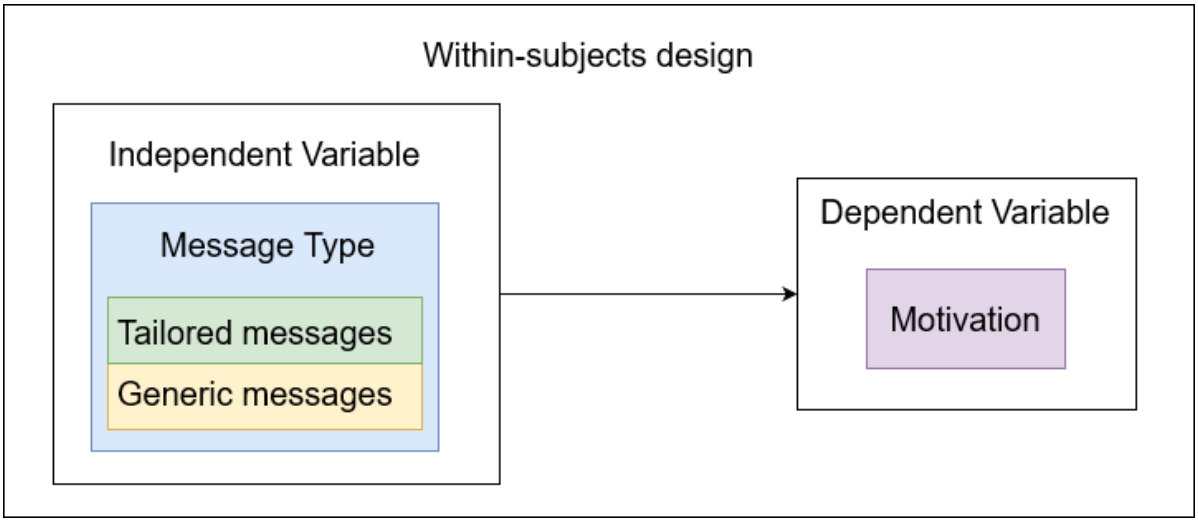

Figure 4.2: Overview of the conceptual model.

4.1.2. Materials

Scenarios tailored to a user's mood, self-efficacy and progress levels were used in the experiment. A complete list of the scenarios can be found in Appendix B. The materials used in the experiment included the motivational messages written by experts. Along with the tailored messages described in Chapter 3, experts were asked to write six messages each to motivate people to increase their physical activity levels regardless of their mood, self-efficacy or progress levels. These messages were labelled generic messages, and were collected with the purpose of comparing the effects of generic messages to tailored messages on motivation. These messages were written based on commonly used formulations psychologists use, which are based on guidelines such as the ones provided by World Health Organisation [111]. The differences in the two types of messages for a given scenario are shown in table 4.1. The generic message is picked randomly out of the pool of 12 messages, as it does not correspond to any scenario. All the messages collected by the experts are given in Appendix B. The scenarios and messages were further used in the questionnaires given to participants. The online platform Prolific[1] was used to recruit participants for the study. The survey platform Qualtrics[2] was used to build and deploy the questionnaire for the study.

4.1.3. Measures

Primary measures

The primary goal of the experiment was to measure the motivation of messages. Motivation was measured on a 11-point scale from -5 to 5, from "Very demotivating" to "Very motivating", with the mid-point 0 labelled as

[1] https://prolific.co/
[2] https://www.qualtrics.com/

Scenario	Even though Tim has been meeting his goals every day, his confidence has been dropping recently. Yesterday, he did not feel motivated enough to work out, stopped his session halfway through, and therefore, didn't meet his physical activity goal. Since this is the first time he has not met his goal, he feels indifferent about it.
Tailored Message	Only one gap in your amazing activity progress. Just wanted to give you a big thumbs up for making it this far and to tell you that I am excited to see you reach your goals the rest of the week.
Generic Message	Be active with friends and family. Having support is a great way to be and stay active.

Table 4.1: Given a scenario, the different types of messages are shown as above.

"Neither motivating nor demotivating". This scale and its interpretation is similar to the scale used to measure motivation of messages in a study by de Vries et al. [112].

Explorative measures
Apart from the hypothesis testing, explorative measures collected information that could explain variation in the reported motivation. To this effect, motivating and demotivating factors were used as the explorative measures. At the end of the scenario-rating questionnaire section, the participants were asked to describe what they find demotivating or motivating in messages motivating them to do physical activity. They were asked, "How would a message motivate you to do physical activity?" and "How would a message demotivate you from doing physical activity?". The questions were formulated as a modified version of the open-ended questions asked by Fukuoka et al. [113] The answers to these questions were used to determine which factors in the motivational messages were most motivating and which factors could demotivate users. Furthermore, information was gathered about several traits in the pre-questionnaire section for future research and can be found in the OSF form [110].

4.1.4. Participants

A power analysis for the frequentist repeated measures, within-factors ANOVA calculated with 6 repeated measures per condition (12 in total), a small effect size (f=0.17) [114], α value of 0.05, and power (1-β) value of 0.90. The sample size value was calculated to be 30, and was used as a conservative estimate of the observations needed for the experiment. We use the calculated sample size value as a conservative estimate of the observations needed for our experiment as a Bayesian approach is more efficient than a frequentist approach [115]. Furthermore, as a result of our randomization procedures, we had 30 unique scenario condition to assign to participants, and thus, the sample size of 30 also complied with the randomization and counterbalancing procedures. After 30 participants were recruited for the initial study, we estimated to have sufficient funds left to add 30 additional participants for a total of 60 participants. As stated in our OSF-form, once we reach our sample size of 30 participants, and we estimate to have sufficient funds left to pay another 30 participants, we will strive to add 30 additional participants for a total of 60 participants. We wanted our sample size to be a multiple of 30 due to our randomization procedures.

Participants were recruited online through Prolific, and had to give informed consent to be eligible. A pilot study was done with about 20 people during which it was observed that around 75% participants were failing attention checks in the scenario-rating part of the questionnaire. To counteract this, the approval rate of the participants on Prolific was increased from 90% to 95%. This ensures that only participants who have had at least 95% of their total submissions on the platform are eligible. Additionally, a pre-screener was added which allowed only crowd workers with at least 10 previous submissions to take part in the study. The data from the pilot study was excluded from the data analysis. Participants were screened based on the below mentioned criteria, using the built-in pre-screeners provided by Prolific.

Pre-screening criteria:

1. have an approval rate of >= 95% on Prolific, to ensure submissions from reliable participants,

2. speak English fluently, and
3. at least 10 previous submissions on Prolific, to avoid low-effort or low-quality submissions (as recommended by Prolific to recruit experienced users [3]).

Participants were paid for filling in the questionnaire based on the payment rules on Prolific (i.e. min. 5 GBP/hour). The questionnaire consisted of two sections, a pre-questionnaire section and the scenario-rating questionnaire section. Attention checks were implemented in the questionnaires, which were questions with one correct and obvious answer, meant to check if the participants were paying close attention to the instructions given. If the participants passed at least half of the attention checks in both the pre-questionnaire section and the scenario-rating section, gave informed consent, and passed the pre-screener validation about English fluency, they were paid. If participants violated any one of these conditions, they were rejected and disqualified from payment. The data from the rejected participants was not included in the data analysis.

Participants were recruited over four weeks, and a total of 121 participants took part in the study. Out of the 121 participants, only 60 participants were approved based on the conditions mentioned above. The participants were nationals of diverse countries, majorly from Poland, Portugal, United Kingdom, Greece and Italy. To mitigate the biases such as the ones mentioned in Draws et al. [116], specifically loss aversion and self-interest bias, participants were informed that their responses to the questionnaire would not affect their payment in any way, unless it violated the conditions mentioned above.
Table 4.2 shows the participant characteristics.

Variable	**N = 60**
Age	Mean = 28 (SD = 7), Range: 19-46
Gender	
Male	35 (58%)
Female	24 (40%)
Other	1 (2%)
Weekly Exercise Amount (In Minutes)	
Never (0 – 60 minutes per week)	10 (17%)
Sometimes (60 – 150 minutes per week)	35 (58%)
Often (more than 150 minutes per week)	15 (25%)
Physical Activity Stage (TTM)	
Maintenance	19 (32%)
Action	16 (27%)
Preparation	11 (18%)
Contemplation	12 (20%)
Precontemplation	2 (3%)

Table 4.2: Participant characteristics

4.1.5. Procedure

Participants who had given informed consent and passed the language validation check continue on to the rest of the study. The study consisted of a questionnaire divided into two sections:

- **a pre-questionnaire section** in which information was collected on traits such as the need for cognition, big-5 personality, and information related to smoking, quitting smoking, and physical activity, and
- **a scenario-rating questionnaire section** in which participants were given hypothetical scenarios that describe a persona with a specific mood, self-efficacy and progress level. A motivational message was given corresponding to a scenario, intended to motivate the persona in the scenario. The motivational message could be either tailored or generic. Participants had to rate these messages depending on how

[3] https://researcher-help.prolific.co/hc/en-gb/articles/360015433114-How-do-I-run-a-pilot-study-

motivating they find the messages. An example scenario and message are shown in Figure 4.3. Participants received 12 scenarios, with six scenarios containing generic messages and six scenarios containing tailored messages. After the scenario rating, participants were given two open-ended questions about what they find motivating and demotivating in a motivational message.

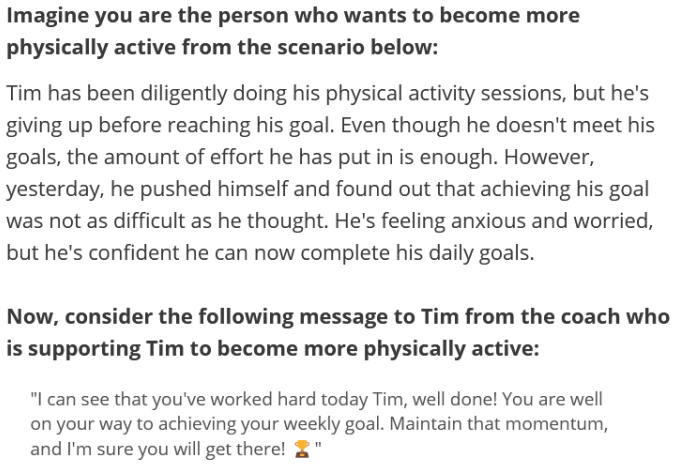

Figure 4.3: An example of a scenario and corresponding message in the scenario rating section

4.1.6. Data Preparation and Analysis Plan

The data collected through the experiment was analysed in R. The data collected and the R analysis files can be found at the 4TU ResearchData Repository [117].

Data Preparation

The data collected from the experiment was cleaned by first removing data of participants who were rejected. Data of participants who failed more than 50% of the attention checks in any section of the questionnaire was excluded. The data was then scrubbed by removing any additional/unnecessary information that was provided by Prolific or Qualtrics as per the data management plan of the project. This included sensitive data and potentially identifiable information (PII). The data was then prepared to be analysed by grouping the ratings for the tailored condition questions together, and similarly for the generic condition questions as well.

Data Analysis Plan

Multi-level Bayesian analysis was conducted on the data obtained from the experiment. The effects of the message type (generic or tailored) on the motivation of the participant were analysed. Models were incrementally fit to a mean, a random intercept for the participants, and a fixed effect for the message type. In effect, the data obtained from the experiment was first fit for motivation to a base linear model with random intercepts for each participant (m1). The second model (m2) extended m1 along with a fixed effect for message type. Diffuse priors were used when estimating the models. A prior sensitivity analysis was also conducted to assess the impact of different settings for the priors, and a t-distribution was fitted. The prior sensitivity analysis was done by varying the priors for the parameters in m2. The posterior probability of the hypothesis holding remained unchanged for the tested priors. The estimated models were compared based on the Watanabe–Akaike Information Criterion (WAIC), which gives an estimate of the out-of-sample deviance, and consequently, the model with the smallest WAIC is the best predictor for data points not included in the sample.
Additionally, a thematic analysis [118] was done on the participants' responses to the open-ended questions about how a message could motivate them to do physical activity, and how a message could demotivate them from doing physical activity. Identifying medical information was scrubbed from the answers by the researcher to remove sensitive and potentially identifying information from the data.

Inference criteria

To evaluate our hypothesis H1, sampling for the dependent variable, motivation, is done from the posterior of an estimated model, and 95% highest posterior density interval (HPDI) for estimators was reported. A HPDI

is the narrowest interval containing the highest values of posterior probability. Based on these samples, the posterior probability of H1 being true for our dependent variable was computed. This posterior probability was evaluated based on the guidelines described by Chechile [119]. Thereby, the guidelines by Chechile are extended to also account for posterior probabilities less than 0.5 based on Andraszewicz et al. [120].

4.2. Results

4.2.1. Effect of message type on motivation

In Figure 4.4 we can see the comparison of motivation, reported by the participants of the study, for the two message types, where the boxes represent the range of values reported by the participants for the particular message type, and the black line represents the mean of the distribution. From a quick visual inspection, we see that the mean score for motivation is higher in case of tailored messages, as compared to generic messages. Additionally, from Figure 4.5, it can be seen that model two has lesser deviance than model one. It follows that of the two, model two will perform better for out-of-sample predictions. Table 4.3 summarizes the parameters of model two, with a mean (SD) value of 1.01 (0.13), and a 95% HDPI of [0.76, 2.37]. The posterior probability of the hypothesis being true was calculated to be > 0.99999. According to the guidelines by Chechile, the given posterior probability can be evaluated as virtually certain for H1.

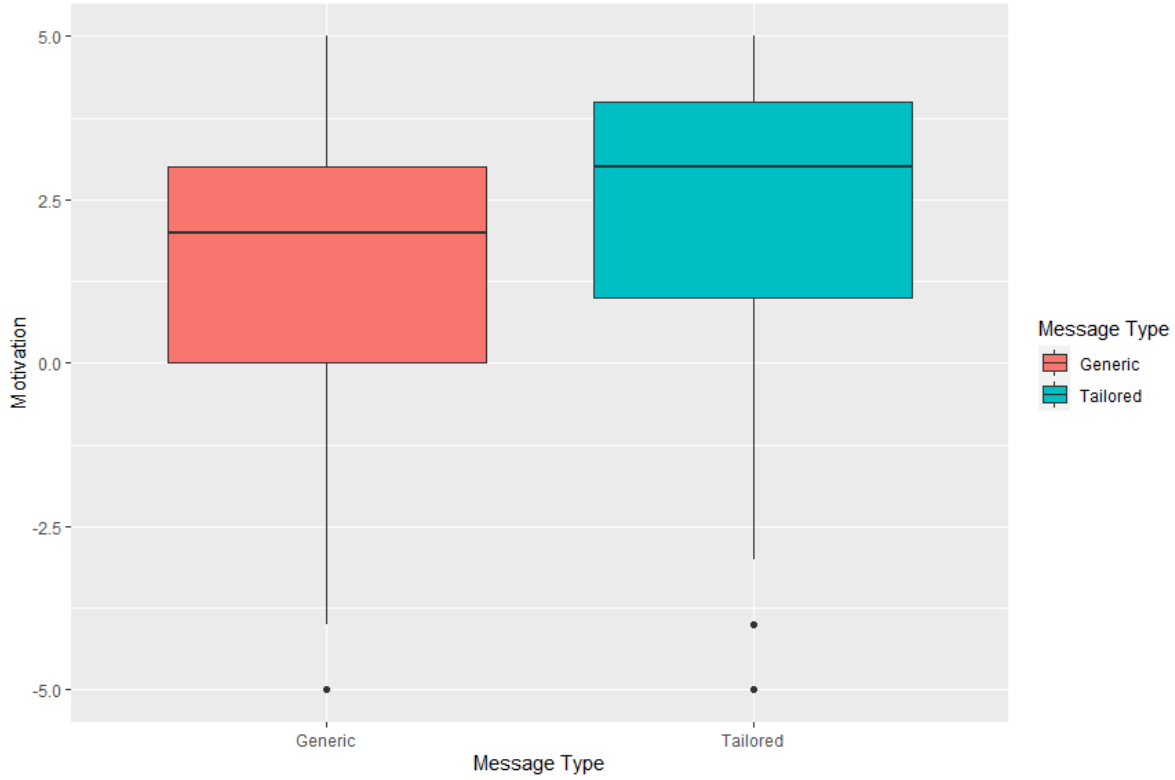

Figure 4.4: Comparison of the motivation of the two message types.

	μ (SD)	95% HPDI	p (posterior prob.)	Bet evaluation
Model 2				
Participant + Message Type	1.01 (0.13)	[0.76, 2.37]	>0.99999	[0.99995, 1): Virtually certain for H1

Table 4.3: Summary of model 2 (m2)

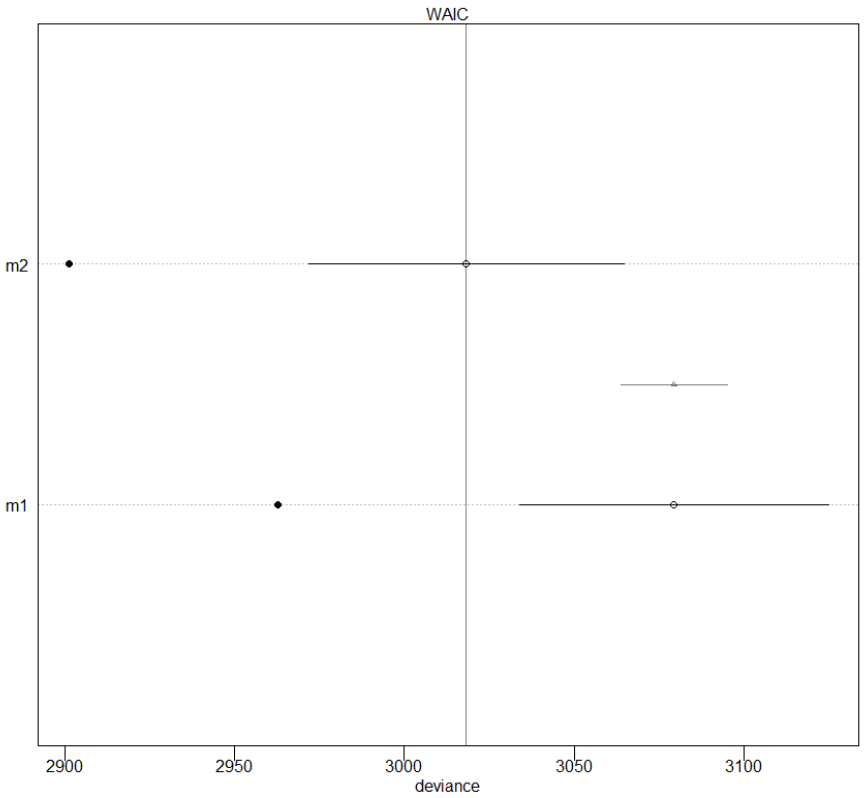

Figure 4.5: Comparison of the two models fitted on motivation based on WAIC.

4.2.2. Motivating and Demotivating Factors in a Message

A thematic analysis was done on the responses given by the participants for the open-ended questions. Figure 4.6 shows the themes derived from the question about the motivating factors, and Figure 4.7 reports the themes derived from the question about the demotivating factors. Both figures also contain quotes from the participants which fit the corresponding themes.

The major themes for both the questions were:

- **Goal-related information** - Goal-related information encompasses all information related to a user's physical activity goals. In motivating factors, the most commonly recurring sub-themes in goal related information were goal progress, benefits and personalized goal setting, while in demotivating factors, the sub-themes were no feedback, goal difficulty, and generic goal setting. Participant 18 answered the following as a demotivating factor, which can be classified as a feedback-related factor: *"A message would demotivate me by not validating any progress made, not being understanding of my needs and not providing alternative solutions to reach my goals."*
- **Intention** - The intention of the message is the overall tone the message has. Participants reported that encouraging and empathetic messages were motivating whereas messages that provide negative feedback, or only focus on the goals they have missed/focus on failures are demotivating. Participant 44 reported *"It must have some kind of encouragement for me, to make me understand that I can do it and I have what it takes"* when asked about what motivates them.
- **Message structure** - The structure of the message, specifically length, and content style. Messages tending to be short and simple were perceived to be motivating whereas long and verbose were considered to be demotivating, as also demonstrated by participant 49 who said, *"Short messages, that make senses and at the same time push me forward"*.
- **Tailored or Generic** - Whether the message is tailored to a particular user's situation, or it contains cliched, empty platitudes. Tailored messages that provided personalised information were perceived to be motivating. On the other hand, generic messages were reported to be demotivating. This is evidenced by the answer of participant 56 when asked about demotivating factors in a message: *"If the message is*

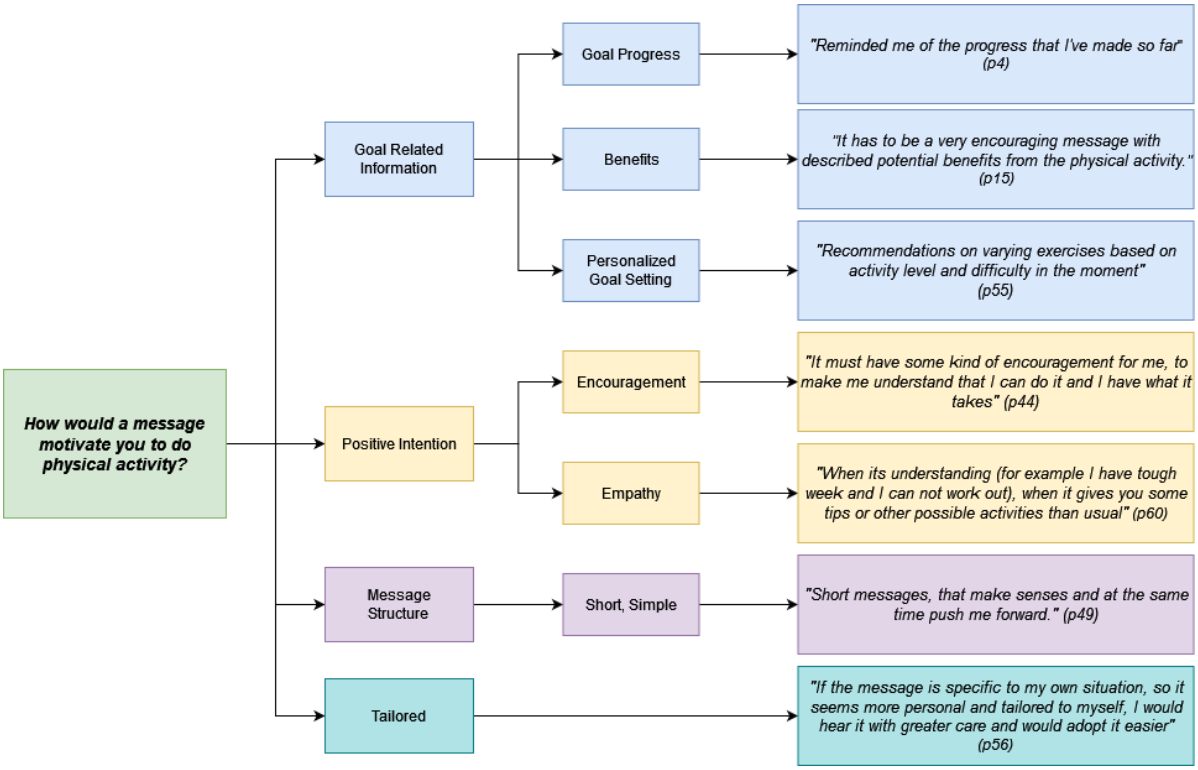

Figure 4.6: Thematic analysis of factors participants found motivating in a message, along with a few illustrative responses.

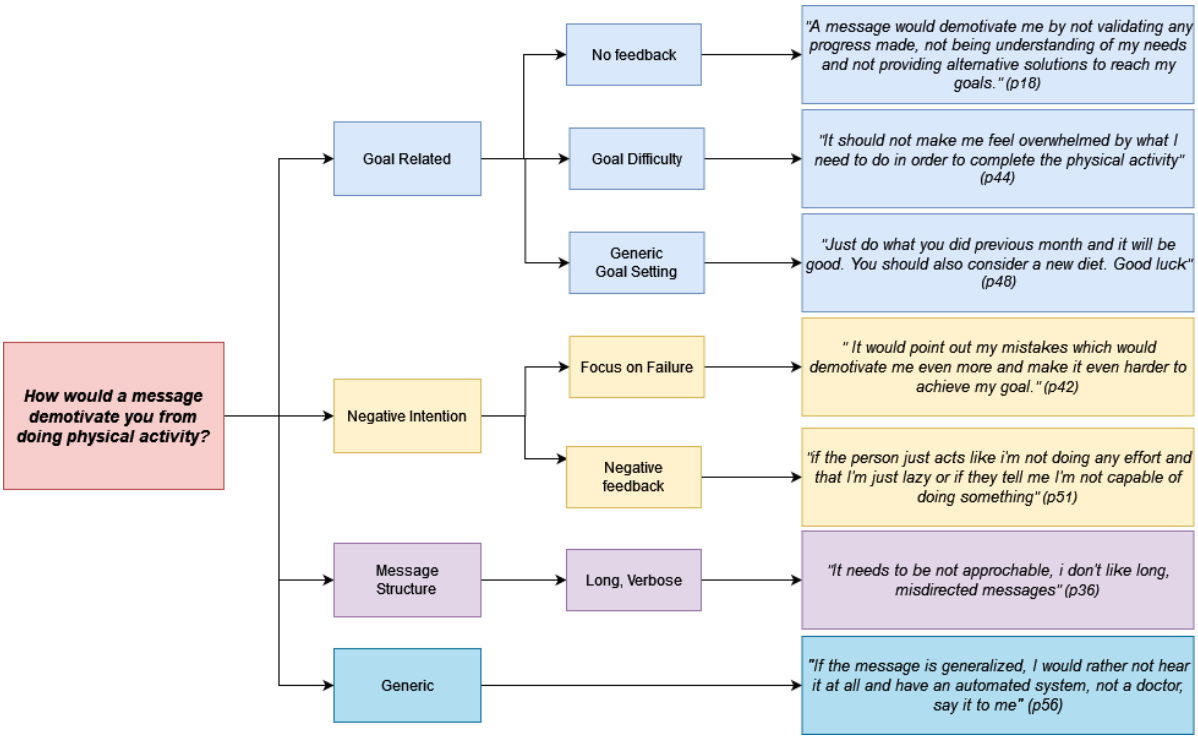

Figure 4.7: Thematic analysis of factors participants found demotivating in a message, along with a few illustrative responses.

generalized, I would rather not hear it at all and have an automated system, not a doctor, say it to me", and motivating factors, *"If the message is specific to my own situation, so it seems more personal and tailored to myself, I would hear it with greater care and would adopt it easier."*

4.3. Discussion

Given the results reported in the previous section, it can be suggested that messages tailored to a user's mood, self-efficacy and progress are perceived to be more motivating than generic messages, thus supporting the hypothesis H1. This is inline with existing research which has shown that tailored messages have modest success in motivating users given the context of health behaviour change [29, 121, 122], and the inclusion of user state variables such as mood, self-efficacy and progress level is motivating to the user.

The thematic analysis done on the participants' responses to the open-ended questions about the motivating and demotivating factors in a message yielded some interesting results. Regarding the theme of goal-related information, participants found that mentions of progress and personalized goal setting, along with information regarding the benefits of the physical activity they are doing was motivating. On the contrary, it was found that no feedback, the difficulty levels of the goals, i.e., too easy or too difficult, and generic goals were detrimental to the motivation of the participants.

Similarly, for the theme of intention, positive intentions of the message which makes it uplifting, empathetic, is positively reinforcing, and encouraging is motivating. Empathy has been shown to be a notable factor while communicating with users regarding health behaviour [123]. Conveying human-like emotions to the user was another factor to be considered, as found in a study about interactions with a social robot [124]. Conversely, messages which focus on failure, provide negative feedback/criticism, or lack empathy were found to be demotivating. Incidentally, false positivity, too much empathy, excessive compliments and praise were also perceived as demotivating. It can be surmised that the more genuine the message seems, the more motivating it is perceived to be, subsequently, messages that seem fake are perceived to be demotivating.

Furthermore, short and simple messages were found to be motivating while long and verbose messages were found to be demotivating. This finding is also supported by studies involving dialogs with virtual coaches, where it was found that lenghty messages hinder motivation for behaviour change, as well as resulting in the message losing its importance [125, 126]. The exception is when the message is short because it contains no real information, in which case it was found to be demotivating.

Lastly, one of the most crucial and recurring theme that was derived from the thematic analysis was regarding the adaptivity of the message. Participants found that messages that were tailored to the individual's needs and goals were more motivating than generic messages containing cliched platitudes that could apply to anyone. This further strengthens the evidence that our hypothesis H1 is true.

4.3.1. Limitations

The main limitation of the experiment is that participants had to rate the motivational level based on hypothetical scenarios, perceiving themselves to be the persona in the scenario, and rating the message accordingly. The participants might have rated the messages differently if they were in the situation described in the scenario, and consequently, the motivational rating of the messages would be more accurate to how much a message would actually motivate the participant. As an ideal case, the messages would be shown to the user when they have made similar progress in their physical activity, or have a similar mood or self-efficacy level. In order to minimize the risk involved in the experiment such as risk of injury, and due to the restrictions around Covid-19, we regarded that the hypothetical scenarios were a good alternative.

Another limitation is that only the motivational level of the messages were measured, and not the impact of the messages on users to do physical activity. In other words, it was not tested if the intervention could actuate behaviour change, but only if it could motivate it. Although, motivation has been shown to be a predictor of behaviour change in models such as the Capability, Opportunity, Motivation, Behaviour (COM-B) model [127].

4.4. Next Steps

The following chapter will discuss the research work done in this thesis as a whole, and the answers to the main research question. The chapter also elaborates on research work which could be an extension of this thesis.

5

Discussions and Conclusions

This chapter concludes the research work done in this thesis, in which we have tested the effects of tailored and generic messages on motivation. The findings of the exploration in Chapter 4are detailed in Section 5.1, as depicted in Figure 5.1. Thereafter, we discuss the main weaknesses of the work in Section 5.2. The key contributions and vale additions of the thesis are discussed (Section 5.3) and suggestion on how this work can be extended and improved upon are detailed in Section 5.4.

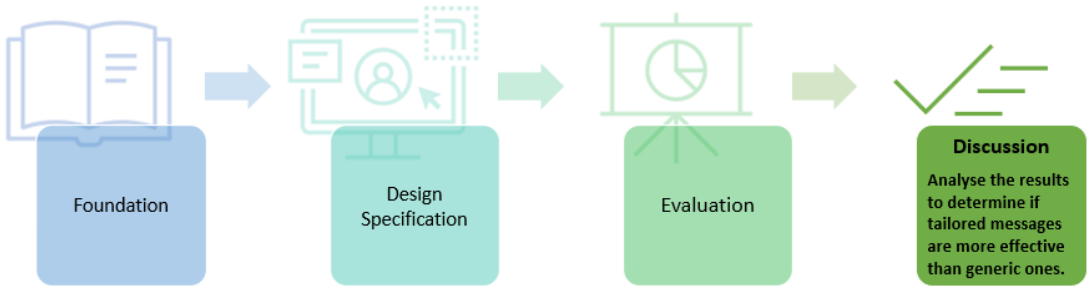

Figure 5.1: This chapter discusses the results obtained in the experiment described in Chapter 4.

5.1. Findings

Let's circle back to Chapter 1. To recap, the research question of this thesis is:

> ***RQ: How can user monitoring be effectively used to motivate people in a physical activity intervention?***

We set about answering the research question by first splitting it into three sub-research questions, with each question being answered in a dedicated chapter previously.

The first sub-research question is:

> *SRQ: What are the requirements of using user monitoring to motivate people in a physical activity intervention?*

A literature study was done, after which a consultation with experts from the field of psychology and biomedical sensors and systems was conducted. The importance of requirements like tailoring and empathy were highlighted, and these concerns were taken into account during the design of the system. From the

literature study and the focus group, the main requirements that were extracted are shown in table 5.1. The main requirements were personalising to user state variables, especially emphasizing user's goals and progress in feedback given to the user. To help with future research and improve reproducibility, a formal schema is added as a requirement to the design.

	Requirements
R1	The messages should be designed to motivate the user to do physical activity.
R2	The messages should provide adequate feedback about the user's progress.
R3	The messages should be tailored to the user's state during their physical activity intervention.
R4	The content of the messages should be simple and easy-to-understand.
R5	The messages should follow a formal schema to help reproducibility.

Table 5.1: Consolidated list of requirements

The second sub-research, as answered in Chapter 3, is stated below:

SRQ: What is the design proposed to motivate people in a physical activity intervention?

From the requirements gathered in Chapter 2, a design was devised to model the content of the messages delivered by the virtual coach to motivate users during their physical activity intervention. The final design of the motivational messages uses mood, self-efficacy and progress as user state variables to tailor to the user. For systematic gathering of motivational messages, and to help with reproducability, an ontology [92] was adopted to model tailored messages for physical activity coaching. This ontology was modified by adding qualitative and quantitative elements to the feedback component. To tailor the messages to the user's state, it could be argued that self-efficacy, mood, and progress were beneficial in motivating a user. The incorporation of user's progress in their physical activity goals, and the corresponding feedback were central to the design of the motivational messages. We needed messages that were adapted to the user's state, which were obtained by first devising hypothetical scenarios with personas having a specific mood, self-efficacy and progress level. Two experts from the field of psychology were then asked to provide motivational messages with the ontology provided. Along with the tailored messages, the experts also were asked to write generic messages to be later used in the experiment as the baseline.
The final sub-research question is:

SRQ: What is the effectiveness of the system to motivate people in a physical activity intervention?

To determine the validity of our design, an experiment was conducted which measured the effect of tailored and generic messages on motivation. The experiment had a within-subjects design. Each participant was given scenarios and corresponding messages, and were asked to rate the motivational level of the message in the context of the scenario. Participants were given six scenarios for each condition, tailored and generic. A total of 60 participants were recruited for the experiment. The results of the experiments provided evidence that tailored messages are perceived as more motivating than generic messages. Thus, the inclusion of user state variables such as mood, self-efficacy and progress could be key to better tailored messages for motivation. The thematic analysis of the motivating and demotivating factors in messages as described by the participants revealed that motivation and de-motivation had common but complementary themes. For instance, goal-related information was a theme that was discovered in both motivating and demotivating factors, where participants found information about their progress, benefits of physical activity and personalised goal setting motivating. On the other hand, participants found lack of feedback, goals that are too easy or too difficult, and generic goal setting to be demotivating. Inclusion of progress and feedback in messages was a key component of the design devised in Chapter 3. There were other ways the responses validated the design, for instance, with participants repeatedly highlighting that messages pertaining to their own situation would be more motivating, i.e., tailored messages, while reporting cliched, generic messages as demotivating. It stands to reason that motivating and demotivating factors are two sides of the same coin.

5.2. Limitations

The research work in this thesis has certain limitations, as described below.
Firstly, there are variables apart from motivation that can lead to behaviour change. Even motivation can be

talked about in terms of automatic vs reflective, as stated in the COM-B model [127] where motivation is one of the three indicators of behaviour change (opportunity and capability being the other two.) We consider reflective motivation, in which a user is actively and consciously involved in motivation, as opposed to automatic motivation which is a result of impulsive, habitual or drive-related behaviour. That being said, motivation is a good predictor for behaviour change [97, 98, 127], as described in previous chapters, with the advantage of being easier to record as it is less noisy a signal than actual behaviour.
Secondly, the participants' free text responses about the motivating and demotivating factors cannot be relied upon 100%. Even though people know about themselves, and their personalities, to a certain extent, they are limited in their self-awareness [128]. Thus, it would be fair to say that people would not know for certain what motivates them and what demotivates them, though it is a good starting point to learn what motivates the user, or as stated by Vazire et al. [128], "...self-knowledge exists but leaves something to be desired."

5.3. Contributions

We provided a systematic and reproducible way to obtain motivational messages from experts. With the ontology given, messages can be obtained from crowd workers as well, making message generation cheap as well as time and resource efficient.
Another contribution is the literature-backed user state variables a message can be tailored to, to improve the motivation of a user. As described in Chapter 3, there is research individually linking mood [102], self-efficacy [99], and progress [107] directly to motivation, but testing the combination of these variables as tailoring factors is completely new, to the best of our knowledge.
Lastly, we have provided a dataset of motivational messages that can be used during various stages of a user's physical activity intervention, along with a set of scenarios containing the aforementioned levels of the user's state. Furthermore, demographic data and traits about participants have been anonymised to remove personally identifiable information, and released to make future work about studying these characteristics and its effect on motivation possible.

5.4. Future Work

This research could be extended in several ways, a few of them are elaborated upon in this section. Firstly, a user's state could be automatically detected to tailor the messages and model content accordingly. As a next step, user's responses to the messages could be recorded to learn what kind of motivation the user prefers, and adapting the virtual coach accordingly. Reinforcement learning by automatically detecting the user's state and tailoring the virtual coach appropriately would help in better personalisation. Current work on reinforcement learning for determining the best time to send a message [129], and sending a feedback-based reminder by monitoring the user's progress [130] makes the idea of tailoring the message by automatically adapting to user state variables a feasible next step.
Secondly, we only considered messages represented in text form for our study. Research can be done into other types of representation, like images, videos or even emoticons which could be used to supplement or replace the text. The effects of these various types of representation, and their effects on motivation can be studied. If found effective, user's preferred representation of the messages could be learned, thus adapting the form of the message to the user. Audio, visual and haptic representation of a motivational message was proposed by den Akker et al. [92]. Auditory feedback was used in a study by Singh et al. [131] to motivate people with chronic pain to be more physically active. Thus, the delivery of motivational messages through different modals could be investigated.

5.5. Conclusion

We set out to answer our research question,

> ***"How can monitoring the user be effectively used to increase motivation in physical activity based smoking cessation programs"***

After following a framework of literature study, requirements elicitation, design and experimentation, it can be concluded that messages tailored to a user's progress, mood and self-efficacy are perceived to be more motivating to a user than generic messages. We have provided suggestions for this work to be improved upon which could help people in physical activity interventions, and potentially also in other interventions like

smoking cessation, eating disorders, and alcohol consumption. We hope this research contributes to people becoming more physically active, and consequently, reducing the risk of cardiovascular diseases.

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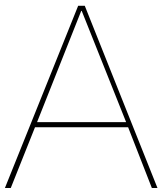


Appendix A - Randomization

Block Randomization - ABBA counterbalancing

This is done to expose the participants to both the generic and tailored conditions, and to account for order effects.

Participants are given one of two types of ABBA counterbalanced blocks shown below:

A	B	B	A	A	B	B	A	A	B	B	A
B	A	A	B	B	A	A	B	B	A	A	B

A	Tailored messages
B	Generic messages

Modified Latin squares transformation

This is done to expose the participants to all the mood, self-efficacy, and progress levels of the persona described in the scenarios given to the participants, while keeping the combination of elements unique.

We also try to account for order effects by counterbalancing this way.

The three variables of the persona in a scenario - mood, progress, and self-efficacy - and all their possible values are described in the tables below:

Mood

Level	Abbreviation
High	H
Neutral	N
Low	L

Self-efficacy

Level	Abbreviation
High	H
Low	L

Progress Levels

Level	Abbreviation
Continued Progress	CP
First-time Lapse	FL
First-time Success	FS
Continued Lapse	CL
Flip-Flopper	FF

Each row in the progress levels matrix is superimposed upon each row in the mood and self-efficacy matrix to generate 30 unique orders, which are randomly assigned to the participants.

The elements used in the Mood and self-efficacy matrix(MSM) are defined below:

	Mood	Self-efficacy
HH	High	High
HL	High	Low
NH	Neutral	High
NL	Neutral	Low
LH	Low	High
LL	Low	Low

The elements used in the progress levels matrix are defined below:

CP	Continued Progress
FL	First-time Lapse
FS	First-time Success
CL	Continued Lapse
FF	Flip-Flopper

Mood and self-efficacy matrix(MSM)

HH	HL	NH	NL	LH	LL
HL	NH	NL	LH	LL	HH
NH	NL	LH	LL	HH	HL
NL	LH	LL	HH	HL	NH
LH	LL	HH	HL	NH	NL
LL	HH	HL	NH	NL	LH

Progress Levels Matrix:

CP	FL	FS	CL	FF	FS	**PL1**
FF	CP	FL	FS	CL	FL	**PL2**
CL	FF	CP	FL	FS	CP	**PL3**
FS	CL	FF	CP	FL	FF	**PL4**
FL	FS	CL	FF	CP	CL	**PL5**

The tables shown below are the results of superimposing each row in the progress levels matrix upon each row in the mood and self-efficacy matrix.

PL1xMSM

CPHH	FLHL	FSNH	CLNL	FFLH	FSLL
CPHL	FLNH	FSNL	CLLH	FFLL	FSHH
CPNH	FLNL	FSLH	CLLL	FFHH	FSHL
CPNL	FLLH	FSLL	CLHH	FFHL	FSNH
CPLH	FLLL	FSHH	CLHL	FFNH	FSNL
CPLL	FLHH	FSHL	CLNH	FFNL	FSLH

PL2xMSM

FFHH	CPHL	FLNH	FSNL	CLLH	FLLL
FFHL	CPNH	FLNL	FSLH	CLLL	FLHH
FFNH	CPNL	FLLH	FSLL	CLHH	FLHL
FFNL	CPLH	FLLL	FSHH	CLHL	FLNH
FFLH	CPLL	FLHH	FSHL	CLNH	FLNL
FFLL	CPHH	FLHL	FSNH	CLNL	FLLH

PL3xMSM

CLHH	FFHL	CPNH	FLNL	FSLH	CPLL
CLHL	FFNH	CPNL	FLLH	FSLL	CPHH
CLNH	FFNL	CPLH	FLLL	FSHH	CPHL
CLNL	FFLH	CPLL	FLHH	FSHL	CPNH
CLLH	FFLL	CPHH	FLHL	FSNH	CPNL
CLLL	FFHH	CPHL	FLNH	FSNL	CPLH

PL4xMSM

FSHH	CLHL	FFNH	CPNL	FLLH	FFLL
FSHL	CLNH	FFNL	CPLH	FLLL	FFHH
FSNH	CLNL	FFLH	CPLL	FLHH	FFHL
FSNL	CLLH	FFLL	CPHH	FLHL	FFNH
FSLH	CLLL	FFHH	CPHL	FLNH	FFNL
FSLL	CLHH	FFHL	CPNH	FLNL	FFLH

PL5xMSM

FLHH	FSHL	CLNH	FFNL	CPLH	CLLL
FLHL	FSNH	CLNL	FFLH	CPLL	CLHH
FLNH	FSNL	CLLH	FFLL	CPHH	CLHL
FLNL	FSLH	CLLL	FFHH	CPHL	CLNH
FLLH	FSLL	CLHH	FFHL	CPNH	CLNL
FLLL	FSHH	CLHL	FFNH	CPNL	CLLH

Given a row from the ABBA counterbalanced blocks(as shown below), a sequence is formed by populating the blocks matching the starting block(A, in this case) with a row from one of the above tables, and the alternate blocks(B, in this case) are populated by reversing the order of the selected row.

A	B	B	A	A	B	B	A	A	B	B	A

For instance, given the below row:

CPHH	FLHL	FSNH	CLNL	FFLH	FSLL

The resulting final sequence will be:

CPHH	FSLL	FFLH	FLHL	FSNH	CLNL	FSNH	CLNL	FFLH	FLHL	CPHH	FSLL

B

Appendix B - Messages and Scenarios

Progress levels	Mood levels	Self-efficacy levels	Scenarios
Continued Progress	High	High	Tim is two weeks into a program that promotes physical activity, and he has achieved his goals every day in the program. He believes he can successfully keep going. It's also an advantage that the workouts always leave him feeling good and satisfied.
	High	Low	Jane has been consistently achieving her goals for a week now, and she feels pretty good about herself. However, lately, she's feeling exhausted after her workouts, and she doesn't think she can keep up her progress.
	Neutral	High	Tim is doing his physical activity every day, and he is confident he will make this a habit and incorporate active living into his lifestyle. The workouts do not have any strong impact on his mood.
	Neutral	Low	Even though Jane is accomplishing her goals, she feels like she is not making any progress, and as a result, her self-esteem is taking a hit. There is no considerable change in her mood before and after working out.
	Low	High	Tim is six weeks into a physical activity promotion program, and he has not missed his targets even for a day. However, he is getting bored of his workouts as they seem too routine and mundane. He is continuing with the physical activity sessions since he's confident he can finish his scheduled workouts, but they seem like a chore.
	Low	Low	Jane is two weeks into a physical activity promotion program, and she has achieved her goals every day in the program. However, she is feeling quite tired after her workouts, and she doesn't think she'll be able to continue with the program at this rate.
First-time Lapse	High	High	Jane has been achieving her goals for three days consecutively, but today she did not feel like going walking and complete her step goal and, as a result, failed her goal for the first time. She is sure this is a one-time failure, and she's optimistic about achieving her goal tomorrow.
	High	Low	Tim has been consistently meeting his goals, although his attitude towards the program has changed, reflected in his progress. Previously, Tim used to surpass his goals exceedingly, and after a while, he started barely meeting his goals and this behaviour culminated in him skipping his workout today. He looks forward to his walking sessions, but he's losing faith in his abilities to reach his goals.

	Neutral	High	Jane has been a sincere follower of a physical activity promotion program. She has met her goals continuously since the start of the program. Alas, even though Jane started her physical activity session yesterday, she did not work out long enough, and as a result, she wasn't able to meet her goal. She's confident she'll meet her goals tomorrow and is not feeling anything particular about it.
	Neutral	Low	Even though Tim has been meeting his goals every day, his confidence has been dropping recently. Yesterday, he did not feel motivated enough to work out, stopped his session halfway through, and therefore, didn't meet his physical activity goal. Since this is the first time he has not met his goal, he feels indifferent about it.
	Low	High	Jane did not meet her goal for the first time yesterday. She had a rough day at work and was too gloomy to work out, even though she knew she could successfully achieve her step count if she wanted to. Even though it was a first-time lapse, Jane is worried this might continue and that she'll undo all the excellent work she has put in to develop her habit.
	Low	Low	Tim lapsed for the first time yesterday as he did not meet his physical activity goal. He started his workout, but felt anxious about not completing it, and so stopped in between the session. He is worried about slipping up again.
First-time success	High	High	Tim has started a physical activity promotion program today, and he has achieved his step count goal for the first time. He is feeling pretty good, and he believes that he can maintain his active behaviour this time.
	High	Low	After a week of missing her goals, Jane mustered up the energy to do her physical activity session today and achieved her goal for the first time in a week. She feels great, but she doesn't think she's capable of sticking with the program.
	Neutral	High	Tim has become lazy, and he's missing his goals every day. However, today he decided to get back on the program. He achieved his goals for the first time in a while. He is now confident about his abilities and has no strong feelings about working out.
	Neutral	Low	Jane has been in a funk lately and has not been feeling up to fulfilling her goals. Today, however, was a fresh start, and she achieved her goal for the day. She still is worried if she's capable enough to work out every day, especially as she doesn't feel any inclination to work out.
	Low	High	Tim has been diligently doing his physical activity sessions, but he's giving up before reaching his goal. Even though he doesn't meet his goals, the amount of effort he has put in is enough. However, yesterday, he pushed hiMSMlf and found out that achieving his goal was not as difficult as he thought. He's feeling anxious and worried, but he's confident he can now complete his daily goals.
	Low	Low	Jane has had a slump for a few days during which she couldn't achieve any of her step count goals due to personal and professional reasons. She started working out again today and reached her step count goal. She is still distressed and doesn't think she can meet her goals regularly.
Continued lapse	High	High	Jane has been doing a physical activity promotion program for about three weeks now. However, she has not met her daily goals for the past 3-4 days. She doesn't see the point in sticking with the program anymore. She feels good after a workout and is sure she'll ace her goals, but her motivation is fading away.

	High	Low	Tim has become lazy, and he's missing his goals every day. He feels good every time he works out, but Tim has a mental block when it comes to working out as he thinks he won't be able to achieve his goal and will fail.
	Neutral	High	Tim had been achieving his goals daily up until last week, after which he stopped doing his physical activity sessions. The workouts are a piece of cake, but he never seems to be in the mood to work out.
	Neutral	Low	Jane has been in a slump lately and has not been feeling up to fulfilling her goals. She abandons her workout sessions mid-way. She feels like she cannot finish the workout and is not very interested in achieving her daily goal either.
	Low	High	Tim has been doing his workouts daily, but he is only partially fulfilling his daily goals lately. He believes that even the short bursts of exercise will help him, so he does not see the point in finishing his workouts as intended and reaching his goals. It doesn't help that he does not feel good after the workout, even though he's confident in his abilities to achieve his goals.
	Low	Low	Jane has been missing her daily goals for over a week. She is scared of not being able to meet her daily goals, which is making her anxious. To avoid the fear of failure, she avoids doing the physical activity sessions altogether. She wants to be physically active and continue the physical activity promotion program she has enrolled in.
Flipflopper	High	High	Jane has had a strenuous relationship with working out. She's highly confident she can get fit if she sets her mind to it, and working out also makes her feel good, but she's not dedicated to maintaining the habit. She doesn't see the harm in missing a day or two of her goals, and as a result, her progress is erratic.
	High	Low	Tim has been working out daily, but there are days when he meets his goals and days where he makes little to no progress on his goals. He knows that working out puts him in a good mood, but occasionally he loses faith in his abilities which halts his progress.
	Neutral	High	Jane has no strong feelings towards working out, but she knows the benefits of maintaining an active lifestyle and strives towards meeting her goals. However, she doesn't make regular progress towards her goals, and it's normal for her to skip 2-3 days of working out in a week. To be sure she can meet her goals, she makes sure to work out every other day.
	Neutral	Low	Tim enthusiastically follows a physical activity promotion program, but he does not yet think of himself as an active person. Due to this attitude, he works out only when he finds the time, which results in him skipping working out a few days due to time constraints. There are days when he meets his goals, and other days he makes varying amounts of progress towards his goals, and therefore his overall progress is inconsistent. He feels indifferent to working out and thinks he's not capable enough to work out and meet his daily target.
	Low	High	Jane used to achieve her goals every day perfectly, but recently, she's missing daily targets, and as a result, her progress has become irregular. There are days when she exceeds her targets and days when she does not make any progress at all. She feels low after her physical activity sessions, but it's not because she thinks she cannot do her workouts.

	Low	Low	Tim works out when he feels he is motivated enough, and his progress depend on what he is feeling on a particular day. He's used to working out on alternate days now, which means he meets his targets on one day and misses them the next day. He feels anxious and distressed, which doesn't help his confidence levels either.

Table B.1: Scenarios tailored to mood, self-efficacy and progress.

Scenarios	Messages	
Tim is two weeks into a program that promotes physical activity, and he has achieved his goals every day in the program. He believes he can successfully keep going. It's also an advantage that the workouts always leave him feeling good and satisfied.	You are achieving your goals for two weeks in a row now, and it is a real mood-booster. Keep going like this!	You are doing great and are achieving your goals. Impressive! Keep up the good work.
Jane has been consistently achieving her goals for a week now, and she feels pretty good about herself. However, lately, she's feeling exhausted after her workouts, and she doesn't think she can keep up her progress.	Great job! You have already achieved your goals for a week now. It is normal to feel exhausted after your workout sometimes, but you will notice that it will become easier and that your fitness will improve. Maybe you will gain new energy if you change up your workout a little bit this week.	You made such a good start by achieving your goals for a week already. I am confident you can keep this up and that step-by-step, your body will get more used to your activity level. Make sure to end your workout with some relaxing stretches and a good rest. You can do it!
Tim is doing his physical activity every day, and he is confident he will make this a habit and incorporate active living into his lifestyle. The workouts do not have any strong impact on his mood.	You are being physically active every day. Keep going like this. You are doing a great job!	You are achieving your physical activity goals every day, so your body is becoming fitter and healthier every day. Keep up the good work!
Even though Jane is accomplishing her goals, she feels like she is not making any progress, and as a result, her self-esteem is taking a hit. There is no considerable change in her mood before and after working out.	You are doing great and have been accomplishing your goals for quite some time now. Sometimes it feels like you are not making that much progress, but your body is slowly getting stronger and more used to your physical activity level, and your general health will improve. Try to focus on small benefits you notice (being less tired when you walk the stairs, being outside in the sun due to your workout etc.). Keep it up!	You achieved your goals! It can take some time before you will notice the benefits of working out. However, if you keep going like this, your workouts will become more and more of a habit, it will become easier, and you will notice the benefits. Keep going like this!

Tim is six weeks into a physical activity promotion program, and he has not missed his targets even for a day. However, he is getting bored of his workouts as they seem too routine and mundane. He is continuing with the physical activity sessions since he's confident he can finish his scheduled workouts, but they seem like a chore.	Well done. You are achieving your goals for six weeks in a row now! I can imagine that you would like some new challenges to keep yourself on your toes. Maybe you can switch up your workout routine a little bit by doing some new exercises, working out in a new environment or by creating a new music playlist that you can listen to during your workout. Keep up the good work!	You are doing a great job of achieving your goal every week! Physical activity leads to great benefits for your body (fitness) and your mind (relaxation), and these benefits will be even greater when you switch up your workout routine every now and then (to keep your body and mind sharp). Add some new variations to your workout and keep going like this!
Jane is two weeks into a physical activity promotion program, and she has achieved her goals every day in the program. However, she is feeling quite tired after her workouts, and she doesn't think she'll be able to continue with the program at this rate.	You are doing a great job and are achieving your goals every day! It is normal to feel a bit tired after working out, but it should also give you more energy in general as your body is getting fitter. If you have the feeling that you are so tired after your workouts that you will not be able to continue with the program at this rate, it might be good to set goals that are a bit smaller. Or you can switch up your workout routine by doing another activity on some of the days (e.g., walking instead of running or incorporating your activity in your daily activities by doing some household chores). You can do it!	You have achieved your goals for two weeks now. Great job! What unfortunate to hear that you are feeling quite tired after your workouts. Do you always feel tired after your workouts? Or does it depend on the type of workout you do or on the other activities you are doing that day, for example? It could help to make your goals a bit smaller or try some other types of activities (e.g., walking instead of running or incorporating your activity in your daily activities by doing some household chores) so that you feel more energetic. I feel confident that you can do it!
Jane has been achieving her goals for three days consecutively, but today she did not feel like going walking and complete her step goal and, as a result, failed her goal for the first time. She is sure this is a one-time failure, and she's optimistic about achieving her goal tomorrow.	I missed you at 6 o'clock for your walking activity Jane. Luckily tomorrow is a new day with a new chance. See you at 6 o'clock for your walking? :)	Taking a little break today, Jane? Hope you did something fun instead of walking. You've been doing so well lately, you deserved to indulge. It would be such a shame to break your brilliant streak, though, so back at it tomorrow?

Tim has been consistently meeting his goals, although his attitude towards the program has changed, reflected in his progress. Previously, Tim used to surpass his goals exceedingly, and after a while, he started barely meeting his goals and this behaviour culminated in him skipping his workout today. He looks forward to his walking sessions, but he's losing faith in his abilities to reach his goals.	Hi Tim, I can't help but notice a change in your physical activities. You used to exceed your goals, however lately, I see that you have missed a few activities. Have you thought of the possibility that your goals were maybe too easy? Or that you have pushed yourself a little too hard at the beginning? If you recognize yourself in this, please don't hesitate to change your goals. This journey is yours and is meant to suit you.	So close, Tim! You only need 10 more minutes to reach your activity goal for today. Wanna grab your shoes and go for a run/hop on your bicycle?
Jane has been a sincere follower of a physical activity promotion program. She has met her goals continuously since the start of the program. Alas, even though Jane started her physical activity session yesterday, she did not work out long enough, and as a result, she wasn't able to meet her goal. She's confident she'll meet her goals tomorrow and is not feeling anything particular about it.	You have been doing truly amazing so far, Jane. Let's not even mention yesterday's unfinished activity and only focus on the ones ahead. Keep going like this. You are a champion	What an achievement, Jane! You have completed all, but one planned physical activity on your program since the start of the program. Keep this up to reach all your goals and become your new desired self.
Even though Tim has been meeting his goals every day, his confidence has been dropping recently. Yesterday, he did not feel motivated enough to work out, stopped his session halfway through, and therefore, didn't meet his physical activity goal. Since this is the first time he has not met his goal, he feels indifferent about it.	Only one gap in your amazing activity progress. I just wanted to give you a big thumbs up for making it this far and wanted to tell you that I am excited to see you reach your goals the rest of the week.	What's one uncompleted activity in the grand scheme of this program? Exactly, not a big deal at all. We all have days that we don't feel like it or our bodies don't feel right. Considering your excellent goal achievement these past weeks, I'm sure you will smash your goals the rest of the week.
Jane did not meet her goal for the first time yesterday. She had a rough day at work and was too gloomy to work out, even though she knew she could successfully achieve her step count if she wanted to. Even though it was a first-time lapse, Jane is worried this might continue and that she'll undo all the excellent work she has put in to develop her habit.	Hi Jane, it looks like you missed your activity for the first time. That's really no big deal and completely normal. We all have days when we feel less motivated to be physically active. You've been doing great so far. Keep up the good work!	Oh no, one activity missed! No worries, it is not a problem or a failure, only part of the journey. Some days are better than others. I'm sure tomorrow will be a better day.

Tim lapsed for the first time yesterday as he did not meet his physical activity goal. He started his workout, but felt anxious about not completing it, and so stopped in between the session. He is worried about slipping up again.	It's perfectly normal to feel anxious at times, Tim. We all do. And you've done the hardest part, which is to start your workout. Don't let this one experience bring you down. Next time, maybe tell yourself upfront that you are capable of finishing or visualize that you've successfully completed your workout before starting. Enjoy your next workout!	Some days we feel more confident than others. Today was a day with less confidence. That's completely ok, Tim, and I'm sure next time will be better, and you will complete your workout!
Tim has started a physical activity promotion program today, and he has achieved his step count goal for the first time. He is feeling pretty good, and he believes that he can maintain his active behaviour this time.	What a great start Tim, congratulations on achieving your very first activity goal! Hopefully, you've experienced that increasing your physical activity can be easy as taking one step, and then another, and then another :)	You're off to a great start Tim, congratulations on achieving your first activity goal! Complete your activities as planned in the next weeks to earn badges, feel great and become the new you!
After a week of missing her goals, Jane mustered up the energy to do her physical activity session today and achieved her goal for the first time in a week. She feels great, but she doesn't think she's capable of sticking with the program.	Well done today, Jane! I can't help but notice you have not reached your activity goals lately. Would you like us to review them together and see if they still suit you?	Great job completing your activity, Jane! I can't help but notice you have not completed your activity goals as planned lately. Do the goals still suit you? Don't forget, this is your journey, you can always alter your goals if need be.
Tim has become lazy, and he's missing his goals every day. However, today he decided to get back on the program. He achieved his goals for the first time in a while. He is now confident about his abilities and has no strong feelings about working out.	I'm so glad to see you back Tim, well done completing your workout today! Getting back to it can be difficult, but you've done the hardest part already. Keep up the good work! :)	Welcome back Tim, I'm so happy to see you working out and reaching your goals again. I am excited to see you continue on this path and reach all your goals.
Jane has been in a funk lately and has not been feeling up to fulfilling her goals. Today, however, was a fresh start, and she achieved her goal for the day. She still is worried if she's capable enough to work out every day, especially as she doesn't feel any inclination to work out.	I'm happy to see you working out again Jane, well done! It's never too late to pick up the thread again, and you've just taken the first step towards achieving your goals. Yay, you!	Tremendous work on reaching your goal after some absence, Jane! It's not always easy to get back in the game, so you are a champion for doing so. Maybe we can think of ways to stay on track together?

Tim has been diligently doing his physical activity sessions, but he's giving up before reaching his goal. Even though he doesn't meet his goals, the amount of effort he has put in is enough. However, yesterday, he pushed himself and found out that achieving his goal was not as difficult as he thought. He's feeling anxious and worried, but he's confident he can now complete his daily goals.	I can see that you've worked hard today Tim, well done! You are well on your way to achieving your weekly goal. Maintain that momentum, and I'm sure you will get there!	Wow, Tim, you've really worked hard today! Don't you feel great now? Keep up the good work this week, and you will surely reach your (weekly) goal!
Jane has had a slump for a few days during which she couldn't achieve any of her step count goals due to personal and professional reasons. She started working out again today and reached her step count goal. She is still distressed and doesn't think she can meet her goals regularly.	Hi Jane, I've noticed you haven't completed your physical activities for a few days now. I've also noticed you are reporting feeling a bit down. Are the two linked? You know you can always talk to me if need be. I'm there for you.	Hi again, Jane. Applause for completing your activity and reaching your step goal today. How did it feel to get back in the game?
Jane has been doing a physical activity promotion program for about three weeks now. However, she has not met her daily goals for the past 3-4 days. She doesn't see the point in sticking with the program anymore. She feels good after a workout and is sure she'll ace her goals, but her motivation is fading away.	It looks like you've missed a few activities in a row. You were doing so great before. Has something changed?	Hi Jane, it looks like you have missed a few activities in a row this week. No big deal, we all have moments when we feel less inclined to be physically active. Dips are part of the process and can make reaching the finish line even more satisfying. Don't let this dip throw you off course, ok?
Tim has become lazy, and he's missing his goals every day. He feels good every time he works out, but Tim has a mental block when it comes to working out as he thinks he won't be able to achieve his goal and will fail.	Hi Tim, I can't help but notice gaps in your activity program. Is everything ok? I've noticed you feel happy every time you do work out. Is there maybe something preventing you from starting the activity?	Hi Tim, I can't help but notice numerous gaps in your activity program. Sometimes physical activity can feel like an inconvenience. But if you are able to see it as an opportunity to become the new you, then I'm confident you will be able to stick to your program.
Tim had been achieving his goals daily up until last week, after which he stopped doing his physical activity sessions. The workouts are a piece of cake, but he never seems to be in the mood to work out.	Hi Tim, I see that you have not completed your activities in a little while, is everything ok? Know that you can always reach out to me if you want to talk.	It seems as if you have a little dip in your physical activity, Tim. Remember that you can always review your goals if they no longer suit you or your routine.

Jane has been in a slump lately and has not been feeling up to fulfilling her goals. She abandons her workout sessions midway. She feels like she cannot finish the workout and is not very interested in achieving her daily goal either.	You do not feel capable of finishing your workouts, but you do start with your workouts which is quite an accomplishment already! Being physically active on a regular basis can improve your mood and give you an energetic feeling. It could be easier to finish your workouts if you try out a different type of sport/activity (e.g., cycling, walking, playing tennis with friends, incorporating your activity in your daily activities by doing some active household or gardening chores). If you like to do an activity, it might be easier to achieve your goals!	What unfortunate to hear that you've been in a slump lately and that this keeps you from achieving your goals. Could it be that your daily goals are a bit too difficult to achieve? Or that you are not doing the activity/workout that you like to do most? If you set goals that are reachable and do a sport/activity that you enjoy, it becomes easier to be physically active and experience the benefits of this (like a good mood, feeling energetic, being fit). Try to find out what works best for you, and you have already made a great start!
Tim has been doing his workouts daily, but he is only partially fulfilling his daily goals lately. He believes that even the short bursts of exercise will help him, so he does not see the point in finishing his workouts as intended and reaching his goals. It doesn't help that he does not feel good after the workout, even though he's confident in his abilities to achieve his goals.	Good that you are doing your workouts every day! What unfortunate to hear that you do not feel good after working out. Physical activity can benefit your health and your mood, but it is important to work out on a regular basis so that your body will get used to working out. Maybe you can make your goals a bit smaller and gradually increase them in the long term. This way, it becomes easier, and you will hopefully feel more energetic and experience a positive mood!	You do not always finish your workouts, but you do start with your workouts which is quite an accomplishment already! When you have a balanced workout routine, working out becomes more of a habit which makes it easier to achieve your long-term goals and to notice the benefits of this (improved mood, fitness and health). To complete your entire workout session, you could try to make your goals a bit smaller or try out another type of sport to motivate yourself. You can gradually increase your goals if you feel like you are ready.

Jane has been missing her daily goals for over a week. She is scared of not being able to meet her daily goals, which is making her anxious. To avoid the fear of failure, she avoids doing the physical activity sessions altogether. She wants to be physically active and continue the physical activity promotion program she has enrolled in.	You have not achieved your goals this week, but you are clearly motivated to become more physically active. Try to set a daily goal that is not too difficult to achieve. Once you are achieving your daily goals, being physically active will become more of a habit, and your self-confidence will improve, which will make it easier to achieve your goals, and you can gradually increase your goals.	You have not achieved your goals this week, but I am confident that you are motivated enough to achieve your goals this coming week. Being physically active does not only benefit your strength, fitness and wellbeing, but it can also improve your self-confidence! Therefore, try to break up your physical activity sessions into smaller activities instead of seeing it as one long session. For example, first, motivate yourself to put on your workout clothes and search for a suitable playlist, then start with some warming up exercises, then do a set of 10 leg exercises, etc. Keep in mind: every minute of physical activity is good for your health!
Jane has had a strenuous relationship with working out. She's highly confident she can get fit if she sets her mind to it, and working out also makes her feel good, but she's not dedicated to maintaining the habit. She doesn't see the harm in missing a day or two of her goals, and as a result, her progress is erratic.	You are very motivated to work out on some days and other days are more difficult. Your body will get used to working out more easily when you work out on a regular basis. Maybe you can make your goals a bit smaller and gradually increase them in the long term. This way, you could feel more motivated to work out every day. Keep working on it!	You achieved your goals for quite some days, but some days you have less motivation for working out. It is important to form a habit and to work out regularly. This way, it becomes easier to achieve your goals and to maintain them for a longer period. It could help to plan your workout at the same time every day. You definitely showed what you are capable of, so I am confident you can do it!
Tim has been working out daily, but there are days when he meets his goals and days where he makes little to no progress on his goals. He knows that working out puts him in a good mood, but occasionally he loses faith in his abilities which halts his progress.	You have been achieving your goals for quite some days already! As you might notice, physical activity can improve your mood and your fitness, which will make it easier to be active and reach your goals with every workout. On the difficult days, try to think back to your previous workout session, how you started and finished the session and how you felt afterwards. Use this to motivate yourself!	You are very motivated to work out on some days and other days are more difficult. This is very normal. It can be difficult to make your workout routine a habit, but with every finished work out it becomes a bit easier. Maybe you can reward yourself with something small (buying flowers, calling your friend to tell him/her about your achievement, reading in your favourite book) every time you finish your work out. You deserve it!

Jane has no strong feelings towards working out, but she knows the benefits of maintaining an active lifestyle and strives towards meeting her goals. However, she doesn't make regular progress towards her goals, and it's normal for her to skip 2-3 days of working out in a week. To be sure she can meet her goals, she makes sure to work out every other day.	You have been active for quite some days already! As you know, an active lifestyle can have many benefits. But did you also know that when you are active every day, it is easier to turn your active lifestyle into a habit and to maintain this lifestyle? Maybe you can incorporate your physical activity into your daily activities on the days that you are not doing a workout session. For example, you can walk to the supermarket instead of taking in the car, take the stairs instead of the elevator, or do some active household or gardening chores. This way, it is easier to be physically active every day!	You are achieving your weekly goal by working out a few times per week. It is easier to maintain an active lifestyle if you have a workout scheme that you can follow every week. For instance, some people do a more intensive workout session 3 / 4 times a week and incorporate their physical activity into their daily activities on the other days. You can walk to the supermarket instead of taking in the car, take the stairs instead of the elevator, do some active household or gardening chores or go for a nice long walk together with a friend to catch up. Try to find a scheme that suits your lifestyle!
Tim enthusiastically follows a physical activity promotion program, but he does not yet think of hiMSMlf as an active person. Due to this attitude, he works out only when he finds the time, which results in him skipping working out a few days due to time constraints. There are days when he meets his goals, and other days he makes varying amounts of progress towards his goals, and therefore his overall progress is inconsistent. He feels indifferent to working out and thinks he's not capable enough to work out and meet his daily target.	You have been active for quite some days already! Try to challenge yourself to also work out on the days when you feel you have less time. It could help to plan your workout for the next day when you finish a workout session (e.g., think about what kind of physical activity you want to do, when and for how long). Working out every day will improve your fitness and can increase your confidence in your abilities. You can do it!	You are doing great! You are on your way to becoming an active person! Being physically active can give you a feeling of fulfilment and can make you feel like you have more energy. However, it can be difficult to do your workouts on busy days. On these days, it could help to incorporate your physical activity into your daily activities. For example, you can walk to the supermarket instead of taking in the car, take the stairs instead of the elevator, or do some active household or gardening chores. This way, you will be active and productive!
Jane used to achieve her goals every day perfectly, but recently, she's missing daily targets, and as a result, her progress has become irregular. There are days when she exceeds her targets and days when she does not make any progress at all. She feels low after her physical activity sessions, but it's not because she thinks she cannot do her workouts.	You are working out every day, great! A balanced workout schedule (doing about the same amount of physical activity every day) will ensure a stable energy level and makes it easier to maintain your progress. Try to reach the same target every day and gradually increase this target if you feel like you are ready. You can do it!	You are very motivated and work out every day! Of course, it is great that you sometimes have so much energy and motivation that you exceed your target. However, this can also make it more difficult to reach your target the day after, as you may have less energy after an active day. Next week try to stop when you reach your target and use the rest of your energy the next day to reach your target again. See if you notice a difference in your energy level. Keep it up!

Tim works out when he feels he is motivated enough, and his progress depend on what he is feeling on a particular day. He's used to working out on alternate days now, which means he meets his targets on one day and misses them the next day. He feels anxious and distressed, which doesn't help his confidence levels either.	You are doing great and working very hard to achieve your goals! Physical activity can improve your mood and decrease feelings of stress and anxiety by making you feel more relaxed. Try to be physically active every day, especially on the days that you feel distressed or anxious. Motivate yourself by saying out loud sentences like "I can do it!", "I am an active person", "I will feel good when I finish my workout". I am confident that you can do it!	You are very motivated to work out on some days and other days are more difficult. This is very normal, and it can be difficult to work out on days that you feel distressed or anxious. However, you might have noticed that working out can make you feel more relaxed and boost your mood. On the difficult days, try to think back to your previous workout session, how you started and finished the session and how you felt afterwards. With every workout session, it will become easier!

Table B.2: Scenarios and corresponding motivational messages written by experts.

Generic Messages
You are working very hard! Being physically active is good for your mental (feeling good) and physical health (becoming fit). You can do it!
The more you work out, the easier it gets! So keep going.
Working out can be a moment of relaxation, a social activity (when you work out together with a friend/group) and / or can give you a feeling of fulfillment. Go for it!
I know you can do it! It can be difficult to start with your workout, but once you have done it, you can be really proud of yourself and take a well-deserved break.
Working out can improve your mood. Think about the times when you successfully finished a workout or completed another task and how you felt afterwards. Use this to motivate yourself to do your next workout!
Being physically active every day can improve your sleep quality, and this, in turn, can make it easier to be physically active the day after. If you have difficulty with starting your workout, try to break it down into smaller steps. For example, as a first step, select a nice music playlist or podcast you want to listen to. The second step, change into your workout clothes, etcetera. You can do it!
”Think of physical activity/movement as an opportunity, not an inconvenience. Any form of PA/movement of the body is an opportunity for improving health, not as a time-wasting inconvenience.” [111]
”There are many ways to build the right amount of activity into your life. Every little bit adds up, and doing something is better than doing nothing.” [111]
It’s never too late to start! Find the activity that fits you and your schedule best, and start right now with a few minutes a day.
Increasing your physical activity can be easy, simply do the activities you are doing now, but more often or for longer periods of time.
You don’t need to fundamentally change your habits to be more active. For example, make a habit of walking whenever you can instead of using the car or taking the stairs instead of the elevator.
Be active with friends and family. Having support is a great way to be and stay active.

Table B.3: Generic messages written by experts based on the scenarios given to them.

C

Appendix C - Expert consultation: Physical activity intervention and smoking cessation

Table C.1 contains the summary of the scenario-based expert consultation conducted to elicit requirements.

Persona: Hasan is a 37-year old Uber driver, with a wife and two kids. Hasan smokes two packs of cigarettes a day and intends to quit to spend quality time with his children. Hasan is also not an active person, but aspires to be one so he can engage in sports and games with his kids.

Scenario	Claim	Suggestions
Daily progress motivation	The virtual coach is able to motivate the user when they are achieving their goals daily.	- There is a balance that needs to be maintained between positive reinforcement and frequency of celebration. - The users need small wins as motivation to maintain their progress. - To avoid repetitive celebrations of the same kind of achievements, unique milestones achieved by the user should be celebrated instead.
First time lapse	The virtual coach is able to assist the user when they lapse so they don't lapse further.	The user needs to be reassured, and be treated with empathy. In the case of smoking cessation: - The virtual coach can remind them of their coping strategies. - If it is not the user's first-time lapse, the virtual coach can ask about their previous lapse and suggest different coping strategies In the case of a physical activity intervention: - The virtual coach can acknowledge the failure and shift the focus on how to improve the next day. - The virtual coach can reaffirm the user's commitment to achieving their physical activity goal the next day in the absence of any external barriers.
Escalation in terms of relapse	The virtual coach can recognize and escalate when the user relapses.	The user needs to be reassured, and be treated with empathy.

		In the case of smoking cessation: - After the first 3 days of continuous lapses, the users can be reminded of their future identity, and if that does not help, after the first five days, the user can be advised to talk to someone they trust about their relapse, and if the behaviour persist for seven days, the user can be advised to contact their GP. - Ask the user about the optimum time to escalate based on their past experience. - The users can be given a reminder about their coping strategies, and evidence-backed information on why being abstinent is good for their body, with details like how much lung capacity they have recovered since quitting smoking, the amount of money they have saved on cigarettes and other such factors. In the case of a physical activity intervention: - If the user frequently lapses, the virtual coach should discuss the kind of barriers being faced by the user. - If a user repeatedly fails to meet their physical activity goal, they can be prompted to reflect upon the goals they have set and if there is a need to modify them, or if there are certain barriers that are preventing them from meeting their goals.
User safety	The virtual coach can ensure the user's safety when they are doing the physical activity intervention.	- There is an increased risk of injury if the a user does physical activity in a fatigued state, therefore adequate amount of rest should be advised before the next workout session.
Feedback to the user	The virtual coach provides adequate feedback to the user about their progress.	- Feedback to the user is necessary for the user to measure their progress. - This feedback can be based on physical factors such as maximum aerobic capacity, which is a critical indicator of cardio-respiratory fitness. - Data points that can be used to motivate the user are an injury risk estimation, distance covered in the past week, total time ran in the past week, highest heart rate during the run, number of steps and so on. - The user should not be overwhelmed with the information, instead, the information should be presented to the user in an easily digestible format. - Achievements like fastest run, longest run, and first-timer milestones should be highlighted and celebrated.

Table C.1: Suggestions from the expert consultation.

Figure C.1 shows an example of the scenario presented to the experts.

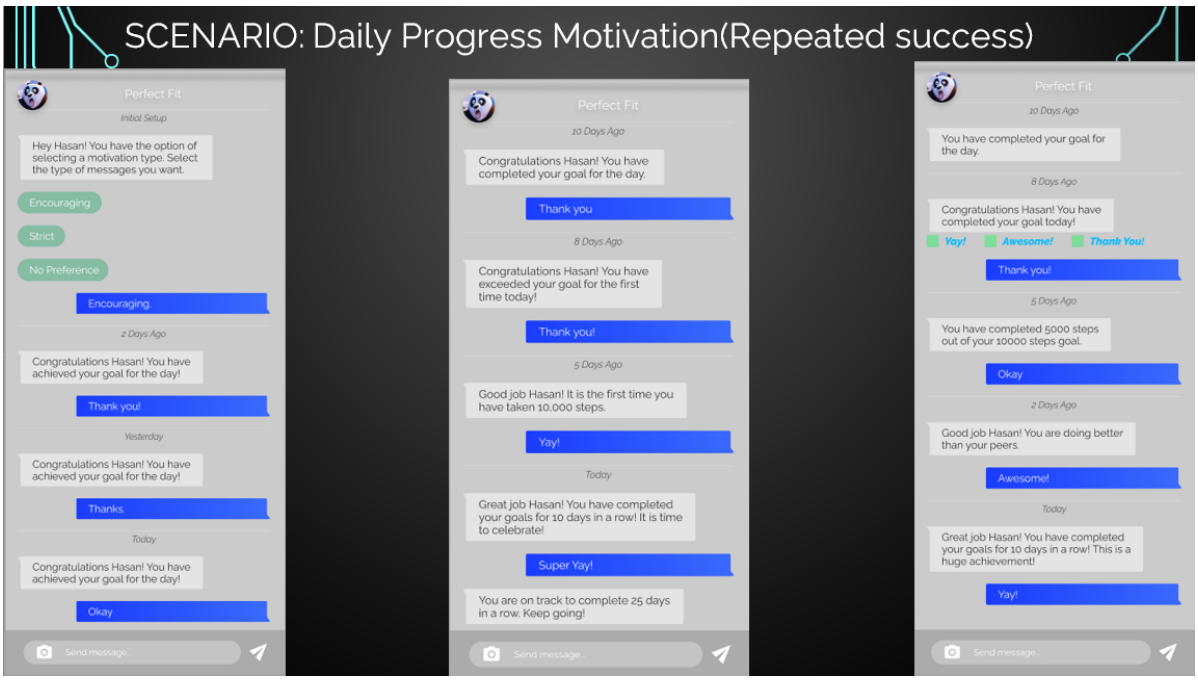
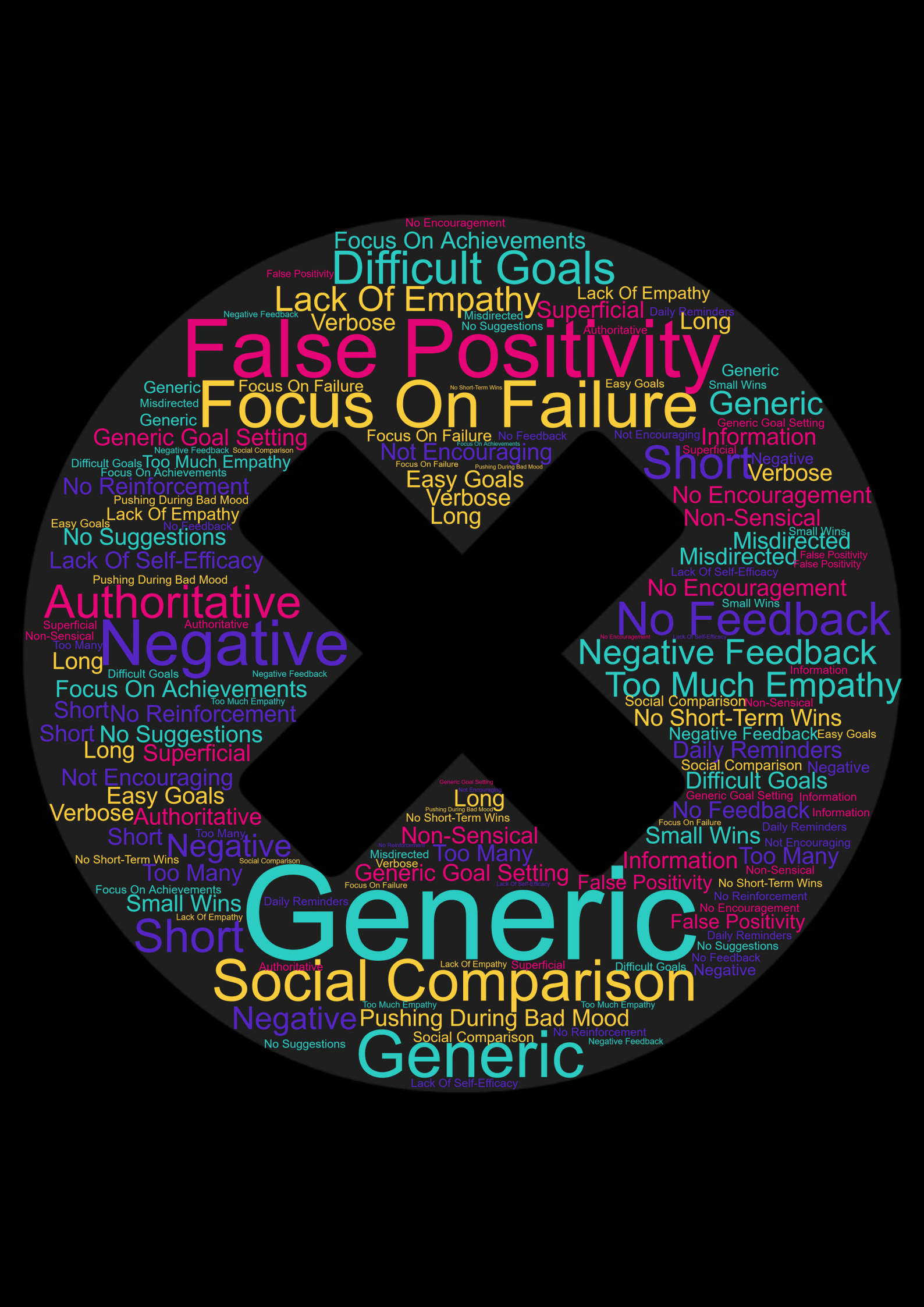


Figure C.1: An example of the scenario presented to experts


No Encouragement
Focus On Achievements
Difficult Goals
False Positivity
Lack Of Empathy
Lack Of Empathy
Superficial
Daily Reminders
Negative Feedback
Verbose
Misdirected
No Suggestions
Long
Authoritative
False Positivity
Generic
Focus On Failure
No Short-Term Wins
Easy Goals
Small Wins
Generic
Misdirected
Focus On Failure
Generic
Generic
Generic Goal Setting
Generic Goal Setting
Focus On Failure
No Feedback
Not Encouraging
Information
Negative Feedback
Social Comparison
Focus On Achievements
Not Encouraging
Superficial
Short
Negative
Difficult Goals
Too Much Empathy
Focus On Achievements
Focus On Failure
Pushing During Bad Mood
Verbose
No Reinforcement
Easy Goals
No Encouragement
Pushing During Bad Mood
Verbose
Non-Sensical
Lack Of Empathy
Long
Small Wins
Easy Goals
No Feedback
Misdirected
No Suggestions
Misdirected
False Positivity
Lack Of Self-Efficacy
False Positivity
Lack Of Self-Efficacy
Pushing During Bad Mood
No Encouragement
Authoritative
Small Wins
No Feedback
Superficial
Authoritative
Non-Sensical
Negative
No Encouragement
Lack Of Self-Efficacy
Too Many
Negative Feedback
Long
Information
Difficult Goals
Negative Feedback
Too Much Empathy
Focus On Achievements
Social Comparison
Non-Sensical
Too Much Empathy
No Short-Term Wins
Short
No Reinforcement
Negative Feedback
Easy Goals
Short
No Suggestions
Daily Reminders
Long
Superficial
Social Comparison
Negative
Not Encouraging
Difficult Goals
Easy Goals
Generic Goal Setting
Information
Verbose
Authoritative
Generic Goal Setting
Not Encouraging
Long
No Feedback
Information
Pushing During Bad Mood
No Short-Term Wins
Short
Too Many
Negative
Non-Sensical
Focus On Failure
Daily Reminders
Small Wins
Not Encouraging
No Short-Term Wins
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Misdirected
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