

Using Mobile Apps to Support People with Implementing Coping-relevant Behaviour Change Techniques for Stress Self-management

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Declaration

I, Nora Stern, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis. This thesis has not been submitted, in whole or in part, for any other degree, diploma or qualification at any other university.

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Abstract

Mobile apps have shown potential in early stress self-management interventions, yet they remain less beneficial than face-to-face therapies. One of the most effective ways people can cope with stress is to identify what their stressors are and take action in managing them. Coping-relevant behaviour change techniques (BCTs), such as self-monitoring, goal setting, and action planning, have the potential to support this process. Nevertheless, there is little guidance on how to incorporate such techniques into stress management apps. Drawing on mixed methods research, this thesis provides two contributions.

First, it improves our understanding of how existing stress management apps support coping-relevant BCTs and suggests areas for improvements. An app functionality review and follow-up 3-week intervention using Welltory stress monitoring and Coach.me goal setting apps revealed that existing apps do not support users' efforts with coping-relevant BCTs. Participants reported that Welltory did not yield sufficient data to gain insights into the factors affecting their stress. Relatedly, the way in which these apps implemented coping-relevant BCTs diminished peoples' sense of autonomy and competence.

Drawing on peoples' experiences with existing apps and principles of positive computing, the second contribution of this thesis is the design and evaluation of Reffy - a chatbot prototype that integrates coping-relevant BCTs in a way that meets people's stress management needs. Based on findings from a field evaluation study, we identify specific benefits and challenges of using a stress self-management chatbot. We find that chatbot-based reflective questioning helps people identify how factors impact their stress during early stages of self-tracking. Likewise, adding features that promote users' sense of autonomy and competence improves Welltory's ability to support coping strategies. This thesis advances our understanding of how behaviour change and stress coping techniques can be incorporated into mobile apps to effectively support stress self-management.

Impact Statement

Within academia, this thesis improves our understanding of a) how to address the limitations of existing self-monitoring approaches and b) how behaviour change and stress coping techniques can be augmented and incorporated into mobile apps to effectively support people with stress self-management. By applying mixed-methods research, we identify that app features aimed at administering coping-relevant behaviour change techniques (BCTs) need to be designed in a way that support people with gaining insights about what factors affect their stress levels without the need of long-term self-tracking. We also highlight the importance of designing app features that support peoples' needs for autonomy and competence and demonstrate how existing BCTs can be augmented and incorporated into apps to better fit these needs. Collectively the findings of this thesis can be used to inform future research efforts aimed at designing and evaluating effective stress self-management and broader health and wellbeing interventions.

Outside academia, the findings of this thesis are being used to inform the design and development of commercial health and mental wellbeing technologies. The work presented in this thesis lead to the formation of a Affiniti AI, the aim of which is to develop state of the art conversational AI solutions to help experts deliver scalable and accessible wellbeing services. Through Affiniti, the findings of this thesis are being used to directly inform the design and development of a health and wellbeing chatbot developed in partnership with Happence (a UK-based corporate digital health and wellbeing platform). Specifically, the teams at Affiniti and Happence are actively working on implementing the design guidelines provided in this thesis and are continuously evaluating the value and the impact that the different iterations of the chatbot add to the users via a combination of focus groups, field studies, and interviews. In addition to this, Affiniti is also working on building more scalable and dynamic ways of disseminating BCTs through conversational AI – the commercial and societal value of which was realised and reaffirmed by the findings presented in this thesis.

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1 Introduction

1.1 Motivation

Stress is a natural part of living. As our body's instinctive response to feeling threatened or under pressure, stress can motivate us to carry on with the work we need to get through in order to achieve personal goals (Lazarus and Folkman 1984), e.g., undertaking years of research in pursuit of a PhD, overcoming competition to earn a promotion, or enduring late nights to meet a tight deadline. Conversely, unmanaged or excessive stress can lead to debilitating mental, emotional and or physical strain. In this scenario, the stressed person becomes overwhelmed, unable to cope, or at an extreme, out of control. When this state persists over long periods, it can result in a condition known as chronic stress. Chronic stress manifests itself via a variety of psychological and physiological symptoms, including worry, anxiety, muscle tension, and a racing heart, among many others (McGonagle and Kessler 1990). Left untreated, the negative impact of chronic stress inevitably affects our ability to focus and function, and can undermine a sufferer's quality of everyday life (Cohen, Janicki-Deverts, and Miller 2007). In fact, stress-related disorders are now considered to be one of the biggest burdens on healthcare systems worldwide (MHF UK, 2015). In the UK alone, an estimated 165,000 bed days per year are occupied by patients suffering from stress or anxiety, costing British taxpayers some £71.1 million per year (Arnold, 2018). This figure underscores the need for effective and scalable treatment methods to help fight this mental health crisis.

Face to face treatments for stress management are effective (Regehr, Glancy, and Pitts 2013), but they simply do not scale to meet the rising demand (NHS Digital, 2019). This is problematic because timely and immediate access to treatment is of essence to people who are in need of mental wellbeing support – they need help here and now (Price et al. 2014). Mobile apps present themselves as a scalable alternative for delivering accessible and cost-effective stress management interventions (Luxton et al., 2014). However, they are still not reaching their full potential (Christmann, Hoffmann, and Bleser 2017; Coulon, Monroe, and West 2016; Luxton et al. 2011). Evidence indicates that, on average, mobile stress management apps achieve medium intervention effects on stress (Ahtinen et al., 2013; Christmann et al., 2017;

Harrer et al., 2018; Ly et al., 2014; Moberg et al., 2019), as opposed to face-to-face interventions, where observed efficacy measures medium to large (Regehr et al. 2013). From a technology perspective, apps have the capacity to provide access to the same variety of evidence-based treatments that are already being used in face-to-face therapy settings. Many such techniques, including goal setting and problem solving, are procedural and can therefore be implemented into an app interface. In practice though, there is still a lack of evidence-based techniques included into stress management apps (Christmann et al. 2017; Coulon et al. 2016).

One possible explanation of why the currently available stress management apps are not reaching their full potential is because they lack features that incorporate behaviour change techniques (BCTs) (Christmann et al. 2017; Michie et al. 2013). App-based health and wellbeing interventions consists of individual active components, such as self-monitoring or goal setting techniques. Like medication, an active component of a non-pharmaceutical stress management intervention is responsible for producing behaviour and physiological effects associated with the intervention's efficacy and impact. These components can be implemented as *app features* (a functional component of an app), where each feature can support an evidence-based technique (Hekler et al., 2013; Stawarz et al., 2018). There has been a call for health and wellbeing apps to incorporate more features that support BCTs as a way of improving on their impact (Direito et al., 2014; Stawarz & Cox, 2015). Coincidentally, stress management apps include fewer behaviour change techniques than other types of health and wellbeing apps, such as diet and fitness (Christmann et al. 2017). This might partially explain why the currently available apps are not as effective as face-to-face treatments.

According to stress coping literature, among the most effective tactics for managing stress involves people identifying and understanding what their stressors are and then taking direct action in managing them (Aspinwall & Taylor, 1997). For example, a person might notice that, by spending their evenings trying to catch up on the day's work, their stress levels will gradually increase over the course of the week. Upon noticing this pattern, they might decide to employ better time-management strategies. However, in practice, it can be difficult to notice such patterns, and the extent to which they affect us by relying on memory alone. People are prone to forgetting (Choe et al.

2017). Similarly, changing routine behaviours can also be challenging without the right support and guidance (Sniehotta 2009), especially when people are already feeling overwhelmed. There are several approaches that people can rely upon to help them cope effectively. The appropriateness of a given approach will depend on the type of stress people experience and the resources available to them at the time (Ellen A. Skinner and Zimmer-Gembeck 2016). We will discuss the implications of this more thoroughly in the next chapter. For now, it is sufficient to say that when people feel unable to cope, having a clear framework to follow can help them feel more capable in managing their stress. Coping relevant BCTs, such as self-monitoring, goal setting, and planning, act as a good starting point for researching how apps can provide people with a framework and guidance for supporting their stress self-management efforts (Aspinwall & Taylor, 1997; Christmann et al., 2017; Skinner & Zimmer-Gembeck, 2016; Skinner et al., 2003).

We begin our research efforts by focusing on coping-relevant BCTs as they have been shown to help people gain better understanding of the root causes of their stress and guide them toward finding sustainable techniques for effectively dealing with it (Aspinwall & Taylor, 1997; Christmann et al., 2017; Skinner & Zimmer-Gembeck, 2016; Skinner et al., 2003). Self-monitoring is a BCT that helps people identify the trends and patterns in their stress levels and offers them insights into what their specific stress triggers are. Over time, self-monitoring can also lead to improvements in self-awareness and self-regulation (e.g., becoming more alert to stress triggers and working towards minimising or eliminating them) (Bakker and Rickard 2018a). In addition to self-monitoring, people can also benefit from BCTs that help them translate their insights into actions. Among these are goal setting and planning (Sniehotta 2009), which support people with adhering to selected stress management behaviours. Whereas goal setting helps people envision a clear future state that they wish to achieve, planning helps them to see the specific steps they need to take to achieve that goal state (Locke and Latham 2006; Sniehotta, Schwarzer, et al. 2005; Sniehotta 2009). Thus, existing research would suggest that including these coping-relevant BCTs into apps should help support their users with understanding and managing their stress (Christmann et al. 2017).

What is not yet clear, however, is how coping relevant BCTs can be integrated into mobile stress management apps in such a way as to support the needs of people seeking to understand and manage their stressors. Thus far, research assessing stress management apps has focused primarily on either a) evaluating their overall efficacy on reducing perceived mental stress levels (Harrer et al., 2018; Ly et al., 2014; Moberg et al., 2019) or b) simply counting the number of evidence-based techniques that they include (Christmann et al. 2017; Coulon et al. 2016; Ewais and Alluhaidan 2015). Consequently, there remains a lack of understanding as to how (and how effectively) these apps incorporate coping techniques, and what peoples' experiences using them have been. Research focusing on *how* apps incorporate a given technique and/or how such techniques work when used in practice, can help ensure that the app in question is effective in delivering the necessary intervention components. In other words, focusing on peoples' experiences associated with using the app helps to inform whether the end users are able to successfully implement the techniques that the app administers into their day-to-day lives and whether their self-care needs are being met (Klasnja, Consolvo, and Pratt 2011). Understanding peoples' use and their needs associated with the app is important. Although coping-relevant BCTs are commonly used within face-to-face therapy settings, looking at past research evaluating stress management apps (Ahtinen et al. 2013; Christmann et al. 2017; Coulon et al. 2016; Ewais and Alluhaidan 2015; Harrer et al. 2018; Ly, Asplund, and Andersson 2014; Moberg, Niles, and Beermann 2019), it is still unclear how successful people are when applying such techniques on their own, without the guidance provided by a professional therapist. Collectively, understanding how people use, experience, and apply BCTs delivered via a mobile app can help inform how to incorporate such techniques into mobile stress management apps in a way that enables users to leverage their full potential.

1.2 Research Questions

There is currently little guidance on how coping-relevant behaviour change techniques can be incorporated into mobile stress management apps. The objectives of this thesis are therefore to improve our understanding of 1) whether and how existing apps support people with implementing coping-relevant BCTs, 2) whether the way in which

these features are incorporated into existing apps meet users' stress management needs, and 3) what new app features could be designed to better fit user needs. To achieve these objectives, this thesis investigates the following research question:

1. *How can mobile apps incorporate coping-relevant behaviour change techniques in a way that supports people in understanding and managing their stress?*

To answer the above research question, we are first required to gain a better understanding of the research problem at hand. To gain this understanding, we answer the following two sub-questions:

- 1.1. *Do existing stress management apps support people with implementing coping-relevant behaviour change techniques in a way that helps them to understand and manage their stress?*
- 1.2. *How could app features be designed to better support the needs of people who are implementing coping-relevant behaviour change techniques in their efforts to understand and manage their stress?*

1.3 Thesis scope and definitions

To answer the above research questions, this thesis draws on three interrelated areas of research: stress coping, behaviour change, and personal informatics. We use theoretical frameworks stemming from each of these fields to provide a unique lens through which we examine how people use and experience stress self-management technologies. We begin by investigating theories of stress coping and behaviour change to explain how coping-relevant BCTs can support people with stress self-management. We then take an HCI-led approach to study whether the way in which these techniques are incorporated into existing apps provides adequate support for understanding and managing stress. In doing this, we primarily rely on personal informatics models and related theoretical work as they give us a systematic framework through which we can study the above processes as well as enable us to more directly compare our findings to those of others.

Because we draw upon historically distinct, but nonetheless, interrelated areas of research, it is important to emphasise that research on stress coping, behaviour change, and personal informatics each use different terminology to describe overlapping concepts and processes (Figure 1). For example, theory on personal informatics aligns closely with the principles of stress coping: monitoring and understanding the behaviour, and then changing that behaviour to reach the desired state (Aspinwall and Taylor 1997; Carver, Scheier, and Weintraub 1989; Li, Dey, and Forlizzi 2010a). According to the stage-based model of personal informatics (Li et al. 2010a), during the reflection stage users gather insights from their personal data and during the action stage they take actions in relation to those insights. In a stress management context, people may want to reflect on the types of activities that cause them stress and during the action stage they may decide to try meditating to help them manage those stressors and then begin this practice.

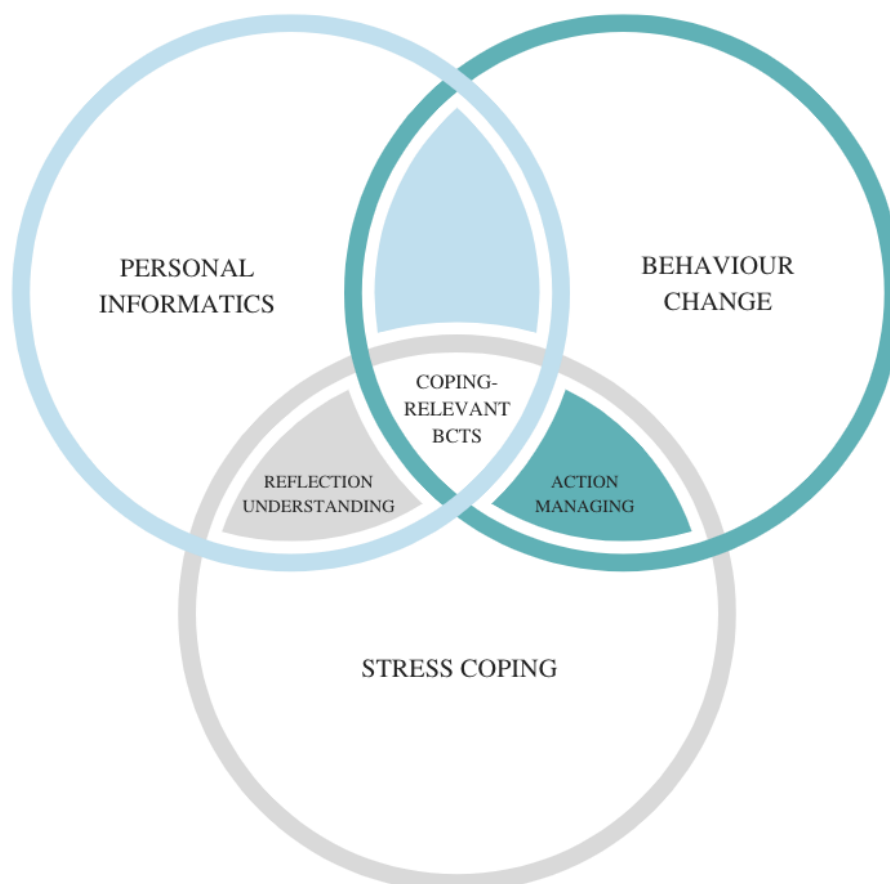


Figure 1. Areas of overlap between stress coping, personal informatics, and behaviour change literature.

Figure 1 was constructed to further illustrate the overlaps and complementary accounts of the different processes associated with stress coping. Notably, even though personal informatics research does discuss action taking (e.g., Epstein et al., 2015; Li et al., 2010), we additionally draw from research on behaviour change (Rhodes and de Bruijn 2013; Sniehotta, Schwarzer, et al. 2005; Sniehotta 2009) to provide a more detailed explanation of how people transition from the reflection (understanding) stage to the action stage. We do so primarily because there is a lack of evidence and clarity around how technology supports behaviour change presented within the personal informatic literature (Dijk et al. 2017a).

1.3.1 Participants and Context of Use

It is also important to define the types of users and contexts our work targets. In the present thesis, we focus on the millennial population within a non-clinical setting. We target this specific population and use-case as millennials are experiencing alarmingly high levels of stress and their acceptance of using digital tools for mental health distinguishes them as a clear target population that can benefit from stress self-management apps (APA, 2015). Moreover, as the aim of our research is to investigate a scalable approach to delivering stress management interventions, the context of the app's use does not consider having a human in the loop. As such, we assume that our target millennial user is willing and able to download a stress management app from an app store, install it and use it without necessarily receiving support and guidance from a human therapist.

Relatedly, our research investigates what is known as problem-focused coping (Skinner et al. 2003). This approach to stress management requires users to practice self-regulatory behaviours as a way of managing their stress. We acknowledge that people will experience different types of stress and that not everyone will benefit from a problem-focused coping approach. We expand on the different types of stress and coping approaches in our second chapter. For now, it is sufficient to say that the aim of our research is to investigate mobile interventions aimed at people who have a certain level of control over the main sources of their stress and are therefore able to benefit from identifying and resolving those sources.

For instance, we distinguish the app-based interventions investigated in this thesis from interventions delivered in an occupational setting. This is primarily because there is a growing body of evidence that, besides incorporating individual-level training (e.g., practicing problem-focused coping techniques), occupational interventions benefit from implementing systematic changes within an organisation, such as job redesign to give workers more decision making autonomy and control over their working environment (Holman, Johnson, and O'Connor 2018; Richardson and Rothstein 2008). For this reason, the findings presented in this thesis may not generalise to an occupational setting because the underlying organisational changes need to be implemented in conjunction with training on using problem-focused coping techniques. In other words, people first need to have the necessary control and autonomy before they can execute on problem-focused coping techniques within their organisational setting.

1.4 Methodology and research approach

Adopting a mixed methods approach is essential for answering the research questions posed in this thesis. Mixed methods research is commonly used within the field of HCI. Its strengths lie in its ability to provide a more comprehensive account of the research problem by drawing on insights collected via both quantitative and qualitative research methods (Turnhout et al., 2014). Taking a mixed-methods approach is particularly well suited for HCI research that aims to evaluate and design technologies for behaviour change. This is because the core aims of such research are to test whether a technology is behaving as expected (i.e., is effective) during the early days of its development and to understand why and how the technology is working (Klasnja et al. 2011). Whilst quantitative methods can help inform whether the interventions are effective, even if only in the short-term, qualitative methods can help paint a bigger picture of users' experiences with the technology. By homing in on peoples' experiences, it becomes possible to identify whether and how specific app features or their combined use contribute towards driving the efficacy of a given digital intervention and what the associated user needs and barriers to its use are. This makes it possible to highlight areas for improvements (Hekler et al. 2013; Klasnja et al. 2011). Within the context of this thesis, a mixed methods research approach is used to identify how existing mobile apps support their users and where the associated feature gaps and

barriers to use are. Once these are identified, we shift our focus towards investigating how new technologies could be designed to address the previously identified deficiencies.

To gain an understanding of how stress management apps can best support people with implementing coping-relevant BCTs we draw on a variety of quantitative, qualitative, and design research methods. The motivation for selecting each method are discussed in more detail in their corresponding chapters. Below, we describe the methods we used for data collection and analysis:

App feature review to investigate whether and how existing apps support people with implementing coping-relevant BCTs. We developed an app evaluation scale based on research in PI and behaviour change and applied it to conduct an in-depth feature review that goes beyond counting how many and what type of features an app includes. Using this method enabled us to describe the extent to which existing apps incorporate evidence-based techniques for stress self-management and how these are implemented. This can highlight potential feature gaps and areas for improvement to better support people's efforts to understand and manage stress.

Field studies with follow-up focus groups and semi-structured interviews.

Whereas app review studies can provide an initial understanding of whether existing apps incorporate features to support coping-relevant BCTs, it is field studies that enable HCI researchers to understand whether the way in which those features are implemented are useful and usable in peoples' everyday lives (Hekler et al. 2013; Klasnja et al. 2011). As mentioned previously, it is expected that peoples' actions will not necessarily align with the theoretical assumptions. Running field studies enables us to capture such discrepancies and, in this way, help us to produce more nuanced design guidelines for where improvements could be made. We therefore run a series of field studies to investigate how people use stress self-management apps in practice, focusing in particular on how people use existing and newly designed solutions to support them with implementing coping-relevant BCTs. To study this, we collect objective app use data, measure changes in perceived levels of stress, and conduct focus groups and semi-structured interviews with the same participants.

Design methods were used to inform how app features could be designed to better support people's needs with implementation of coping-relevant BCTs for stress self-management. This involved the design, development, and deployment of a chatbot prototype. The chatbot was designed by using a combination of our own findings and those reported in related research. In doing so, we designed chatbot-based app features expressly aimed at prompting people to reflect on their self-knowledge about stress and provide them with guidance on applying this knowledge to form action plans for engaging in stress management behaviours. Our motivation behind designing the chatbot prototype shares similarities with a technology probe (Hutchinson et al. 2003). Technology probes can capture rich contextual information with regards to the technology's use as and non-use, and peoples' experiences with that technology within a naturalistic setting. This enables the researchers to investigate the feasibility of that technology, gain a deep and situated understanding of what the users' needs are, and apply this information to inspire novel solutions that support those needs (Hutchinson et al. 2003).

Thematic analysis was used to analyse the qualitative data (Braun and Clarke 2006). According to Braun and Clarke, thematic analysis is a "a method for identifying, analysing, and reporting patterns (themes) within data" (Braun and Clarke 2006, p. 79). The analysis primarily focused on understanding how people used technology to support them with implemented coping-relevant BCTs and whether and how this led to improvements in understanding and managing stress. An inductive, "bottom-up" approach was taken to code the data. By using open coding to identify and describe peoples' experiences with implementing coping-relevant BCTs, we were able to capture and describe the situated use of mobile apps for stress self-management. However, the process by which the resulting codes were organised into themes was inherently guided by behavioural and stress coping theories. Taking this approach was essential for making contrasts between the assumptions made by the theory and the way in which people implement the theory informed strategies delivered via technology in their day-to-day lives (Braun and Clarke 2006; Hekler et al. 2013).

1.5 Contributions

Drawing on a mixed-methods approach, this thesis makes two contributions: empirical and design. First, it improves our understanding of whether and how existing stress monitoring and management apps support peoples' needs in implementing coping-relevant BCTs and where improvements could be made. An app feature review and evaluation and a follow up 3-week intervention study revealed that existing stress monitoring and management apps neither support their users with implementing coping-relevant BCTs, nor do they support them with their stress management needs. Participants reported not yielding sufficient data to gain insights into which factors were affecting their stress during 3-weeks of self-tracking. Relatedly, even though goal setting, monitoring, and reminders encouraged people to engage in more frequent stress management behaviours, the lack of flexibility and guidance in their implementation had the adverse effect of inducing unnecessary stress stemming from pressure to perform. Based on this understanding, we highlight the need to support people with gaining insights into their stress during the early stages of self-tracking and to support them with flexible and guided strategies that promote engagement in stress management behaviours.

Drawing on peoples' experiences associated with using existing apps, the second contribution of this thesis is the design and evaluation of Reffy - a chatbot prototype that integrates coping-relevant BCTs in a way that meets peoples stress management needs. In other domains, such as physical activity, guided conversational approaches afforded by chatbot technology were shown to help overcome challenges similar to those reported in our previous intervention study. Based on the findings from a field evaluation study, we identify benefits and challenges of using chatbots for supporting coping-relevant BCTs. We find that, for people to be successful in implementing coping-relevant BCTs in their day-to-day lives, the app features that incorporate such techniques also need to support peoples' sense of autonomy. We demonstrate how such features can be embedded into apps and used by people to successfully implement coping-relevant BCTs in a way that meets their stress management needs. Specifically, we find that chatbot-based reflective questioning helped people to draw on their own self-knowledge. This led them to identify and become more aware of how different aspects of their lives impact their stress, without the need of having access

to prior self-tracking data. Likewise, integrating action planning into a guided stress management exercise was shown to be effective in providing people with direct guidance on how they could apply their knowledge about stress to manage it. This led to improved sense of autonomy and competence to cope with stress. Finally, our findings also highlighted the importance of personalisation when implementing chatbots, both for sustaining long-term use and ensuring that people are explicitly directed to relevant coping strategies based on their current needs.

Collectively, findings from this thesis advance our understanding of how behaviour change and stress coping techniques can be augmented and incorporated into mobile apps to effectively support people with stress self-management and experiences of autonomy. These findings are particularly relevant to informing the design of mobile health and wellbeing apps aiming to incorporate behaviour change techniques in a way that aligns with peoples' self-care needs.

1.6 Overview of chapters

This thesis consists of eight chapters (see also Figure 2 for an overview of the studies and their findings). **Chapter 2** begins by providing an overview of the different types of stress that people can experience, its causes, and the different ways in which people cope with their stress. Drawing on an existing body of work on stress self-management apps, we identify that the currently available apps lack features that support coping-relevant BCTs, including self-monitoring, goal setting, and planning. Through our investigation of behaviour change and personal informatics literature, we identify that including features that support self-monitoring in conjunction with goal setting, planning, and reminders is essential for helping people to adhere to selected stress management behaviours. However, past research had not investigated whether existing stress management apps incorporate BCTs that support both self-monitoring (understanding) and adherence to selected stress management behaviours (managing). Additionally, because past research on mobile stress management apps had primarily focused on evaluating their overall efficacy or the number of evidence-based techniques they include, it is still unclear how successful people are with implementing such app-delivered techniques in their day-to-day lives.

Chapter 3 describes an app feature review and an in-depth app evaluation (Study 1) investigating whether and how existing stress management and monitoring apps include features to support people with both understanding and managing stress. Because there are no app evaluation methods available that bridge personal informatics and behaviour change research, we developed the REACT app evaluation method that investigates how stress management apps support reflection (understanding) and action (managing). This analysis reveals that the reviewed apps support users with understanding what their stress levels are, but do not include adequate functions to support action taking (managing). This chapter contributes a discussion of how to improve the design of stress management apps with detailed examples of good practice.

Chapter 4 presents findings from a self-tracking field study (Study 2) and follow-up focus-groups (Study 3) with the same participants investigating how people use existing apps to implement coping-relevant BCTs. To study this, we use two apps: Welltory and Coach.me. We select Welltory as our previous app review (Study 1) indicates that it provides state-of the art support for stress self-monitoring. Relatedly, because our previous app review revealed that none of the available stress monitoring apps could adequately support both reflective practices and action taking, we additionally ask our participants to use the Coach.me goal setting app. We discovered that high quality self-monitoring support used together with goal-setting correlates with significant reductions in stress but that, for these features to be maximally effective, they need to be better adapted to fit within a mental wellbeing context. Participants reported not yielding sufficient data to gain insights into which factors affect their stress during 3-weeks of self-tracking. Relatedly, even though goal setting, monitoring, and reminders delivered via Coach.me encouraged people to engage in more frequent stress management behaviours, the lack of flexibility and guidance in their implementation has the adverse effect of inducing unnecessary stress. These findings highlight the need to support people with gaining insights into their stress during the early stages of self-tracking and to support them with flexible and guided strategies that promote engagement in stress management behaviours.

Chapter 5 Drawing on peoples' experiences associated with using existing apps (Studies 2-3), this chapter proposes a technique known as reflective questioning as a

potential solution for helping people to gain insights into their stress during the early stages of using a stress management app. The 3-week intervention study presented in this chapter (Study 4) investigates whether and how the combined use of Welltory and journaling-based reflective questioning can be used to elicit insights about stress. The insights that the participants reported on the Evernote app demonstrate that reflective questioning leads people to: a) reflect on the factors affecting their stress, b) reinforce their existing knowledge about such factors to motivate engaging in helpful self-regulatory behaviours, and c) observe changes in stress across different days. The content of these insights is qualitatively similar to those that people are expected to gain by reflecting on visualisations of their data: identifying trends, patterns, and context factors associated with their stress. We additionally find that people prefer short-term planning to setting and monitoring goals as a method for helping them to adhere to selected stress management activities and/or behaviours.

Chapter 6 provides a synthesis of the findings from studies 1-4 to inform the design of a chatbot prototype. First, we outline peoples' needs with regards to using stress management apps to implement coping-relevant BCTs: 1) being able to gain insight into their stress experiences and triggers without having prior access to extensive self-tracking data; 2) being able to initiate stress management behaviours without undermining their sense of autonomy, and 3) receiving guidance on how to apply their insights about stress to form effective stress management strategies. We identify conversational interfaces as a suitable solution for supporting peoples' needs with regards to understanding and managing their stress. Firstly, in other wellbeing domains, such as physical activity, chatbots have been successfully used for delivering reflective questioning techniques to help people gain insights into their behaviours. Secondly, chatbots lend themselves to imitating conversations that a therapist might have with a client and can be similarly used to guide the users through structured coping exercises. We therefore demonstrate how an existing stress and problem-solving exercise traditionally used in a face-to-face therapy setting can be augmented and incorporated into a chatbot interface. Drawing on our own research insights, literature on chatbot applications in the wellbeing domain, and principles of positive computing, we describe the design and implementation of Reffy: a chatbot prototype which guides people through a series of reflective questions and prompts to help them better understand and manage their stress.

Chapter 7 presents findings from a 3-week field study (Study 5) evaluating the combined use of Welltory and Reffy - the chatbot prototype for stress self-management. This study examines whether and how dialogue-based reflective questioning, short-term planning, and problem-solving helps people to better understand and manage their stress during the early stages of using a stress self-monitoring app (Welltory). The study confirmed that chatbot-based reflective questioning helps people gain insights into their stress during early stages of use. We also find that short-term planning and problem-solving were shown to encourage engagement in self-regulatory behaviours related to stress management. Because the chatbot's short-term planning feature was designed in a way that was agnostic to when a given stress management activity should be performed, people felt that they could adjust their plans based on their current self-care needs. Importantly, this sense of flexibility afforded by short-term planning eliminated peoples' sense of guilt associated with missing a given stress management activity – a finding which contrasts with our previous participants' accounts associated with using goal setting features available in the Coach.me app (Studies 2-3). We additionally demonstrate that, for people to be successful in implementing coping-relevant BCTs in their day-to-day lives, the app features that incorporate such techniques need to support peoples' sense of autonomy and competence. Finally, our findings highlight the importance of personalisation when implementing chatbots, both for sustaining long-term use and ensuring that people are explicitly guided to relevant coping strategies based on their current needs.

Chapter 8 provides a general summary and discussion of the work presented in this thesis, including its key findings, contributions to both HCI research and practice, as well as directions for future research. Collectively, findings from this thesis advance our understanding of how behaviour change and stress coping techniques can be augmented and incorporated into mobile apps to effectively support people with their stress self-management needs.

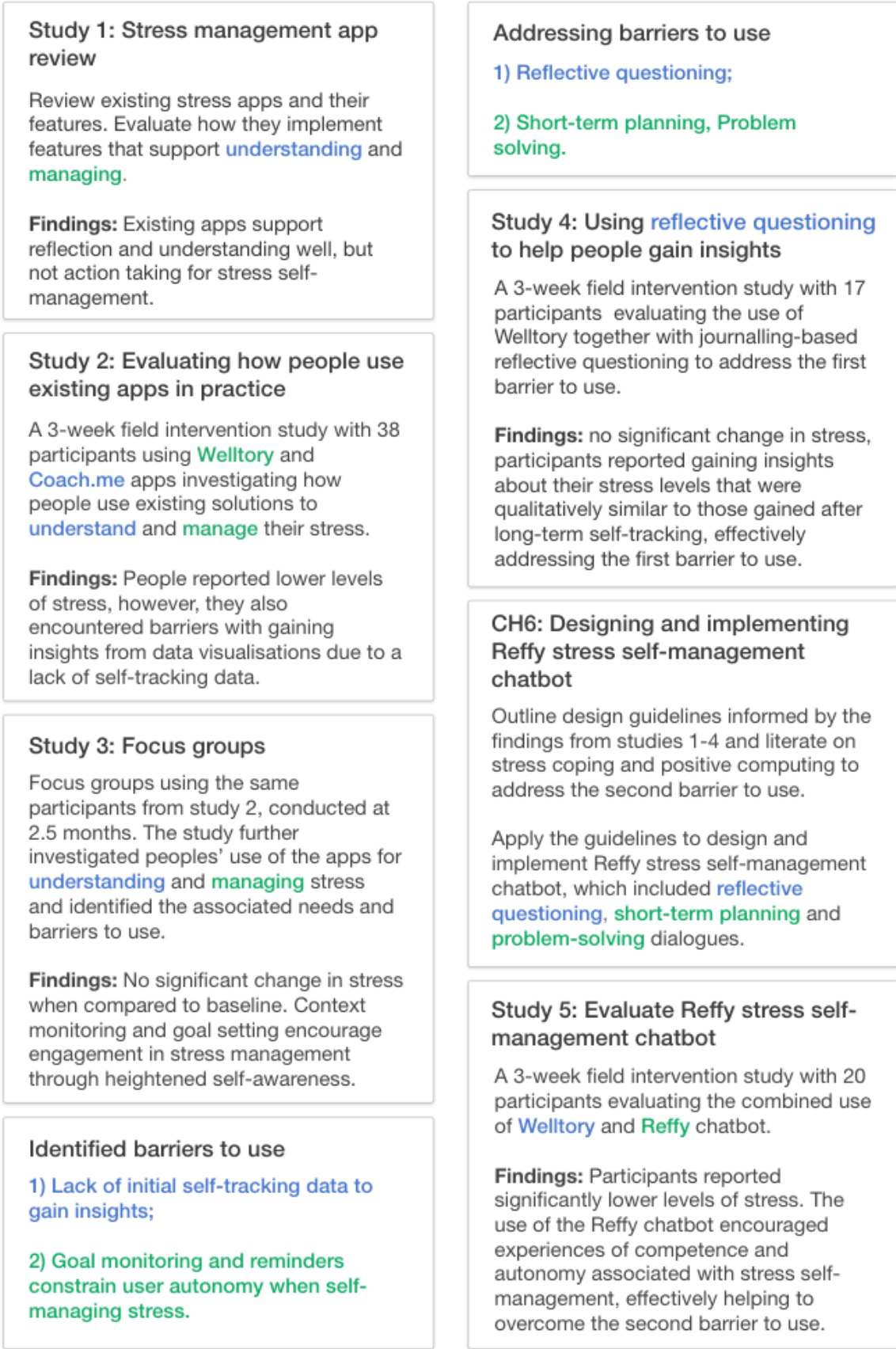


Figure 2. Overview of studies included in this thesis. Text highlighted in blue represent concepts related to reflective practices in relation to understanding stress levels. Text in green represents concepts related to action taking and stress self-management.

2 Background and Related Work

This chapter explores existing literature relevant to this thesis. We begin by defining the concepts of stress and coping, and then turn our focus to millennials (people born between 1980's and early 2000's). With millennials being digital natives who also lead high-stress lifestyles, we argue that this population can benefit from a digital stress self-management intervention. We continue our chapter with a review of studies of existing stress management apps, and discuss our finding that, while currently available offerings do include potentially helpful stress-management features, they do not adequately support their users with problem-focused coping, one of the key elements of effective stress-management interventions. To fill this gap, we first draw on research related to personal informatics, a relatively newly introduced term that refers to a collection of tools used for self-monitoring. We next provide an overview of how existing technologies support users in understanding various health-related outcomes, such as stress, and then turn to behaviour change literature for insight into how people might translate their newfound knowledge into actionable coping strategies. This leads us to identifying a set of coping relevant BCTs that have the potential to help people with stress self-management. We conclude the chapter by arguing that there still remains a need to understand how coping-relevant BCTs can be incorporated into stress self-management apps, as that is the primary focus of this thesis.

2.1 Stress and Coping

In their seminal book on stress and coping, Lazarus and Folkman (1984) define psychological stress as “*a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being*” (Lazarus and Folkman, 1984, p. 19). This relationship comprises two stages: 1) cognitive appraisals and 2) coping. Cognitive appraisal refers to the process by which people evaluate whether a given stimulus is a potential threat. If a given stimulus is perceived as threatening, people will likely respond to it by engaging in coping, which is defined by people's cognitive

and behavioural efforts to reduce and/or tolerate the effects of a stressful experience (Lazarus and Folkman, 1984).

Stress can be caused by a variety of individual and environmental triggers, also known as stressors. Poor sleeping and eating habits, high workloads, and financial difficulties are among the most commonly noted examples (Lazarus and Folkman 1984; McGonagle and Kessler 1990; Ross, Niebling, and Heckert, 1999). Depending on the nature of the sources of their stress, people's experiences may be either acute or chronic. Acute stress refers to a sharp and brief increase in arousal, usually triggered by point-in-time events such as an argument or job loss. In contrast, chronic stress typically stems from ongoing issues such as a high-pressure job or financial difficulties, and as such, it has more prolonged detrimental effects that can, over time, lead to mental and physical fatigue (Lazarus and Folkman 1984; McGonagle and Kessler 1990). Although people can experience stress at any age, one population, known as Millennials, stands out.

2.2 Millennials and Stress

There is a large body of research on Millennials (people born in the 1980s and 1990s), in no small part because of their alarmingly high stress levels, particularly as compared to those reported by previous generations. More than 45% of Millennials surveyed in 2015 said that they were contending with increased levels of stress over the prior year, and 82% indicated experiencing at least one symptom of stress in the past month (APA, 2015). Putting this into perspective, on a scale of 1 to 10, Millennials rated their stress levels at 6, a figure higher than either of the two preceding generations. Baby Boomers, those born between the mid 1940s and the mid 1960s, rated their stress levels at 4.3 on average, whereas Generation X, people born between the Baby Boomers and Millennials, came in at 5.8 (APA, 2015). All three generations listed the main causes of their stress to be uncertainty related to work or academic pursuits, and finance-related worries. Yet the extent to which such stressors affect the Millennial cohort seems to be higher than that reported by the other generations (APA, 2015). One explanation may lie in the perceived rationale for their stress. Besides the stressors indicated by all three adult age groups, Millennials additionally pointed to

lack of sleep, sedentary lifestyles, poor time management, and challenges with personal relationships as contributing factors (Britz and Pappas 2010; Welle 2011).

The impact of these behaviours on Millennial stress has been well-documented. For example, Mark et al. (2014) found higher levels of stress among Millennials to be positively associated with the sleep deprivation they experience as a result of long hours spent on the internet late at night. In a study investigating work-related stress in young professionals, Melchior et al. (2007) found that individuals subjected to higher job demands (e.g., excessive workloads and severe time pressures) experienced far more strain than their peers working in less demanding roles.

While research into factors contributing to Millennials' high levels of stress provides valuable insight into why and how their situations differ from those of previous generations, an equally (if not more concerning, from our perspective) aspect of Millennials' struggles with stress relates to their coping strategies – or more accurately, the maladaptive coping strategies they tend to employ when faced with managing their stress levels on their own. Amongst the most often-employed self-help tactics Millennials have reported using are: browsing the Internet (68%), watching more than two hours of television a day (58%), eating (41%), and drinking alcohol (25%) (APA, 2015). Toward that end, we argue that the Millennial population could benefit greatly from interventions aimed at promoting more adaptive (as opposed to maladaptive) stress coping strategies, and as such, we devote the remaining segments of this chapter to discussing stress management intervention-specific research, approaches, and technologies.

2.3 Coping with Stress

There are many ways people cope with their stress, with some strategies, as alluded to above, being more effective than others (Skinner et al. 2003). For instance, *avoidant coping*, where a person avoids their stressor rather than deal with it, is a maladaptive coping strategy (that is to say, one that more often than not, will prove ineffective over the long term). In comparison, *approach-oriented coping*, which involves an individual partaking in a variety of adaptive behaviours and/or cognitions, usually leads to more

positive and enduring recovery outcomes (Carver and Connor-Smith 2010; Lehrer, Woolfolk, and Sime 2007). Approach-oriented coping strategies can be categorised as either *emotion-* or *problem-focused* (Aspinwall and Taylor 1997).

***It is important to note that the concepts of emotion- and problem-focused coping are an oversimplification of stress coping but they provide a simple yet descriptive heuristic that can serve as a good starting point towards understanding which stress coping approaches are most likely to help when facing different types of stressful experiences and why (e.g., chronic vs. acute) (Skinner & Zimmer-Gembeck, 2016; Skinner et al., 2003).*

Emotion-focused coping works by regulating emotional responses to stress (Lazarus and Folkman 1984; McGonagle and Kessler 1990). It involves trying to remove oneself from a stressful situation through either distraction or by altering one's reaction to a given trigger. For example, when people find themselves unable to control the cause of their stress (e.g., anxiously awaiting test results), they might turn to activities such as yoga and meditation to help regulate their response (Aspinwall and Taylor 1997; Skinner et al. 2003). Besides providing temporary distraction and relief from the stressor at hand, over time such activities can help people become less receptive to the negative sensations induced by stress (Aspinwall and Taylor 1997; Carver et al. 1989).

Problem-focused coping, on the other hand, is aimed at eliminating or altering the sources of peoples' stress (Aspinwall and Taylor 1997; Carver et al. 1989). This type of coping is especially effective for managing stressors caused by something that is within the individual's immediate control, such as giving in to a propensity for constantly missing deadlines. In such cases, stress coping strategies geared more toward time management and/or planning would better address the source of the stress than an emotion-focused strategy. As highlighted earlier in this chapter, Millennials are exposed to a variety of different stressors, stemming from both their work and personal lives (Aspinwall and Taylor 1997; Skinner et al. 2003; Ellen A. Skinner and Zimmer-Gembeck 2016). A combination of both emotion- and problem-focused coping strategies would therefore offer the best potential for helping Millennials successfully self-manage their stress (Skinner et al., 2003).

Decisions regarding which stress-coping approaches to employ are rarely, however, "either-or". Most people will at some point in their lives encounter stress-inducing

situations where they will employ a combination of emotion- and problem-focused coping strategies in an effort to gain the most benefit (Skinner et al. 2003). An individual's selection as to which technique(s) to engage in will usually depend on their appraisal of the stressor and the context in which it is occurring (Folkman and Lazarus 1980). When people appraise a given stressor as something within their immediate control, they will often attempt to manage it using problem-focused coping, such as by trying to alter or eliminate the source(s) of their stress. Alternatively, if they feel powerless over the source of their stress, they might be more inclined to turn to emotion-focused coping strategies, such as taking yoga classes or meditating, to make themselves feel better (Aspinwall and Taylor 1997; Carver et al. 1989; Folkman and Lazarus 1980).

2.4 Stress Coping Apps

Fortunately, stress self-management apps support an array of adaptive coping techniques, and they do so in a manner conducive to Millennial uptake. In fact, in terms of accessibility, mobile stress-coping apps offer some key advantages over traditional intervention methods. For example, most Millennials are avid users of technology enjoying both access to and an ability to operate smartphone devices. Thus, the underlying mobile technology-oriented premise of stress-coping apps fits well with Millennials' lifestyles. Similarly, Millennials frequently report being stressed due to financial challenges (APA, 2015), signalling that they would not only benefit from, but potentially gravitate to low-cost interventions. The cost of mental health and wellbeing apps ranges between £20 and £80 per year, some even offering free basic plans (Verywell Mind, 2021). This is in contrast to paying anywhere between £40 and £100 for a single face-to-face therapy session, with an average course of treatment lasting between 5 to 20 sessions (NHS, 2021). Similarly, UK's national health service does offer free face-to-face therapy sessions, however, this can take up to a year to access (Mind, 2013). This is, of course, not an option for those who suffer from mental health challenges and need immediate access to treatment. Therefore, the blend of convenience and affordability that app-delivered interventions can offer makes them a more accessible and less financially stressful alternative to traditional face-to-face treatment methods (Luxton, Hansen, and Stanfill, 2014).

While financial and accessibility-related merits can be helpful for enticing Millennial stress-management app usage, to offer the most potential benefit, the apps' features must incorporate a variety of evidence-based techniques, including those that support both emotion- and problem-focused coping (Christmann et al. 2017; Coulon et al. 2016). Examples of emotion-focused coping activities commonly seen in stress-management mobile apps would include instructions for performing relaxation exercises, such as meditation and yoga, etc., (Christmann, Hoffmann, and Bleser, 2017), whereas typical app-based problem-focused coping strategies (those aimed at helping people identify the sources of their stress and work towards eliminating them (Skinner et al., 2003)), would be self-tracking, goal setting, planning, reminders, time-management, and problem-solving (Christmann, Hoffmann, and Bleser, 2017). Self-tracking can help people identify and become more aware of what their stress levels are and the factors that affect them (Ahtinen et al., 2013; Kocielnik and Sidorova, 2015). Goal setting, reminders, planning, time-management, and problem-solving add to this process by helping ensure that people take appropriate action to adapt their behaviour in a way that allows them to tackle their stressor(s) head-on (Aspinwall and Taylor, 1997; Sniehotta 2009; Sniehotta et al. 2005). There is evidence to suggest that both types of app features can lead to improvements in stress levels (Ahtinen et al., 2013; Bakker and Rickard, 2018; Flett et al., 2019; Moberg, Niles, and Beermann, 2019).

Looking first at s evaluations of stress management apps which emphasise emotion-focused coping, studies have shown that apps that deliver guided meditation and self-help exercises can help users improve their mental wellbeing. For example, a study evaluating [Headspace](#), an app that provides guided and unguided mindfulness meditation exercises, reported significant improvements in user stress levels (Flett et al., 2019). Similarly, participants in Ahtinen et al. (2013) study evaluating the Oiva app, which is based on acceptance and commitment therapy and includes self-help materials, reported significant improvements in stress after a month's use.

There is also evidence to suggest that features supporting problem-focused coping techniques, such as self-monitoring and emotional self-management, can help users better understand and manage their stress. A study by Bakker and Rickard (2018) evaluating [MoodPrism](#) self-monitoring app found that the app led to improvements in

mental wellbeing. The MoodPrism app primarily uses self-monitoring and journaling features, which the study found were helpful in individuals' efforts to improve their emotional self-awareness and self-regulation. Similarly, a study evaluating the Pacifica app (now called [Sanvello](#)) (Moberg, Niles, and Beermann, 2019), which includes cognitive behavioural therapy (CBT), mindfulness, and self-tracking features, reported significant improvements in stress-related outcomes. They found that the use of journaling and CBT-related features, in particular, could be linked to lower stress and anxiety.

Naturally, research and theory on stress coping suggests that apps including both emotion- and problem-focused coping techniques have the most potential for helping users better cope with stress. Rather surprisingly, though, several reviews of currently available stress management apps have indicated that, although many include instructions on how to engage in emotion-focused coping, few support their users with similarly detailed guidance on how to implement problem-focused coping strategies (Christmann, Hoffmann, and Bleser, 2017; Coulon, Monroe, and West, 2016). We argue that, because people will engage in both emotion- and problem-focused coping (Skinner et al., 2003), it is essential that stress management apps support both techniques.

Incorporating techniques such as goal setting and planning is not unfeasible, and in fact, such features are frequently incorporated into other types of health and wellbeing apps, such as fitness and diet (Direito et al., 2014). Nevertheless, many stress self-management apps still do not equip their users with such tools. This is unsurprising considering the lack of protocols provided by research that focuses on investigating stress management interventions (SMIs). As Richardson and Rothstein (2008) highlighted in their review of various types of SMI's and their efficacy, there is a lack of information on how such interventions implemented and disseminated problem-focused coping techniques. Without this key piece of information, it remains unclear how problem-focused coping techniques could be incorporated into mobile apps.

In considering how to address the issue of self-monitoring, reflection, and self-regulation feature gaps, it can be beneficial to draw on research from other disciplines, namely personal informatics and behaviour change. Personal informatics theory informs how people reflect on and understand their data (Choe et al., 2014; Fleck and

Fitzpatrick, 2010; Li, Dey, and Forlizzi, 2010), whereas behaviour change research can help identify additional features needed to support users with self-regulation (Bailey, 2019; Sniehotta, 2009; Sniehotta et al., 2005). Insights coming from both fields can therefore provide a good foundation for understanding what additional features should be incorporated into existing stress management apps to improve on their impact.

2.5 Strategies for Understanding the Causes of Stress: Personal Informatics, Wellbeing Self-tracking, and Reflection

Personal informatics theory aligns closely with the principles of problem-focused coping, as it involves monitoring and understanding a target behaviour, and then changing that behaviour to reach a desired state (Aspinwall and Taylor 1997; Carver et al. 1989; Li et al. 2010a). According to the stage-based model of personal informatics (Li, Dey, and Forlizzi, 2010), users gain insights from their personal data during the reflection stage and then decide what actions to take in relation to those insights during the action stage that follows. According to North (2006, p. 6) an insight is “*a non-trivial discovery about the data or, as a complex, deep, qualitative, unexpected, and relevant assertion*”. Placing the stage-based model of personal informatics into a stress management context, people may want to first reflect on the types of activities they believe are causing them stress and then, during the action stage, can use the insights they’ve just gained to decide upon a course of action, e.g., to begin meditating, to help them manage those stressors. Below, we draw from research on personal informatics to help explain how people collect, reflect, and gain insights from their self-tracking data, and how technology supports these practices via tools such as mobile sensing and data visualisation.

Self-tracking to gain a better understanding of one’s behaviour and wellbeing is at the core of the quantified-self movement (Choe et al., 2014; Rapp and Cena, 2014; Swan, 2012). Quantified selfers are known for engaging in N=1 experiments, that is to say, tracking on an individual basis to gain self-knowledge. For example, a person can

decide to log their data manually by using pen and paper or by using some form of digital journaling. At the moment, the quantified-self community is particularly excited about the novelty and increasing accessibility to sensors embedded into smartphones and wearable devices, and their ability to quantify various health and behavioural indicators. They see digital devices as offering a means of data collection that could enable people to gain insights into behaviours that they simply would not achieve, or at least not easily achieve, by manually logging their data. Classic examples of sensor-based self-tracking include collecting step count data via a pedometer or tracking running speed via an accelerometer. The data captured via sensors can be automatically logged and transformed into visual representations, making it easier to both self-track and make sense of the data collected. In addition to measuring physical activity-related variables, mobile sensing can also capture mental states as they can manifest into physiological responses and behavioural changes. Commonly used methods for inferring mental states from physiological changes include PPG (photoplethysmography), GSR (galvanic skin responses), and EEG (electroencephalograph) (Swan, 2012, 2013). Irrespective of what type of health-related data the sensors are capturing, the primary aim of interpreting such data, specifically for those who are tracking it to achieve behaviour change, is to receive a novel perspective and insight into the behaviour of interest (Swan, 2012, 2013).

The quantified-self movement is increasing in popularity and this has triggered the development of new types of self-tracking apps specifically oriented toward tracking multimodal data. The term multimodal, as applied to collected data, refers to the ability to simultaneously monitor multiple behaviours. For example, www.wearecurious.uk offers its users the ability to integrate their data from multiple modalities (e.g., stress, exercise and heart rate variability) so it can be viewed on a single graph. [PACO](#) (“the personal analytics companion”) allows users to gather data on attitudes and behaviors over time. Both platforms enable and facilitate citizen science experiments and data sharing, allowing researchers and individuals without advanced statistical and/or programming knowledge to gather and analyse behavioural data (Swan, 2012, 2013). Looking at commercially available tools, apps such as [Exist.io](#) and [Welltory](#) leverage the users’ ability to integrate self-tracking data from various sources and visualise it back to them. For instance, Exist.io works with more than 150 apps and provides visual data exploration tools to help people gain a better understanding of their behaviours,

experiences, and the effects that these have on their mental and physiological states. Similarly, Welltory uses smartphone-based PPG to infer peoples' physiological stress. This information becomes visualised alongside various other measurements monitored by the users, such as step counts or sleep. With their ability to collect, analyse and communicate various types of data, personal informatics tools can enable people to gain a better understanding of themselves in an attempt to help them become healthier, happier, and more productive.

Personal informatics researchers see studies on the quantified-self community's use of self-monitoring tools as useful for providing insight into how personal data is collected and explored. Li et al. (2010b), for example, developed a *stage-based model of personal informatics* (see Figure 3) based on the Transtheoretical Model of Behaviour Change (TTM) (Prochaska and DiClemente 1983). According to TTM, people do not change their behaviours instantaneously, but instead move through five temporal stages: *Precontemplation* (no intention to change their behaviour within the next six months), *Contemplation* (intending to change their behaviour within the next six months), *Preparation* (intending to change their behaviour within the next thirty days), *Action* (already taking steps to change their behaviour), and *Maintenance* (sustaining a change in behaviour for more than six months). The TTM model has since been applied to various health-behaviour change interventions, ranging from smoking cessation (Spencer et al. 2002) to exercise (Marshall and Biddle 2001).

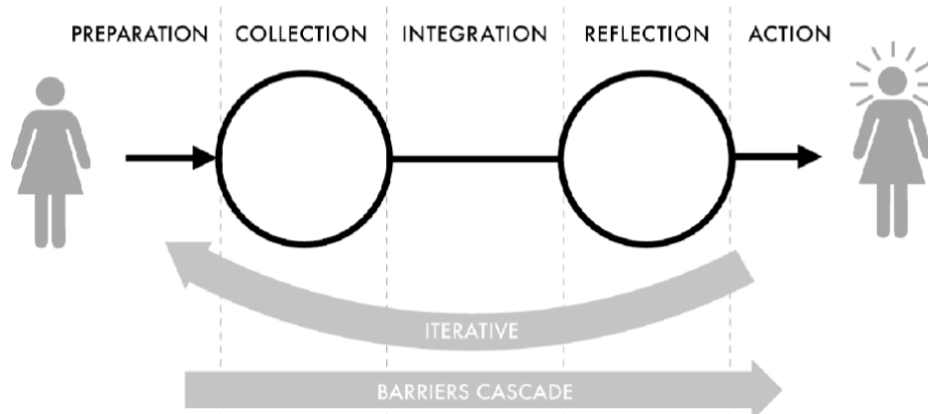


Figure 3. Stage based model of personal informatics, demonstrating the iterative process that leads to action taking, i.e., behaviour change in response to self-reflection on personal data (Li et al., 2010).

Li et al's (2010b) model does not attempt to describe people's motivation and readiness to change their behaviour, but rather explain how people engage in self-tracking and offer a framework for supporting their practice. Like TTM, Li et al's (2010b) *stage-based model of PI* also consists of five stages. Notably, the final two stages of the model – *reflection* and *action* – are central to this thesis. Yet familiarity with the complete model helps place these two stages into context by outlining the conditions required for people to reach the reflection and action stages. In the initial, *preparation* stage, people decide what types of data they want to collect and select the tools they intend to use to do so. During the *collection* stage, they begin engaging in self-tracking, i.e., logging various types of personal data such as exercise, sleep, and mood. This can be done as frequently as several times a day (e.g., for activities like counting steps that can be tracked with the help of automated sensors) or as infrequently as only a few times per month (e.g., for tracking activities that happen over longer intervals, such as tallying up the number of books the individual has read). The actual figures reached will depend on the behaviour being tracked and the user's needs. Once all the data is collected, the model moves on to the *integration* stage. This is when pre-processing and combining data for visualization and reflection occurs. The *reflection* stage, where users gather insights from their data, is next. Here, people can either reflect on their data immediately, that is to say, as soon as it has been collected, or look back upon existing data weeks or months after its collection for a more long-term perspective. It is important to note that reflection can be done for both cross-sectional (i.e., between different types of information) and time-series data. The final stage of the model is the *action* stage. This is when the individual decides what action to take in light of the newly discovered insights. For example, if the person utilises self-monitoring as a tool for modulating goal attainment, they can use what they have learned about themselves to adapt their behaviours in a way that promotes achieving their goal (Li et al. 2010b).

Since its original publication, Li et al. (2010b) stage-based model of PI has been extended by other researchers to offer more comprehensive accounts of people's lived experiences of using PI tools in their everyday lives (Epstein et al. 2015), and to describe the processes by which people reflect on and gain insights from their data (Choe et al. 2014b). Toward that end, Epstein et al. (2015) argue that, besides using tracking to achieve behaviour change, people may also track to record behaviour or events of interest to them, both to gain rewards as well as simply out of pure curiosity.

Reflecting these and other changes in technologies and how people approach self-tracking, Epstein et al constructed the *lived model of PI*, which moves away from Li et al's original concept of having five distinct stages and instead puts forward the notion that people will frequently lapse and/or interrupt their self-tracking practices. Epstein et al's model also builds on Choe et al. (2014b) research that finds that people frequently reflect on their data as it is captured. Thus, Epstein et al's (2015) lived model of PI defines the broader practice of *tracking and acting*, taking into account and encompassing the continuous processes of collection, integration, and reflection. Broadly speaking, though, both Li et al's stage-based model and Epstein et al's lived model of PI share the same underlying assumption that people will use PI tools to collect and reflect on data with the aim of gaining insights into themselves, and that they will also in some cases apply those insights to change their behaviours (Dijk et al. 2017a).

More recent work on PI systems have branched into more psychological and/or phenomenological streams (Ayobi, Marshall, and Cox 2016). In a similar vein, Rapp and Tirassa's (2017) *Theory of the Self for Personal Informatics* moves away from the traditional utilitarian view of PI tools to focus on a "*more experience-centered approach to PI*" that champions self-knowledge, self-awareness, and change in the *self* instead of in the behaviour.

As one of the primary aims of this thesis is to define how people use PI tools to understand and manage their stress, most of the work presented in the remainder of this chapter aligns more closely with the psychological stream of PI research, specifically the reflection (understanding) and action (managing) stages described in Li's stage-based model. That being said, though, we do take into consideration some of the more relevant views that have come out of the phenomenological stream. For instance, our work draws on Rooksby et al's (2014) notion of *lived informatics*, where we consider how people use PI tools in their everyday lives. We additionally consider Rapp and Tirassa's (2017) call for PI systems to treat people's self-knowledge (and, relatedly, their own interpretations of their objective self-tracking data) as being inherently subjective and biased by their needs and memories. In drawing from both streams of PI research, we aim to inform the use and design of PI tools that can

encourage changes in behaviour as well as consider the everyday “messiness” typically associated with the use of PI tools.

In the following sections, we take a closer look at how people reflect on their self-tracking data to gain a better understanding of a target behaviour or outcome (e.g., stress) and how data visualisation can help support this process.

2.5.1 Reflecting on Self-Tracking Data

Research focusing on PI practices provides detailed insight into *how people reflect on the data they collect*. Li et al. (2011) formalized the data collection process by identifying six types of information users seek during the reflection stage:

1. *Status* - How does the current state compare with the goal state?
2. *History* - Are there any trends and patterns in the data?
3. *Goals* - What goals should be pursued?
4. *Discrepancies* - Are there any discrepancies between the current state and the goal state?
5. *Context* - What other factors might be affecting the present state\behaviour? (e.g., although an individual’s main goal might be to track sleep to determine stress levels, they will also track context information, such as physical activity levels and their effects on stress)
6. *Factors* - Are there any factors/trends influencing behaviour change outcomes over longer periods of time? (e.g., the realisation that that weight loss depends on both physical activity and diet over time).

Li et al.’s identification of these questions highlights how the way in which users change their behaviour depends not only on the type of data they collect, but how they collected it. Their model also states that self-trackers go through phases of maintenance and discovery. During the maintenance phase, users continuously monitor whether their current state is in line with their goal state. During the discovery

phase, they observe other factors affecting their existing goal or set new goals that relate to newly found insights.

Within the context of personal informatics, reflection can be considered an iterative process during which specific questions are asked to detect causal links between diverse types of data or data points (Li et al., 2011). According to Fleck and Fitzpatrick (2010), there are five levels of reflection, R0 through R4, each providing qualitatively different insights. They are:

R0 - Revisiting: revisiting the data simply to see a description of events that have happened.

R1 - Revisiting with explanation: revisiting and explaining that data, but only in a descriptive way, without looking for alternative explanations.

R2 - Exploring relationships: looking for relationships and patterns in the data; coming up with alternative explanations; hypothesizing.

R3 - Fundamental change: revisiting the information and restructuring the event or behaviour; changing existing assumptions and practices.

R4 - Wider implications: considering the context in which this data is interpreted.

Levels R3 and R4 build on levels R0 - R2, as the lower levels provide the necessary foundational resources for engaging in deeper levels of reflection. For example, to change existing assumptions, users initially need to know what their current behaviours are and understand them (R0-R1). Once more data is aggregated, they can then begin viewing their data from different perspectives, as they now have both access to more information than was initially available and the benefit of hindsight due to the passage of time. This can in turn lead to challenging existing assumptions (R3) and interpreting the data by referring to the bigger picture (R4).

Building on Fleck and Fitzpatrick's work, Baumer (2015) further distils the process of reflection into three interrelated dimensions:

1. *breakdown* involves reflection on puzzling, surprising, and conflicting situations that capture people's attention and this way make mundane, implicit phenomena more explicit;

2. *inquiry* is defined by practices that question the nature and basis of knowledge, such as hypothesis testing and re-examination of existing knowledge and/or past experiences;
3. *transformation* defines practices that lead to change by transforming our existing knowledge into new ways of thinking and/or understanding of a given phenomenon.

Unlike the assumption made by Fleck and Fitzpatrick, Baumer does not assume that reflection occurs in linear stages, but posits instead that the stages are interrelated. For instance, in some cases, says Baumer, breakdowns are necessary for transformative reflection to occur as they challenge and change our existing ways of thinking. That is not to say, however, that one stage necessarily leads on to the next. In fact, both Fleck and Fitzpatrick and Baumer provide theoretical foundations that help guide and inform the design of technologies aimed specifically at facilitating reflection – and we draw upon these frameworks throughout the studies detailed in Chapters 4, 6 and 7 in this thesis. But first, in the next section of this chapter we take a closer look at how existing wellbeing technologies support reflection, paying particular attention to data visualisation due to its unique role in enhancing peoples' reflective practices.

2.5.2 Data Visualization for Exploring and Reflecting on Personal Data

Within personal informatics, data visualization is one of the primary tools used for facilitating self-reflection for behaviour change. The primary aim of data visualisation is to enable people to gain insights (Shneiderman 1996). Within the context of personal informatics, people may gain insight into behavioural trends and patterns as well as how various aspects of their lives and wellbeing relate to one another (Choe, Lee, and schraefel, 2015). Data visualisations can help people gain such insights by providing general overviews and summaries of their data, and/or by enabling people to group, filter and otherwise adjust the information presented by using different ranges or data visualisation types (Yi et al. 2008). Similarly, because people are usually interested in tracking multivariate time series data (either for self-experimentation or for diagnostic tracking), using representations such as charts or graphs can be advantageous as

they easily allow for trends and patterns to be identified between several variables over time (Cuttone, Petersen, and Larsen, 2014). Ensuring that mobile apps provide adequate visual data exploration support, e.g., by using appropriate visualisation types, clear labels, and filtering options, can help users gain insights into their behaviours. This, in turn, can lead to improvements in people's self-knowledge and/or help guide them towards achieving their behaviour change goals.

Cuttone et al. (2014) described four heuristics for designing informative and efficient data visualizations that can lead users to gaining insights. The first is to "Make the data interpretable at a glance". This capability allows users to interpret their data quickly and with minimum effort. For example, [Fitbit](#) uses a dashboard to summarise daily progress in terms of several different modalities, such as steps taken and calories burned (see Figure 4) Dashboards such as this are useful for asking questions such as "How does sleep affect my stress or physical activity levels?". Where there is an obvious visual correlation between variables, the heuristic can prompt users to adjust their behaviours accordingly. Cuttone et al. (2014) suggest that apps first start with simple visualizations that demand minimal effort and then build up to displaying levels appropriate for more experienced users. Looking again at *Figure 4*, the Fitbit dashboard achieves this by adding more visualization layers and data modalities that users can access by clicking on or hovering over each graph/window displayed.



Figure 4. [Fitbit](#) dashboard summarising daily activity goals.

Cuttone et al's second heuristic, "Enable exploration of patterns in time series data", suggests allowing users to spot fluctuations in their data over time and observe any periodic changes. This might include, for example, users tracking hourly or daily patterns at which a specific event occurs. Time series data is often visualized through line plots, as this is a convenient method for displaying changes on a variable over time. The disadvantage of using linear data representations, however, is that they can make it difficult to observe trends. This is where other representations, such as calendars or spiral heatmaps (sometimes termed radial charts) can be useful (see Figure 5) (Cuttone et al., 2014).

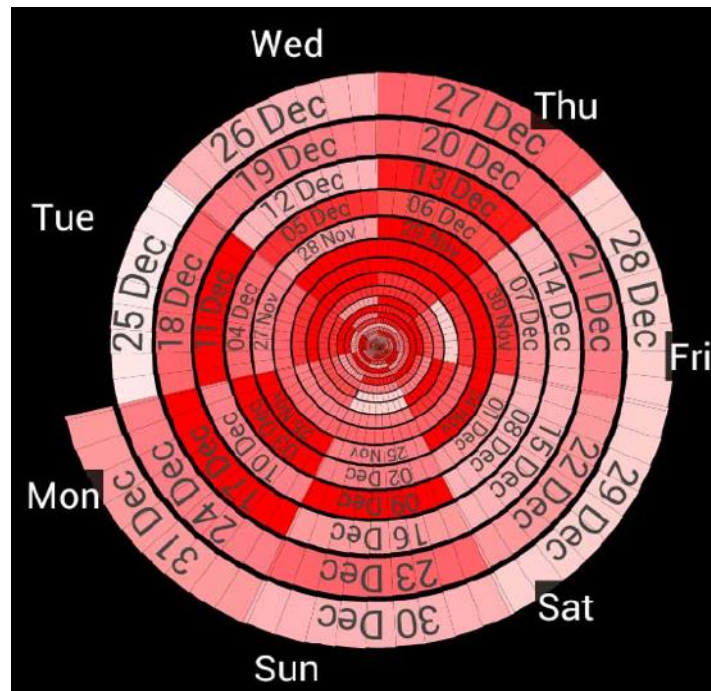


Figure 5. Spiral heatmap of daily step count over a year. This form of visualization allows users to notice trends based on a record of days (Cuttone et al., 2014).

According to the third heuristic, “Enable discovery of trends in multiple data streams”, the self-tracking system should allow for multivariate data analysis. This type of analysis enables the comparison of multiple variables over time to determine whether there are any relationships between those variables – a feature that is particularly important for users who wish to engage in self-experimentation. For instance, a scatterplot can be used to indicate whether there are any positive or negative correlations between the variables through the direction in which the data points are scattered. Similarly, a heatmap (sometimes also called a corrgram) uses colour coding to indicate positive and negative relationships (see Figure 6) (Cuttone et al., 2014).

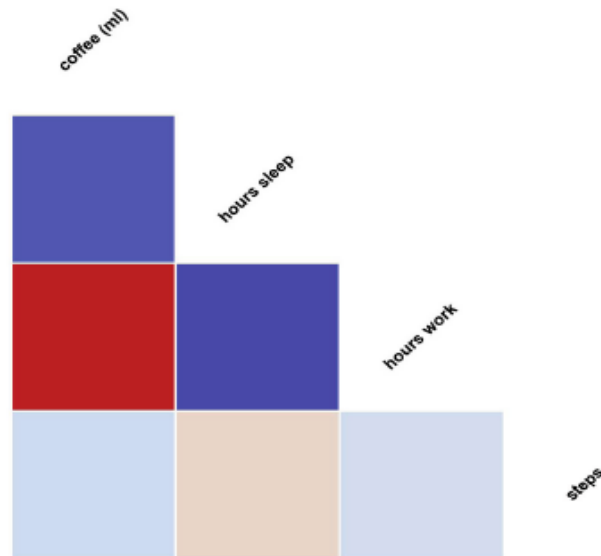


Figure 6. Heatmap indicating correlations between multiple variables. Red =positive correlation, blue = negative correlation, grey = no correlation (Cuttone et al., 2014).

The fourth heuristic “Turn key metrics into affordances for action” highlights the importance of users interacting with the data -- that is to say, generating initial data and updating existing data views to find new insights. Doing so can facilitate new questions about their behaviour or determine thresholds which, when reached, can be used as prompts for action taking. For example, if a threshold of 10,000 steps a day has not been met by 8pm, an app user’s intuitive response might be to go for a walk or walk in place in their home until this target is reached. To recognise that this action is needed, however, they first need to be alerted to it. This is where filtering options come in. Filtering options allow users to zoom in on historic or current data. They can be helpful in reducing the information overloads often associated with overcrowded information displays. A common means of incorporating filtering options is to have the system provide a generic overview of the data, but also allow users to zoom in and filter it, and then request further details in relation to their needs (Cuttone, Petersen, and Larsen, 2014; Shneiderman, 1996). The reflection process can be even further facilitated by enabling users to annotate data points and log more detailed qualitative information (Cuttone et al. 2014).

Research that covers both reflective practices and data visualisations can help evaluate the extent to which existing stress self-management apps support their users

in gaining insights about their stress. This work will become particularly relevant in Chapter 3, when we present a systematic feature review of stress self-management and monitoring apps, and where we will also be focusing in more detail on how such apps support their users in the reflection and action stages described in Li's stage-based model. First, however, we complete our discussion of the personal informatics model's five stages. In the following section, we address the fifth and final PI stage: action. We argue that, although self-tracking and reflection can help people become more aware of their stress levels and the factors affecting them, reflection alone is insufficient for eliciting behavioural change. To support our contention, we draw on research from the behaviour change field, and from there, we provide insight into how this gap may be filled.

2.6 Action Taking and How to Facilitate It According to QS and PI Research

Action taking, the last stage-based model of PI (see Figure 3), has been left relatively unexplored by researchers within the personal informatics domain. While at first glance, the premise of taking an action and seeing a result might seem relatively straightforward, the lack of extensive PI action stage-specific research leaves researchers themselves prone to drawing conclusions from incomplete data. In fact, past research has shown that self-tracking alone does not guarantee that behaviour change will take place (Dijk et al., 2017; Patel, Asch, and Volpp, 2015).

Several studies within the realm of personal informatics have sought to specify or provide guidelines on how to design and develop successful persuasive technologies (Consolvo et al., 2009; Fogg, 2002; Fritz et al., 2014; Hamari, Koivisto, and Pakkanen, 2014). For example, Swan (2012), suggests that effective QS systems should include roadmaps or instructions that clearly delineate exactly what steps people need to take to achieve a desired behaviour change outcome. Indeed, insights drawn from studies on behaviour change encourage the adaptation of features aimed at directly supporting users with their behavioural regulation efforts, particularly during the earlier stages of using such apps. These are the functions allowing for planning, goal setting, and prompts (Dijk et al., 2017; Rhodes and de Bruijn, 2013).

A good example of how wellbeing data can be represented to promote action taking can be seen in the Mio PAI activity tracker (see Figure 7). The tracker uses a wristband with an integrated sensor to track heart rate variability (HRV). It converts the data collected into an easily interpretable PAI score, which then acts as a feedback loop aimed at facilitating behaviour change. A target score of 100 is needed to prevent cardiovascular disease, and the derived score corresponds to a healthy heart rate level based on the user's demographics, with a target score of 100 needed to prevent cardiovascular disease. The advantage of using a single metric to highlight the link between cardiovascular disease and metrics (such as physical activity) is that it can be interpreted at a glance, and the action that it promotes (again, in this case, physical activity) is intuitive (e.g., users realise they must be more physically active to reach PAI 100). Nes et al. (2017) find this representation method to be both concise and informative, as it 1) enables self-monitoring, 2) prompts action taking and 3) encourages further user engagement by offering additional details which can be accessed via the Mio PAI app or website. The downside of representations such as this is that they can act as a “black box”, where it might not always be clear to users which of the variables (e.g., low or high intensity physical activity, weight gain/loss, etc.) are contributing towards their higher or lower PAI score (Nes et al., 2017).



Figure 7. MIO Pai wearable activity tracker and its associative app (Nes et al., 2017).

The end goal of any behaviour change technology is of course to establish habituation (Forster et al., 2017). There are at least two ways that this can be addressed, the most often used being ambient reminders and push notifications. Notifications can be in the form of SMS messages, visual cues (e.g., light displays), or mobile device vibrations. To maximise their effectiveness in supporting sustainable habit formation and maintenance, they should take into account contextual information, such as a user's location or schedule. Sensor data can be used to infer the times of the day when reminders to engage in behaviour are sent, with consideration given not only to when the reminders would be most effective, but also to when they would be least obtrusive. Similarly, micro practices (e.g., do a 5-minute breathing exercise) can be introduced, with the goal of encouraging the user to engage in practices that require little effort. These can gradually build up to more time-consuming/effortful challenges (e.g., take a light jog for 30 min) (Swan, 2012). Overall, the contention among PI and QS researchers is that, after visualizing and reflecting on the data, users will be well equipped to take action to change their behaviour - a process which, over time, should ideally become habitual.

We argue here that visualization and reflection on the gathered data, while relevant, is only an initial step in the broader behaviour change process. As noted above, currently, research on QS and PI provide only limited insight into how users might translate what they have learned from their data into actions. This is not surprising considering that most foundational studies within the two domains usually draw their conclusions from extreme users (Dijk et al. 2017a; Rapp and Cena 2014) – a population which has already formed their intentions and is sufficiently motivated to change their behaviours in response to insights gathered from their data. That same mechanism might not apply for users who are in the earlier stages of behaviour change or who are experiencing stress, and may require additional motivation and/or self-regulation support. Fortunately, research on behaviour change has identified a set of behavioural techniques and strategies that can significantly improve outcomes for people with lower levels of motivation and behavioural control.

2.7 Behaviour Change and How to Facilitate It According to Behaviour Change Research and Theories

As detailed in the previous section, PI and QS research informs how and what data should be collected and how it should be presented to users. Integral to the success of any health and wellbeing intervention, however, is its grounding in a sound and comprehensive theoretical framework, as frameworks can better inform which techniques and motivational constructs offer the best potential to help people reach their health and wellbeing goals (Rhodes and Nigg, 2011). Toward that end, we argue that app-based stress management interventions (SMIs) should also integrate research and theories from the behaviour change field, as these complement the PI and QS models by providing insights into how to encourage people to take action after they have interacted with their self-tracking data. When looking at SMIs based on problem-focused coping in particular, it becomes evident that these types of interventions inherently incorporate a range of behaviour change techniques. To better understand which techniques offer the most potential for supporting people with stress self-management, this section provides an overview of four of the most commonly studied behaviour change models and theories, including some of the more recent dual-phase models which integrate conscious and unconscious factors that influence decision making. Based on insights gained from the models presented, we then select and discuss a set of coping-relevant BCTs that could be incorporated into the framework of an app-based stress self-management intervention.

2.7.1 Theory of Planned Behaviour

One of the earliest and most influential theories of behaviour change is the *Theory of Planned Behaviour* (TPB) (Rhodes and Nigg, 2011). Central to the TPB is the construct of intention, which social and cognitive theorists, Rhodes and Nigg, describe as the most proximal antecedent of behaviour (see Figure 8). According to Ajzen (1991), who initially proposed the TPB in 1980, intention is preceded by three belief-based constructs 1) *attitude* towards the target behaviour, (2) *subjective norms* (responsible for reactions to social influence and/or other outside pressure to engage

in the target behaviour), and (3) *perceived behaviour control* (the ability to perform the target behaviour) (Ajzen, 1991). To illustrate the TPB model in context, if an individual holds a positive attitude towards a target behaviour (i.e., believes it is healthy and/or fun), receives support for pursuing that behaviour from their social surroundings and is physically capable of doing so, their intention to undertake the target behaviour will be stronger, and they are thus more likely to transform that intention into active engagement. Results from meta-analysis studies provide evidence of the effectiveness of interventions which apply the TPB model, especially in such domains as increasing physical activity, reducing drinking and smoking, adopting safer sex practices, and improving dietary behaviours (Hagger, Chatzisarantis, and Biddle, 2002; McEachan et al., 2011).

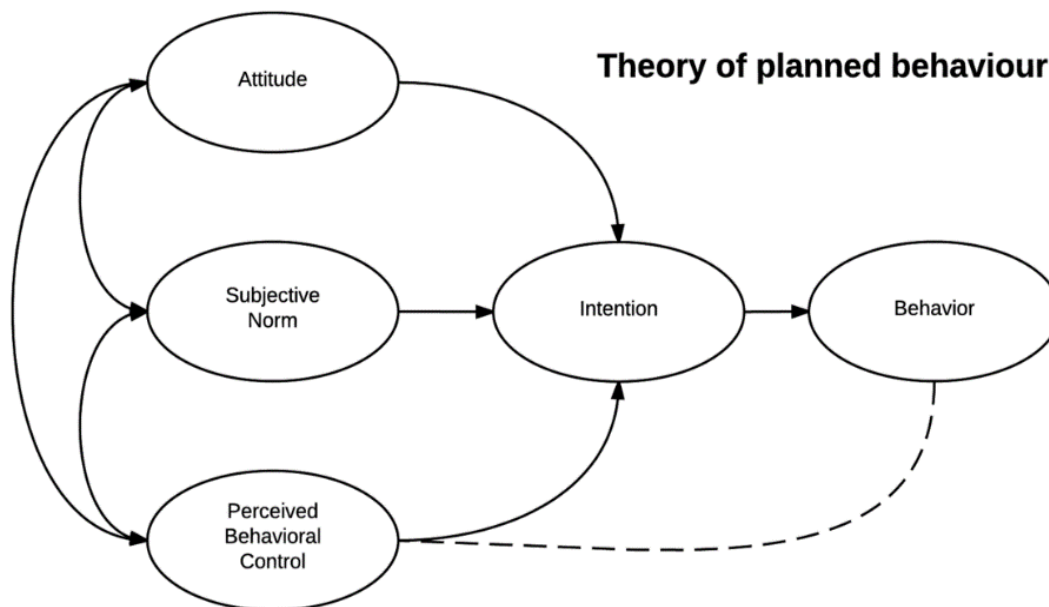


Figure 8. TPB constructs and structure (Rhodes & Nigg, 2011).

According to Ajzen (1991), the three behavioural constructs that precede intention are formed over time through experiences with the behaviour in question. People rely on these experiences to form schemas, which they then employ to evaluate future opportunities to engage in the behaviour. A main criticism of the TPB is that this narrative does not adequately explain the impetus behind the development of the three belief-based constructs, nor does it account for how they themselves come to be formed. One attempt to address this shortcoming, *Self-Determination Theory* (SDT)

(Deci and Ryan 1985b), appeared just five years after the theory of planned behaviour was first published, and has since be integrated into the TPB to complement and clarify the TPB's constructs and the relationships between them (Hagger and Chatzisarantis 2009).

2.7.2 Self-determination Theory

SDT was developed by Deci and Ryan (1985b) in an effort to better understand motivation and the choices people make. According to self-determination theory, human behaviour is driven by a compulsion to satisfy three basic psychological needs: 1) *autonomy*, including experiences of agency and acting in accordance with one's goals and values, 2) *competence*, believing oneself to be capable of carrying out a task or engaging in a given behaviour, and 3) *relatedness*, feeling connected to others. SDT complements the TPB by specifying that the three belief-based constructs (attitude, subjective norm, and perceived behavioural control) are formed by individual motivational orientations (Deci and Ryan 1985b; Hagger and Chatzisarantis 2014). It postulates that people naturally seek out adaptive behaviours and activities that they believe will improve their well-being (Deci and Ryan 1985b). The specific factors that drive an individual's motivation, however, can be qualitatively different (see Table 1). *Intrinsic motivation* occurs when a person engages in self-driven and enjoyable activities. Regardless of whether the activity is in fact productive or rewarding, an intrinsically motivated person's attitude toward engaging in it is typically positive due to their high degree of perceived personal control and/or autonomy. In contrast, *extrinsic motivation* refers to behaviours instigated by social or other pressures outside the individual's control. Extrinsically motivated experiences tend to be perceived as less enjoyable than those that are intrinsically motivated, and as such, they are more likely to be discontinued in the absence of external influences goading the person into engaging in them (Hagger and Chatzisarantis 2014; Ryan and Deci 2000).

Intrinsic Motivation	Extrinsic motivation
Autonomy	Compensation
Mastery	Punishment
Purpose	Reward

Table 1. Drivers of intrinsic vs. extrinsic motivation (Deci & Ryan, 1985).

2.7.3 The Integrated Behaviour Change Model

An over reliance on the motivational constructs presented in the earlier behaviour change models, has resulted in many studies relying on incomplete accounts of how intentions translate into behaviours. This has resulted in generally poor performance track records for interventions aimed at modifying intentions as a means of achieving behaviour change (Sniehotta, 2009; Webb and Sheeran, 2006). The often-observed phenomena of people not acting in accordance with their intentions is known as the *intention-behaviour gap*, a common example of which is abandoning a diet or an exercise regime, even though we know it is healthy and good for us (Hagger & Chatzisarantis, 2014; Sniehotta et al., 2005). Although intention is a necessary predictor of behaviour change, in practice, intention alone is not sufficient to trigger it. In an effort to address this limitation, in 2009, Sniehotta et al (2009) postulated that a general model of behaviour change needs to account for the processes by which people translate their intentions into behaviours. Toward that end, they advanced the notion that, rather than restrict the focus of intervention to how people think about a given target behaviour, it should instead concentrate on what people can do (e.g., plan, self-monitor, etc.) to reach their target behaviour.

One model that takes a broader approach is the Integrated Behaviour Change (IBC) model (Hagger and Chatzisarantis, 2014), which acknowledges the importance of motivational processes, but in contrast to its predecessors, also advocates that motivational processes on their own are not sufficient for explaining how intentions translate into actions (see

Figure 9). According to IBC, action-taking is regulated by two parallel systems, impulsive and reflective. Impulsive system factors work at an implicit level and as such are often automated and unconscious. The impulsive system utilises behavioural schemas formed through past encounters with actions that are triggered in a nodal fashion by environmental cues. For instance, seeing a gym bag placed near the door might trigger a plan to go to the gym once the person returns home after work. The reflective system, in contrast, involves deliberate considerations based on previously formed beliefs around social and individual behavioural factors (Hagger & Chatzisarantis, 2014; Strack & Deutsch, 2004).

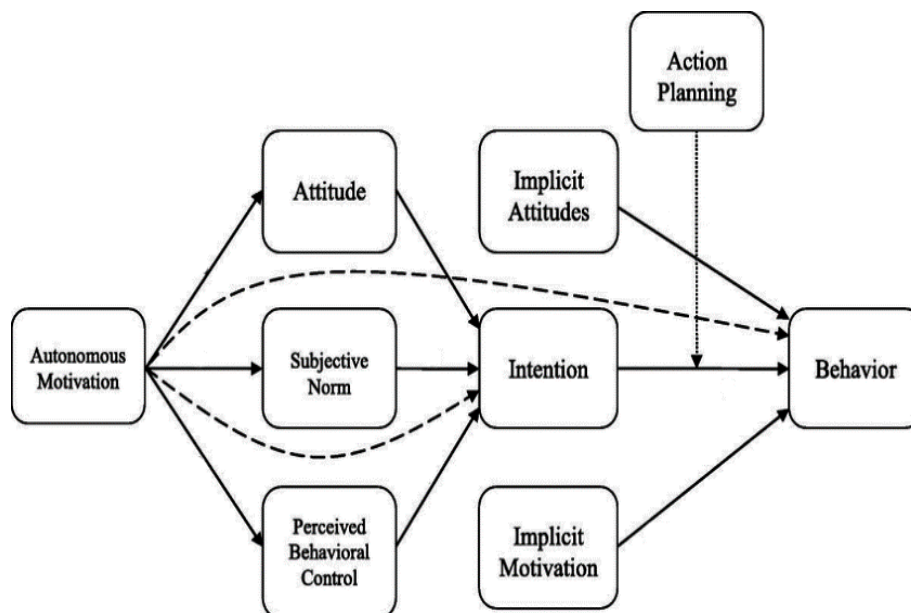


Figure 9. The integrated model of behaviour change (IBC) (Hagger & Chatzisarantis, 2014).

By incorporating these two systems, the IBC model can account for why individuals who are not accustomed to engaging in a given activity, such as exercise or meditation, find doing the activity more taxing than people who engage in it on a more regular basis. For example, instead of relying on deliberate action planning, people who exercise or meditate regularly have already-formed schemas and habits that,

through various environmental cues, facilitate their engaging in those behaviours in a more automated and less cognitively draining fashion. This aspect of the model is adapted from the dual-process theories of behaviour change (Calitri et al., 2009; Keatley, Clarke, & Hagger, 2012; Strack & Deutsch, 2004), which say that people form mental associations between target behaviours and their positive or negative evaluations of them. The stronger these evaluations are, the easier it is to access them. Furthermore, when there is consistency between an attitude and a behaviour, it is more likely that the behaviour will be performed. Or more succinctly stated: implicit attitudes help maintain behaviour (Hagger & Chatzisarantis, 2014; Strack & Deutsch, 2004).

Suffice to say, the behaviour change theories and models presented in this chapter illustrate the importance of understanding and applying sound theoretical constructs to interventions aimed at facilitating stress self-management. For example, all the previously discussed behaviour change theories acknowledge that motivation is one of the main driving forces of behavioural change. The theories and models differ, however, in their views of intention. For example, the TPB suggests that intention is the direct antecedent of behaviour, whereas the IBC models argue that other self-regulation related constructs, such as impulse and reflection, can have similar direct effects (Hagger & Chatzisarantis, 2014; Rhodes & de Bruijn, 2013). Therefore, it is important to consider the motivational antecedents of behaviour change together with self-regulatory strategies that go beyond self-tracking to achieve the most potential when designing effective stress self-management interventions.

2.7.4 Coping-relevant Behaviour Change Techniques

Stepping away from discussing theoretical structures, we now turn to coping-relevant behaviour change techniques beginning with the behaviour change technique (BCT) taxonomy first published in 2008 (Michie et al. 2008) and then refined in 2011 by Michie et al. (2011). The BCT taxonomy includes groupings of techniques that can be used to develop and evaluate various types of behavioural interventions. The authors define a BCT as an “active ingredient” of a behavioural intervention that can be used to alter processes by which people regulate their behaviours. For example, goal setting

is a BCT that can help alter the frequency at which people engage in meditation. Since its introduction, Michie et al's (2011) BCT taxonomy has been widely applied to evaluate a variety of digital interventions (e.g., smoking cessation, exercise, and diet) and the features they include (Bardus et al. 2016; Direito et al. 2014; Ubhi et al. 2016).

Even though there is not a separate list of BCTs specific to stress management interventions, several BCTs have been shown to be effective in helping people regulate their stress. Such coping-relevant BCTs include stress management (i.e., practices such as meditation that aim to alleviate the symptoms of stress but do not target any specific behaviours directly), self-monitoring, goal setting, planning, and time management (Christmann et al., 2017; Richardson & Rothstein, 2008). These are frequently included as part of cognitive-behavioural stress management interventions (SMIs), the aim of which are to help people identify the sources of their stress and provide tools to address those sources.

Cognitive-behavioural SMIs have been shown to produce medium to large effect sizes in stress-related outcomes (Holman et al. 2018; Richardson and Rothstein 2008). These compare favourably to other types of SMIs, such as those based on relaxation and exercise training (i.e., emotion-focused coping techniques). For instance, upon finding that cognitive-behavioural SMIs produced larger effect sizes than those based on relaxation, Richardson and Rothstein (2008) argued that their findings could be explained by the aims of each type of intervention. For example, relaxation techniques such as mindfulness meditation aim to distract people from troubling thoughts and cognitions. As highlighted previously in this chapter, they can produce temporary relief from negative feelings. That is not to say, however, that they can resolve the underlying causes of such thoughts and feelings. In contrast, cognitive behavioural techniques tend to encourage more active ways of coping, and in doing so, can help people tackle their stressors head on (Richardson and Rothstein 2008).

Relating this back to the behaviour change theories and models discussed previously, techniques such as self-monitoring can help people form intentions to change their behaviours, whereas problem-focused coping strategies such as goal setting, planning, reminders, and time management are more apt to help people translate their intentions into actions (i.e., bridge the aforementioned intention-behaviour gap). Thus, coping relevant BCTs have been shown to offer the potential to help people both

understand what the sources of their stress are as well as help them to manage their stress. It is important to keep in mind, however, that most of the theoretical and empirical work on behaviour change to date has been within the physical activity, diet, and addiction domains (Michie, Ashford, et al. 2011; Michie et al. 2012; Michie, Hyder, et al. 2011). As such it remains unclear as to how coping-relevant BCTs can be incorporated into a digital stress self-management intervention. Similarly, because much of the research on cognitive behavioural SMIs has not included full descriptions of the protocols used (Richardson and Rothstein 2008), there have been few insights to be gained from stress management literature into exactly how coping-relevant BCTs were implemented and delivered in previous interventions.

2.8 Conclusion

Mobile apps present themselves as a scalable solution for delivering early stress management interventions to the millennial population (Christmann et al., 2017; Coulon et al., 2016). By providing an avenue to cost-effective and highly accessible evidence-based treatments, they have the potential to support people in self-managing their stress. Yet despite their promise, currently available apps still fail to deliver on their full potential. One explanation is that they lack the features required to support users in problem-focused coping, a technique that has been shown to be helpful in motivating and supporting stress self-management. This deficiency has been exposed in app functionality reviews, which have pointed out that, as opposed to other health and wellbeing-oriented apps, existing stress self-management apps lack in the coping-relevant BCTs they include (Christmann et al., 2017; Coulon et al., 2016). This may partially explain why these apps are still not as effective as face-to-face treatments.

In this chapter, we have reviewed existing literature on stress coping, personal informatics, and behaviour change to identify a set of self-regulatory techniques - namely stress management, self-monitoring, goal setting, planning, and time management - that have the potential to help people better understand and self-manage their stress using mobile apps. Insights into data collection, reflection, and data visualisation found in personal informatics literature provide initial guidelines and frameworks for incorporating self-monitoring and reflection-enabling features into an app interface. In addition, the theoretical work stemming from the behaviour change

domain helps inform which additional coping-relevant BCTs should be included to support self-monitoring and the associated processes and tools (e.g., reflection and data visualisation), to maximise the apps' effectiveness in ensuring people take the necessary steps to engage in stress self-management.

What still remains unclear, however, is how coping-relevant BCTs can be incorporated into stress self-management apps. This is primarily because most of the guidelines used in personal informatics and behaviour change research have been formulated based on studies that evaluate self-tracking practices and/or interventions within the physical activity domain. Even though insights coming from the physical activity literature can help inform processes by which people come to understand their behaviours and adhere to an intervention, people experiencing mental wellbeing challenges have different needs to those seeking to improve their physical wellbeing. For instance, people who are experiencing stress usually feel overwhelmed and out of control. They often suffer from a lack of motivation or a perceived limited capacity to cope, which can in turn lead to engagement in avoidant coping behaviours (Nezu, 2004). Designing app features that can help people regain their sense of control and/or perceived ability to cope can help ensure that they are able to engage in adaptive self-regulatory behaviours for stress self-management.

Having now looked back on the existing literature relevant to stress-self management interventions, the following chapters focus on our work, how it expands upon these past studies and its contribution to the prevailing body of knowledge. To inform how coping-relevant BCTs could be incorporated into stress self-management apps, we first investigate the extent to which currently available apps support their users with reflection and behaviour change. We then build on past research reviewing stress self-management apps by investigating whether and how such apps support their users with understanding and managing their stress (i.e., problem-focused coping). This is followed by field studies, during which we investigate how successful people have been in using app-delivered techniques in practice. Then, based on peoples' experiences with the existing apps, we identify areas where potential improvements could be made. Finally, the second part of this thesis focuses on how we apply our insights in the design of novel app features explicitly aimed at supporting people in self-managing their stress in a need fulfilling way.

3 App Feature Review and Evaluation: how Stress Management Apps Support Reflection and Action

Parts of this chapter have been published in (Ptakauskaite, Cox, and Berthouze 2018)

3.1 Chapter overview

As a first step to understanding whether existing stress management apps were fit for purpose, Chapter 3 presents an app review study investigating whether and how stress management apps incorporate app features to support reflection and action-taking, as defined in the stage-based model of PI (Li et al. 2010b). Specifically, our review focuses on data collection, visualisations and coping relevant BCTs. There are only a handful of studies investigating the features incorporated into stress management apps, and none of these studies focus on how such apps support reflection and action. Additionally, existing app functionality review methods primarily focus on the number of BCTs they include but do not account for how such apps enable data collection and exploration through features such as data visualisation. To understand how existing tools can support people in managing their stress, the work presented in this chapter proposes the REACT method, which is complementary to the existing BCT taxonomy evaluation methods as it was explicitly developed for evaluating the extent to which wellbeing self-monitoring apps support their users with reflection and action, and how features aimed at supporting these processes were implemented into apps. We then apply our method to evaluate commercially available stress self-monitoring and management apps. In doing so, we identify examples of good practice and discuss how these should be used to support reflection and action. The chapter concludes with a brief discussion of future work required to inform how people use such apps in practice and what stress self-management needs are.

3.2 Introduction

Findings from our previous chapter indicate that coping-relevant behaviour change techniques can help people with their stress self-management efforts. Specifically, coping-relevant BCTs such as self-monitoring, goal setting, and planning can help people identify their stressors (understanding) and support them in adhering to stress coping behaviours (managing) (Aspinwall and Taylor 1997; Christmann et al. 2017; Skinner et al. 2003; Ellen A. Skinner and Zimmer-Gembeck 2016). However, what is not yet clear is whether and how existing mobile stress management apps integrate features aimed at supporting the stages of reflection (data collection and visualisation) and action (coping relevant BCTs) (Li et al. 2010b). Understanding how apps support these specific stages is important as it can help inform the extent to which stress management apps support their users with problem-focused coping.

Prior reviews of behaviour change apps have relied on BCT taxonomies to evaluate whether a given category of apps' includes evidence-based techniques (see

Table 2) (Christmann et al. 2017; Coulon et al. 2016). For example, Coulon et al. (2016) reviewed evidence-based content included in 60 stress management apps using a brief list of emotion and problem-focused coping strategies. They found that 20 out of the 60 apps did not include a single evidence-based stress management technique. For the apps that did include at least one evidence-based technique, the most common strategies used were mindfulness and meditation (29 apps out of 60), with 21 apps supporting self-monitoring. However, there was a lack of support for problem-focused coping techniques, including problem-solving (3 apps), cognitive restructuring (2 apps), active coping and behavioural activation (4 apps), which refers to engagement in activities directed towards improving mood.

Christman et al. (2017) provided a more extensive review of emotion-focused coping and behaviour change techniques included in 62 stress management apps. They had initially reviewed stress management literature and used their findings to construct a list of emotion-focused coping techniques that included strategies such as sounds and music, hypnosis and breathing. In addition to reviewing emotion-focused coping techniques, Christman et al. had also included a short list of coping-relevant BCTs, which were stress management, self-monitoring, goal setting, problem solving and

time management. Their findings indicate that the most common emotion-focused stress management strategies used were sounds (30 apps out of 62), breathing (27 apps), meditation/mindfulness (21 apps). The most commonly included coping-relevant BCTs were stress management (48 apps out of 62) and self-monitoring (19 apps). Finally, they also found that stress management apps included four behaviour change techniques on average and that these techniques were similar to those used in conventional, non-app-based stress management interventions (group-based, 8-10 sessions, using a multi-technique approach (Ong et al., 2004)).

	Coulon et al. (2016)	Christman et al. (2017)
<i>Features that support problem-focused coping</i>		
<i>Goal setting</i>	4	6
<i>Planning</i>	-	-
<i>Problem solving</i>	3	0
<i>Time management</i>	-	9
<i>Stress management</i>	-	38
<i>Self-monitoring</i>	21	19
<i>Features that support emotion-focused coping</i>		
<i>Meditation</i>	29	21
<i>Breathing</i>	10	27
<i>Music</i>	-	20
<i>Visualisation/Guided imagery</i>	6	11
<i>Features/processes that support self-monitoring</i>		
<i>Data visualisation</i>	-	-
<i>Reflection</i>	-	-

Table 2. A subset of techniques reviewed in Coulon et al. (2016) and Christmann et al. (2017). Both studies included several coping-relevant BCTs, with Chirstman doing a comprehensive, taxonomy-based (Michie et al. 2008) BCT review. Coulon et al's (2016) and Christmann et al's (2017) work had also considered the inclusion of emotion-focused coping techniques. In contrast, our review was primarily focused on how apps incorporate features that support problem-focused coping, which is why we additionally reviewed whether and how apps incorporate features to support data visualisation and reflection, which was not done by previous research.

However, using a BCT taxonomy alone will be insufficient to gain insight into how existing apps support their users with understanding and self-managing their stress. For instance, a BCT taxonomy (e.g., Michie et al. 2008) used to evaluate stress self-management apps should lead to reliably identifying what proportion of apps include self-monitoring features. However, counting the number and type of BCTs included in apps is insufficient to identify how and to what extent such apps support users in collecting, exploring, and acting on their self-tracking data. Similarly, previous stress management app reviews were not aimed at evaluating whether existing apps accounted for the intention-behaviour gap as they only looked at the inclusion of individual techniques but not their combinations. Without this information, it is challenging to evaluate whether the self-monitoring features included in a given app can help users better understand their stress and the factors affecting it. Consequently, the findings from app review studies that rely on BCT taxonomies alone (Christmann et al. 2017; Coulon et al. 2016) are insufficient for generating design guidelines aimed at explaining how to incorporate app features for stress self-monitoring and management.

We therefore develop a functionality evaluation method called REACT (**RE**flexion-**ACT**ion) and apply it to review whether and how existing stress self-management apps support their users in understanding and managing their stress. The REACT app evaluation heuristics (which will be described in detail in the Methods section) were developed by drawing on personal informatics and behaviour change theory (Li et al. 2010a, 2011; Rhodes and de Bruijn 2013) and on visualisation readability heuristics (Cuttone et al. 2014). Our method is aimed towards evaluating and describing the extent to which stress management and self-monitoring apps support their users with reflection and action, and how features aimed at supporting these processes were implemented into apps. Using this method, we additionally capture whether existing apps account for the intention-behaviour gap (Rhodes and de Bruijn 2013; Sniehotta, Scholz, and Schwarzer 2005) by considering whether a given app supports their users with both reflection and behaviour change for stress self-management.

3.2.1 The present study

The aim of this study is to answer the following research question:

RQ1 How well stress management apps and visualizations generated by such apps support reflection (understanding) and action (managing).

We achieve our aim by systematically reviewing and evaluating commercially available stress management and monitoring apps. A better understanding of how features supporting reflection and action are implemented in existing stress management apps enables us to identify the areas that need improvement and allows us to outline initial design guidelines for increasing the impact of such apps. We additionally use the findings from the present study to inform and direct our future research efforts aimed at understanding how people use stress self-management apps in practice and where additional improvements can be made.

The contributions of the work presented in this chapter are:

- REACT: design and evaluation of a method for stress self-monitoring and management apps. Our method combines heuristics and in-depth app evaluation to describe best practices. This method builds on behaviour change and personal informatics approaches. It allows for fast evaluation and provides early insight into the features and functions included in the existing apps.
- We use the evaluation guidelines to describe and evaluate the state of the art in stress management and monitoring apps.
- We identify opportunities to improve the efficacy of future technologies by providing design implications for increasing the impact of stress management and monitoring apps.

3.3 Methods

3.3.1 Initial Selection of The Apps

A systematic search on a UK based Google Play Store was conducted as Android is the most commonly used mobile operating system worldwide (Statista 2017). Apps that did not allow for self-tracking were excluded. It was necessary for the app to include a self-tracking option because it enables data collection, which is essential for investigating self-reflection and self-discovery. The apps were evaluated on a Galaxy S7 Edge smartphone running Android 7.0. The keywords used in the search were “stress management”, “stress reduction”, “stress relief” and “stress monitoring”, “stress tracking”. The descriptions of the first 250 apps showing up under each search term were reviewed (250 is the limit of apps shown under search results set by Google Play Store) and evaluated against the following app inclusion criteria:

1. The apps should come from “Health & fitness” and “Medical” categories on the Google app store; entertainment focused apps, such as games, were excluded.
2. Are free to use as most of the apps (91.5%) found on Google play store under the categories of “Medical” and “Health and Fitness” are free to use (Appbrain 2017).
3. Each app’s description will be investigated to ensure that the app is not a duplicate and that its main language is in English.
4. The app should be focused on healthy adults as opposed to specific clinical conditions, clinicians or children. These user groups will have their own disease and age specific needs that cannot be effectively evaluated in line with the needs of healthy adults.
5. The app does not require a wearable device as such apps will have different data collection and data representation requirements than apps that do not require a wearable device.

Apps meeting this inclusion criteria were downloaded, installed and tested in November 2017. Upon initial testing of the app, only apps that allowed for self-tracking were included.

3.3.2 The REACT Method

The REACT method consists of two steps:

- Step 1 involves using a set of scales to evaluate whether and to what extent apps include features to support reflection and action (see Table 1 for a short summary and Appendix A for the full evaluation scale).
- Step 2 requires conducting an in-depth review of apps obtaining the highest score from the heuristic evaluation (above 3.5 points out of 5). The features and functions included in these apps are used as examples of best practice to provide a detailed account of how these apps support reflection and action.

This study used a second rater to avoid bias and inconsistencies while rating the apps. The second rater was asked to review 30% of the included apps. In their app review, Mani et al. (2015) demonstrated that a review of 30% of the apps that were randomly selected from the total sample was enough to ensure that the app ratings were consistent across raters.

3.3.3 Step 1: REACT Heuristic Evaluation

The **Reflection-ACTION** (REACT) app evaluation heuristics, which will be described in detail below, were developed by drawing on personal informatics theory (Li et al. 2010a, 2011), data visualization and readability heuristics (Cuttone et al. 2014) and the action control constructs defined in Rhodes and de Bruijn (2013). The following section provides an overview of the literature from which the reflection and action concepts were borrowed to build the items in the REACT evaluation scale.

3.3.3.1 Informing the React Evaluation Heuristics

Reflection: using data to generate insights

Personal informatics lends itself well to helping us understand how apps may support users with identifying what their current and past behaviours are through concepts such as *Reflection, Status, History, Goals, Discrepancies, Context, Factors, Action,*

which were described in detail in Chapter 2, section 2.5.1 (Aspinwall and Taylor 1997; Carver et al. 1989; Li et al. 2010a). Data visualization and readability heuristics (Cuttone et al. 2014) can inform whether self-tracking data is communicated effectively back to the users by looking at their *Interpretability*, ability to support the *Discovery of Patterns and Trends*, and providing *Affordance for Action* (see section 2.5.1). Behaviour change techniques, such as *Self-monitoring, Planning, Goals, Reminders* can help understand how apps support their users with action taking (Rhodes and de Bruijn 2013).

Action: turning insights into actions

Li's (2010) stage-based model of personal informatics explains that during the action stage the users decide whether there is a need for any behavioural adjustments based on the insights gathered during the reflection stage. The common assumption made by personal informatics tools is that it is the discrepancies between the users' current and goal states that prompt them to act. But this assumption fails when peoples' intentions, possibly formed after reflecting on their data, do not translate into actions (Dijk et al. 2017b; Sheeran and Webb 2016). This leads to the previously mentioned phenomena known as the *intention-behaviour gap* (Sheeran and Webb 2016; Sniehotta, Schwarzer, et al. 2005). Behaviour change research specifies that this gap can be bridged by using action control constructs: self-monitoring, planning, goal setting, reminders (Rhodes and de Bruijn 2013; Sniehotta 2009; Sniehotta, Schwarzer, et al. 2005). The inclusion of these constructs helps ensure that the users are not only aware of what their current state is and what might be influencing it (reflection), but that they are also engaging in behaviour change (action) (Christmann et al. 2017; Rhodes and de Bruijn 2013).

3.3.3.2 Using the REACT App Evaluation Heuristics

The REACT evaluation heuristics is split into three sections. Each item (16 in total) is evaluated on a 5-point Likert scale to match the 5-star rating given on the app stores. Each point is accompanied by a description to help guide the rater's decision. The descriptions are iteratively created by reviewing a subset of apps and establishing the extent to which they support each item. That is, deciding which features and functions

the app should include to be assigned a given number of the points for each item. The points are then added together (80 max) and divided by 16 to get the final score.

Before the evaluation of each app, the selected apps were categorised based on the following criteria to ensure that there were no duplicates:

- App name
- Version of the app
- Developer
- Last update of the app
- Brief description of the app

3.3.4 The REACT Scale

Part 1. Action Control

The first part of the scale investigates whether and how mobile apps for stress management include functionalities supporting coping-relevant BCTs, including self-monitoring, goal setting, planning, and prompts (Christmann et al. 2017).

Does the app allow for:

- 1 **Self-monitoring.** Does the app allow for self-monitoring of variables such as stress, mood, and/or stress management activities:

Strongly disagree

Strongly agree

1

2

3

4

5

1. Input of mood/stress only when accessing the app, poor interface/visualization.

2. Input of mood/stress only when accessing the app, no issues with interface/vis.

3. Input of mood/stress and another variable, e.g., exercise but no duration or type.

4. Input of mood/stress and another variable, more info on the extra variable (type/duration).

5. Input of mood/stress and another variable, more info on the extra variable, reminder to input information.

2 **Planning.** Does the app support planning of activities? (e.g., create a plan of when to perform relaxation exercises)

Strongly disagree

Strongly agree

1

2

3

4

5

1. The app allows users to set reminders when first accessing the app, i.e., give a plan on when to do the activity or what activities to do.

2. Provides a pre-specified visual roadmap/plan of connected activities that need to be performed.

3. 1&2 together.

4. Explicitly instructs the user to create a custom plan that will suit their needs but does not provide a visualization of this plan or a visual roadmap.

5. All of the above.

3 **Goal setting.** Does the app support goal setting? (e.g., within the next two weeks I will increase my mindfulness meditation duration from 5 to 10 minutes per session/reduce my overall stress score)

Strongly disagree

Strongly agree

1

2

3

4

5

1. Mentions the importance of goal setting or performing the relaxation exercises/tracking.

2. Any from 1 & Provides a roadmap.

3. Allows the user to track pre-defined goals.

4. Allows the user to customise goals and track them.

5. Allows the user to track short term and long-term goals, customise.

4 **Prompts and/or reminders.** Does the app send prompts to remind the user to log their stress/mood and/or perform a certain stress management activity?

Strongly disagree

Strongly agree

1

2

3

4

5

1. Sends prompts to use the app.

2. Allows users to input mood/stress.

3. Sends prompts to the users to perform an activity.

4. 1&2.

5. 4 & sends customised messages with positive reinforcement “time to exercise to make you feel better” instead of “time to meditate” o the users.

Total for part 1 _____

Part 2. Personal Informatics and The Quantified Self

This section evaluates whether and to what extent do stress management apps and visualizations produced by such apps allow for reflection and action. This was assessed in relation to the stage-based model (Li et al., 2010) and the types of questions asked by self-trackers during the reflection stage (Li et al., 2011). Apps that include features described in the stage based model and further work by Li et al. can facilitate self-insight and self-discovery, allowing the users to identify goals, monitor their behaviours, and adjust these behaviours in accordance with their goals.

How personal data is collected and explored (Li et al., 2010):

1. **Reflection.** Does the app enable the users to reflect on their data and how?

Strongly agree

Strongly disagree

1

2

3

4

5

The app supports reflection by using _____. (Data visualization, sound, cognitive restructuring)

1. The data is visualised, but the visualization is poor in quality and confusing.
2. The visualization is good in quality but confusing OR low in quality but easy to interpret.
3. The visualization is good in quality and easy to interpret, but does not allow the user to spot trend and patterns.
4. The visualization is good in quality and easy to interpret, allows the users to spot trends and patterns.
5. The visualization is good in quality and easy to interpret, allows the users to spot trends and patterns, visualises relationships between several variables.

***Upon completing initial reviews of selected apps, the scale items dedicated to evaluating Reflection were adjusted to primarily focus on data visualisation. This decision was made because the primary means through which the apps included in this review supported reflective practices was data visualisation, which is likely a product of only including apps that focus on self-monitoring. Notably, the in-depth review discusses and describes methods other than data visualisation used to encourage reflection included in the [Pacifica](#) and [Remente](#) apps.*

2. **Action.** Does the app support action taking after interacting with the data? How? This item also accounts for the behaviour change technique *Stress management*.

Strongly disagree					Strongly agree
1	2	3	4	5	

1. The app provides the users with tips and advice on how to manage stress, but this is not linked with how/when the individual is stressed.
2. The apps provides the users with information on how to perform a stress management activity, informs about the behavior-heal link, but this is not linked with how/when the individual is stressed.

- 3. The app provides the users with information on how to perform a stress management activity, informs about the behavior-health link.
- 4. 3 & send prompt/reminders to perform a stress management activity
- 5. 4 & visualises before/after effects.

How people reflect on the data that they collect (Li et al., 2011):

1. **Status.** Does the app allow the users to compare their current state with their goal state?

Strongly disagree Strongly agree
 1 2 3 4 5

- 1. The app visualises only past OR current status, e.g., stress monitor that only shows a chart displaying past stress trends on average.
- 2. The app visualises past AND current status.
- 3. The app visualises past and current states and past and future tasks/activities.
- 4. 3 & allows the user to see an indicator of whether a goal was met or not, e.g, use colour green instead of grey on a bar chart when the goal is met.
- 5. 4 & uses a flexible short and long-term goal setting system to indicate whether the user needs to change their current state to reach their goal. The user can also determine very quickly whether they are meeting their goals, e.g., goal is to have a 100 wellness score or have a heart shape/glass fill up with every stress management activity etc.

2. **History.** Does the app allow for the users to identify whether there any trends and patterns in the data, specifically, how a stress management technique may be affecting the user's stress/mood levels?

Strongly disagree Strongly agree
 1 2 3 4 5

- 1. The app only visualises stress/mood data on average as a score.

2. The app visualises stress/mood data over time on a graph (indicates trends only),

3. The app can visualise stress/mood and other data such as exercise on separate graphs,

4. 3 & the data is visualised on the same graph to show any interactions and makes finding trends and patterns easier.

5. 4 & additional heatmap/calendar view showing patterns, for example, how stress levels vary throughout the week.

3. **Goal monitoring.** Does the app make it clear to the users what goals should be pursued? E.g., reducing stress, increasing the frequency of relaxation/mindfulness exercises.

Strongly disagree

Strongly agree

1

2

3

4

5

1. The apps goal is solely focused on self-tracking and self-insight. The goal is implicitly set by the user.

2. The app defines program level goals, such as “this app will make you less stressed”.

3. 2 & the app also specifies program level goals, however, these goals are more actionable – running or meditating in the mornings.

4. 3 & the app also provides an option for users to monitor and iteratively set goals.

5. 4 & the app provides users with real time feedback/information on whether a goal is met.

4. **Discrepancies.** Does the app allow the users to identify whether there are any discrepancies between their current state and their goal state? For example, visualising a glass of water that gradually fills up with every relaxation activity.

Strongly disagree

Strongly agree

1

2

3

4

5

1. The app only visualises past trends of stress/mood, but has no other indicators of what the current or the goal states are.
2. The app visualises the current state and past trends so that the goal state can at least be checked by the user. E.g., the goal is to walk 10000 steps a day.
3. 2 & the app makes the goal visually explicit, e.g., use colour changes based on whether the user has reached their goal.
4. 3 & the app has a visual (smiley face for low stress) and/or a quantifiable representation that can be interpreted at a glance and used it to take action.
5. 4 & the app instructs the user on how to manage their goals based on the discrepancies.

5. **Context.** Does the app enable the user to recognise what other factors might be affecting **their present state\behaviour**? This is usually done by tracking more than one variable, e.g., stress and physical activity.

Strongly disagree

Strongly agree

1

2

3

4

5

1. The apps tracks two pre-set variables on the current state, visualises them on separate pages/visualizations, and the visualizations are difficult to interpret/explore.
2. The apps tracks several pre-set variables on the current state, visualises them on separate pages/visualizations, and the visualizations are easy to interpret/explore.
3. The apps tracks several pre-set variables on the current state, visualises them on the same page/visualization that is easy to explore.
4. The apps tracks several pre-set variables on the current state, visualises them on the same visualization and separate pages/visualizations, how one variable affects another, e.g., stress before&after breathing exercise.
5. The apps tracks several customisable variables on the current state, can visualise these on the same graph to show interactions and relationships, how one variable affects another.

6. **Factors.** Can the app show whether there any **factors/trends influencing behaviour change outcomes over longer periods of time**? For example, can the app make it explicit that by doing relaxation exercises will reduce the user's stress levels.

Strongly disagree Strongly agree

1 2 3 4 5

1. The apps tracks *two* pre-set variables over longer periods of time, visualises them on separate pages/visualizations, and the visualizations are difficult to interpret/explore.

2. The apps tracks *several* pre-set variables over longer periods of time, visualises them on separate pages/visualizations, and the visualizations are difficult to interpret/explore.

3. 2 & easy to interpret/explore.

4. 3 & visualises them on the same visualization *as well as* separate pages/visualizations.

5. The apps tracks several customisable variables over longer periods, can visualise these on the same graph to show interactions, trends, and relationships, how one variable affects another over time, e.g., how physical activity affects stress levels over time.

Total for part 2 _____

Part 3. Data Visualization

This section investigates how stress management apps visualise personal data. Users of self-tracking apps can collect large amounts of data, which can be challenging to explore if it is presented in a numerical format only. By visualising their personal data, people can begin discovering patterns and trends in their behaviours, this way supporting self-insight and self-discovery (Li et al., 2011). However, the visualizations need to meet specific design and functionality related requirements to be meaningful to the users. Therefore, this part of the scale also evaluates how well do stress

management apps visualise personal data in relation to readability, visual quality, and aesthetics (Cuttone et al., 2014).

1. Evaluating visualizations (*readability*, based on Cuttone et al. (2014)

visualization heuristics):

Strongly
disagree

Strongly agree

1

2

3

4

5

1. The graph is confusing/low in quality, difficult to read, too small.
2. The graph is confusing but high in quality,
3. The graph is easily interpretable but low in quality,
4. The graph is easy to interpret, high in quality,
5. 4 + the data representation is actionable, e.g., you need to reach a stress level of 1/"low stress".

2. Make the data interpretable at a glance.

Strongly
disagree

Strongly agree

1

2

3

4

5

1. The graph is confusing/low in quality, difficult to read, too small.
2. The graph is confusing but high in quality.
3. The graph is easily interpretable but low in quality.
4. The graph is easy to interpret, high in quality.
5. 4 + the data representation is actionable, e.g., you need to reach a stress level of 1/"low stress".

3. Enable exploration of patterns in time series data.

Strongly
disagree

Strongly agree

1

2

3

4

5

1. The chart presents time series data but is very confusing to interpret, e.g., only includes a pie chart depicting average stress levels over time.

2. The data is presented only as a time series chart, providing information on either Hourly OR daily OR weekly OR monthly results.
3. The data is represented only as a heatmap, but not over different periods in time.
4. The data is presented in both a time series and a matrix/heatmap format, allowing to identify trends, but not over different periods in time.
5. The data is presented in both a time series and a matrix/heatmap format, allowing to identify trends and patterns over different periods of time: months/week/day.

4. Enable discovery of trends in multiple data streams

Strongly disagree Strongly agree

1 2 3 4 5

1. Visualises multiple variables but in separate graphs, the graphs are difficult to interpret and are low quality,
2. Visualises multiple variables but in separate graphs, the graphs are difficult to interpret OR are low in quality,
3. Visualises multiple variables but in separate graphs. The graphs are easy to interpret and compare, and are high in quality.
4. 3 + visualises several pre-set variables on the same graph, uses a heatmap,
5. 4 + visualises several customisable variables.

5. Turn key metrics into affordances for action – can the visualizations be used as prompt for action? For example, walk another 5 minutes to reach a 10000 step threshold.

Strongly disagree Strongly agree

1 2 3 4 5

1. Only visualises time series data that might indicate that the person is getting stress and should do something about it,

2. Only visualises the relationship between several variables but does not provide any additional information of how these variables are related, common in self-tracking apps,
3. Uses numerical representation that act like black boxes, e.g., reach a wellness score of 10,
4. Uses transparent numerical or visual representation, e.g., heart rate, stress on a scale from 1-10, and presents guidance on how to perform activities, e.g., relaxation, breathing,
5. 4 + visual representation of goals, e.g., heart shape filling up.

Total for part 3_____

Absolute total_____

3.3.5 Step 2: REACT In-depth Evaluation

Upon completing the REACT heuristics evaluation, an in-depth evaluation was conducted on apps that had a strong focus on supporting either reflection or action and could be used to provide nonoverlapping examples of best practice. This was done to provide detailed examples and descriptions of how existing apps incorporate features known to support coping relevant BCTs and problem focused coping. Drawing on such examples enables us to more rigorously evaluate the extent to which existing apps are able to support their users with understanding and managing their stress. The section below informs the approach used to guide the in-depth evaluation.

3.3.5.1 Informing the React In-depth Evaluation

This part of the review follows the definition of short and long term reflection (Li et al. 2010a) and draws from Fleck and Fitzpatrick's (2010) discussion on reflective practices. Li et al (2010) differentiate between short- and long-term reflection, which can be used to describe the different types of insights that users can gain during the different stages of self-tracking. Short-term reflection can facilitate awareness of the users' current state and how other contextual factors might affect it. During short-term

reflection, people reflect on their data either as they are collecting it (e.g., heart rate displays) or shortly after the data is collected. Long term reflection involves exploring data that has been collected over a longer period, such as weeks or months. During long-term reflection, users can review their previously collected data from a different perspective. It becomes possible to restructure and aggregate data collected across extended time periods and multiple data sources. Having access to this additional information can lead to a different set of interpretations than the ones made during the earlier stages of self-tracking (Fleck and Fitzpatrick 2010; Li et al. 2010a).

3.3.5.2 Applying the REACT in depth evaluation

Upon completing the REACT heuristics evaluation, an in-depth evaluation was conducted on [Welltory](#), [Pacifica](#), and [Remente](#). We additionally include the app Exist as part of the in-depth review. Even though the Exist app did not meet the initial inclusion criteria for the heuristics evaluation, Exist includes excellent features to support reflection, which can add value to our discussion as examples of best practice. Upon selecting the apps, the method requires:

Step 1. Outlining the types of data that can be collected via the app during short- and long-term self-tracking.

Step 2. Describing the data visualisations and other types of reflection methods used. It also requires outlining the insights they might lead to and how these may translate into actions.

Step 3. Identifying the missing features or other barriers to adequately supporting reflection and action.

3.4 Results

3.4.1 App selection

The search returned a total of 1250 apps (250 for every search term). After assessing the apps against the initial inclusion criteria, which mainly focused on the condition

that apps include a self-tracking feature to visualise data on stress levels, 26 apps were downloaded and evaluated. A total of 11 apps were included under the search terms stress + management OR relief OR reduction. The search terms stress + tracking OR monitoring OR log returned 15 apps that met the full inclusion criteria.

3.4.2 Overview of the Total App Scores

The mean of the apps' scores was 42 (SD= 2.68) points (out of 80). The apps had a median of 40.5 points and the highest-ranking app, which was Pacifica, received 68 points in total and the lowest ranking app Zenfie received 31 points. Weighted Cohen's κ showed good interrater agreeability that was performed on 30% of the apps included in the review, $\kappa = .84$, (95% CI, .72 to .95), $p < .001$.

3.4.3 Feature analysis

For analysis purposes, the scales were further categorised into 2 categories focusing on reflection and action (see Figure 10). Reflection part of the scale included items on: reflection, self-monitoring, history, goal monitoring, identifying discrepancies between current and goal states, identifying contextual factors (short- and long-term), patterns and trends. Action part of the scale included items on: supporting action (demonstrating how to perform a specific stress management exercise), affordance for action provided by the visualization (e.g., as exercise levels go up, stress goes down), planning, goal setting, prompts or reminders.

App Name	Reflection	Action
Moodtrack Diary	1	0
Health Log	1.7	0.2
Mood Log	2.2	0.2
Stress Monitor	1.9	0.6
MetaFi	2.3	1.2
MindRazr	2.5	1
TruReach	2.2	1.6
WellMind	1.8	2
Breathe2Relax	2.7	1.2
Moodpath App	2.2	1.8
Zenfie	1.4	2.6
Daylio	3.2	1.4
MoodMission	2.4	2.4
flowt	2.6	2.4
Stop Breathe & Think	3.2	1.8
Thought Waves Pro	2.8	2.6
InnerHour	1.8	3.8
Aura	2.5	3.2
Thrive: Feel Stress Free	3.1	3.2
Moodlytics	4.1	2.6
DeStressify	3.5	3.4
Welltory	3.9	3
HealthyMinds	2.4	4.6
Remente	3.7	3.6
Moodfit	4.2	3.4
Pacifica	4.3	4

Figure 10. List of the 26 reviewed apps together with the information on how well they support functions related to reflection and action. Ordered from lowest to highest ranking apps after applying the REACT heuristics.

3.4.4 Reflection

Reflection was mainly supported through data visualization. 24 apps produced high quality and easy to interpret visualizations. However, only 6 displayed before and after effects to show the link between a relaxation activity and reduced stress (see Figure 12). Fourteen apps used visualizations that enabled the identification of trends. Two apps used visualizations that were low in visual quality and difficult to interpret.

Nineteen apps provided visualizations that are high in visual quality and can be interpreted at a glance. Exploration of patterns in time series data was possible in 15 apps. Discovery of trends in multiple data streams was supported by 15. Eight

visualized multiple variables but in separate graphs, whereas 7 apps allowed the user to visualize several variables on the same graph. Affordance for action through data visualization was provided by 12 apps. Eight of these apps visualized relationships between variables that could be translated into action or used numerical or visual representation of a general wellness score or other indicators such as a heart icon filling up to represent wellness (see *Figure 11*).

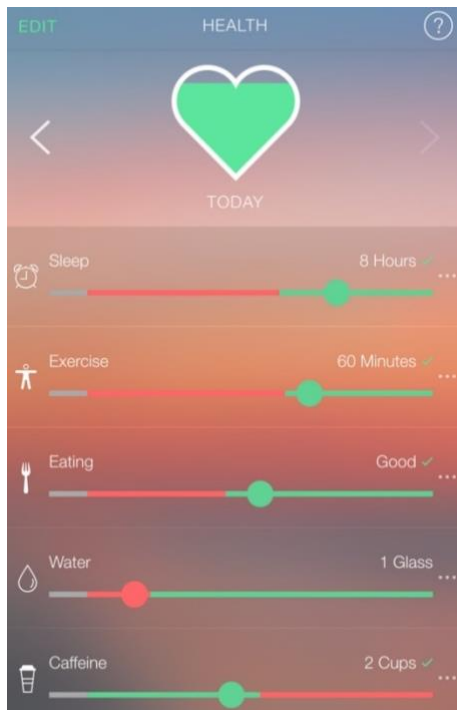


Figure 11. The app Pacifica uses a heart icon to indicate whether the user’s progress towards their goal. This design complies with Li’s et al (2011) work on reflection by showing discrepancies between the goal and the current states. It also aligns with Cuttone’s et al. (2013) visualization heuristics as it provides an actionable visualization that can be easily interpreted at a glance.

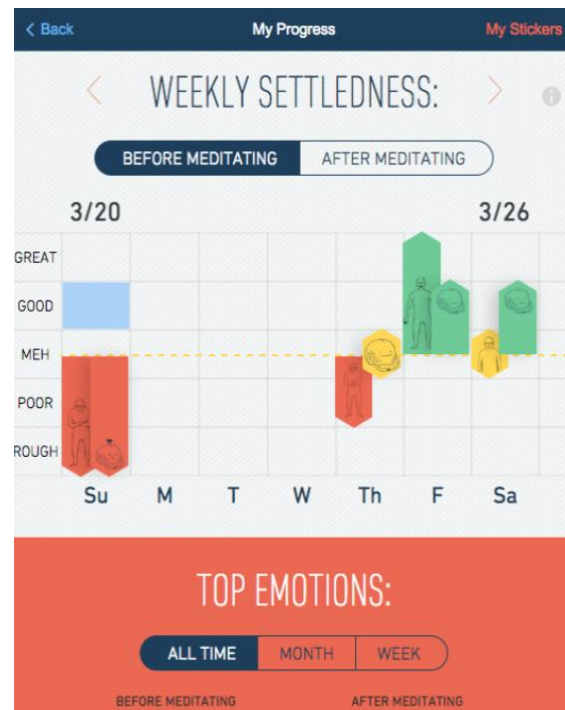


Figure 12. Stop Breathe & Think Meditate app displaying effects on physical (as indicated by a bar with a body shape doodle) and mental wellbeing (a doodle representing the mind) before and after meditating, indicating the behaviour-health relationships and providing actionable insights (i.e., meditate to improve physical and mental states).

***Where Figure 11 displays colour-coded sliders that represent where the users are in relation to their daily goals, Figure 12 represents a time-series visualisation that can effectively highlight how, over time, meditation becomes associated with improvements in mood (which is a possible goal state set by the user). In both visualisations, features such as colour coding and a clear indication of a goal state (in Figure 11 it is the green part of the slider and in Figure 12 it is the orange line dividing positive and negative mood) can help the users quickly interpret whether they have reached their goal state, both in the short- (Figure 11) and long-term (Figure 12).*

Twenty-three apps provided a visualization of the current state, but only 5 apps enabled the users to compare their current state with their goal state (see *Figure 11*). Twenty apps provide visualizations of stress and/or mood trends over time, and an additional 7 apps visualised which activities have an impact on stress over time (see *Figure 12*). Six apps support the identification of discrepancies between the current and the goal states. Only 1 app visualized context factors affecting the current state and 15 apps allowed to track several pre-set variables affecting stress over time.

3.4.4.1 In-depth Review: Supporting Short-term Reflection

As mentioned previously, people will interact with their data differently and gain different types of insights depending on whether they engage in short- or long-term reflection. It is therefore important to gain a deeper and more concrete level of understanding about how existing apps incorporate features known to support both short and long-term reflection (as opposed to reflection in general). To gain this understanding, we will first look at how two state-of-the-art stress management and monitoring apps - Welltory and Pacifica - support their users with short-term reflection.

Welltory

Welltory (Welltory, 2018) is a stress monitoring app that measures levels of stress using photoplethysmography (PPG). The users place their fingertip over a smartphone's camera. A video is then taken, capturing the rate at which the blood flows through the fingertip's capillaries. This information is used to infer the user's stress levels. The app uses biofeedback to display real-time heart rate variability (HRV) as the measurement is taken. After the measurement is taken, the users are

asked to input their subjective mood, physical state, sleep quality and input text-based tags that align with what might have influenced their stress.

The users are then presented with a summary of their measurement results, including their stress and energy levels, productivity score and mood (see Figure 13). This is done by using colour-coded icons, volume-based visualisations and scores. This information is easy to interpret at a glance due to the intuitive icons that align with the variables they represent, the traffic light colour-codes and volume effects.

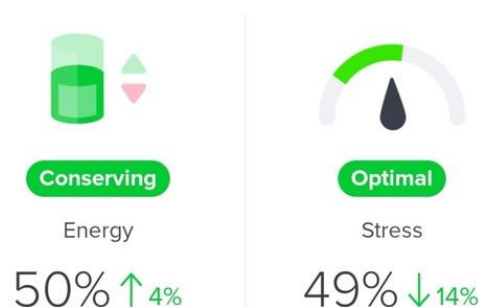


Figure 13. Icon and volume-based visualisations provided by the Welltory app after taking a stress measurement.

The visualisations used by the Welltory app to summarise the stress measurement results are well suited for short-term reflection as the users can begin reflecting on their levels of stress immediately after a measurement is taken. If they identify any unwanted discrepancies, then this information can act as a prompt to take action (Dijk et al., 2017; Li et al., 2010). Each Welltory measurement is associated with a canned response, which is presented to the users after they take a measurement. It consists of text-based interpretations of what the quantitative results mean alongside actionable advice on how to plan and approach their day.

Pacifica

Findings from the functionality review indicate that even though most stress management apps include some form of data collection and visualisation, the functions included in these apps do not necessarily rely on self-tracking data to facilitate reflection and action. A good example of this can be found in the Pacifica app (Pacifica Labs Inc. 2017). In contrast to Welltory, which primarily relies on data

collection and visualisation to facilitate reflection, Pacifica offers a set of CBT-based tools that can help users identify the different emotions they experience, their causes, and how to cope with them. Even though this is not directly linked to identifying explicit triggers of stress, the act of reframing ones thinking can help improve emotional self-awareness and avoid unhelpful patterns of thought that may be inducing stress (Morris et al., 2010).

The free version of Pacifica offers three thought analysis tools. The Basic tool helps users discover how their thoughts, experiences and emotions relate to one another by writing these out and linking them together. The Traps tool (see Figure 14) helps them identify unhelpful reoccurring thoughts by asking them to write out, highlight and label the inaccurate/negative aspects of those thoughts. This is done by assigning the thoughts into categories such as Catastrophizing, Personalization and Blame, and noting whether thought is reoccurring. The Reframe tool helps users reframe the thinking traps into something more balanced. The users are instructed to re-interpret the situation, possibly by looking at the bigger picture or using less extreme language. Once the exercise is complete, this information is summarised and presented back to them by the app. Having completed the exercise and being presented with an overview of the outputs of that exercise should help the users become more perceptive of their thoughts and what triggered these. Upon viewing this pattern of thinking (see Figure 14), users can become better placed at forming more balanced views.

Traps Summary

THOUGHT

I cannot get anything right

THINKING TRAPS

anything

Pressurized / Extreme Words

THE PATTERN

Thinking back, have there been other times you can recall using this distortion?

Pressurized / Extreme Words

Yes, quite often when I'm overworked

Figure 14. Summary of the Trap reflection tool exercise (presented to the user after its completion) offered by the Pacifica app. In this exercise, users are asked to analyse their negative thoughts, the aim of which is to highlight a pattern in their behaviour and the potentially negative effects that this line of thinking has on their mental wellbeing.

3.4.4.2 In-depth Review: Supporting Long-term Reflection

We now take a closer look at how existing apps support long-term reflection. Within the context of stress management, users will benefit from features that allow them to identify the factors that are associated with their stress. This is, in fact, at the core of problem-focused coping. Yet, to gain these types of correlational insights, users will typically need to collect data over a period of several weeks or even months. Once this data is collected, the users are then able to engage in long-term reflection. Considering the above information, the following section describes how existing apps support long-term reflection. In doing so, we present two types of approaches commonly used in self-tracking apps to support their users with monitoring and understanding potential triggers of stress. The first approach uses text-based tags that can be linked to individual stress or mood entries. The second approach utilises traditional data visualisations, such as line and bar charts to reveal trends and patterns in peoples' data.

Tag-based visualisations

Tags can be used for monitoring activities that cannot be captured by sensors alone. They provide users with the flexibility of tracking virtually anything they can think of. The apps can use this information to automatically infer relationships between the selected tags and sensor data. This enables the discovery of how various aspects of the users' lives are related and promotes self-experimentation (see

Figure 15). The users can then apply this information to, for example, test the effects of reducing their caffeine intake, or exercising more frequently.

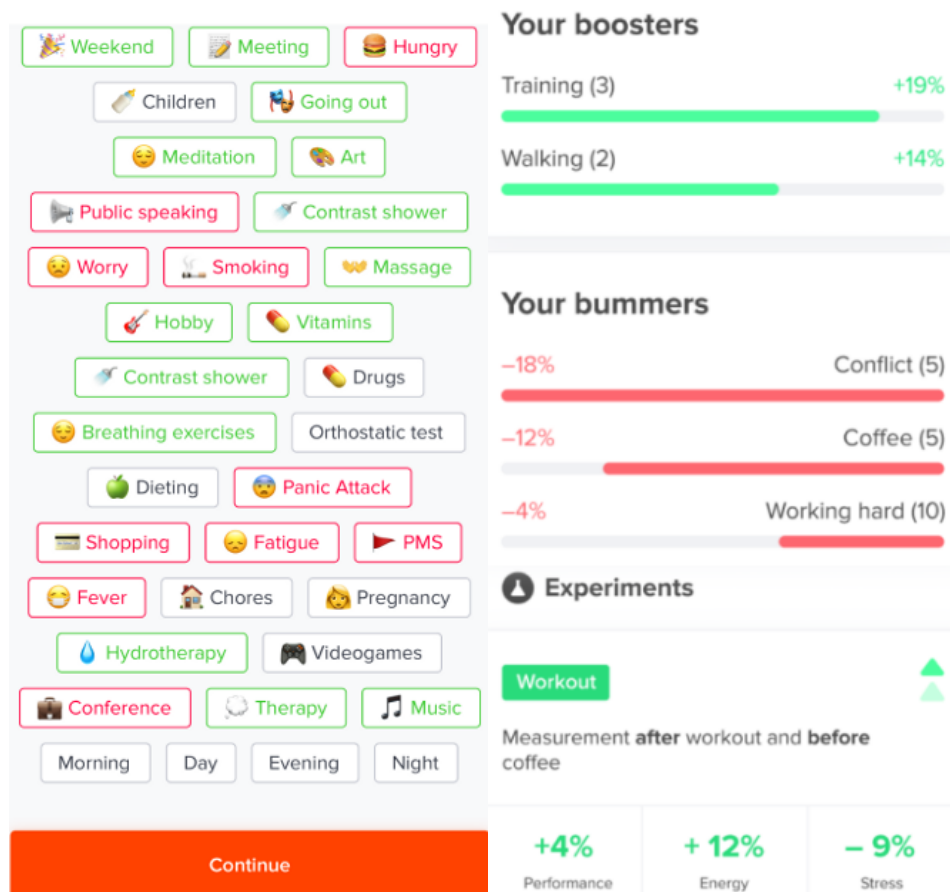


Figure 15. Left: The Welltory tags. The users can either select an existing tag or create their own tag. Right: The tags then appear as either a booster or a bummer, providing a quick overview of the effects that various activities have on the user's stress and energy levels. Experiments (bottom of b) can be performed by taking measurements

before and after performing a given activity. Each tag will come up on a dedicated experiment section displaying % changes in Energy and Stress.

Merging text and graph visualisations

Similar to Welltory, Exist (Exist 2018) is also a personal informatics app. Instead of using HRV-based stress measurements, Exist collects mood reports that can be associated with customised tags or journal entries. Like Welltory, Exist also automatically links the tags to other data streams. However, it differs in the way it visualises data. To explain the relationships and trends observed in the users' data, Exist combines line chart visualisations together with text-based interpretations of what the data means (see Figure 16). The benefit of displaying line charts alongside text over displaying text-only interpretations of correlational information is that the graph can provide a clear indication of the trends and patterns associated with each relationship.



Figure 16. Exist.io combination of time series data visualisations and text indicators representing significant trends and correlations in the users' data.

More generally, the graph-based data visualisations of most apps included in this review indicated interpretability-related challenges. This was due to the finding that most apps lacked clear axis and data point labels, did not include features such as trendlines or colour codes to provide information on whether the graph displays any significant trends or patterns.

3.4.5 Action control

Most apps (19 out of 26) supported the tracking of one or more additional variables alongside mood or stress. Planning was supported by 15 apps, however, only 4 of them did so in a structured way, e.g., helped to plan future activities, provided a visual action plan. 5 apps enabled the users to track predefined goals and 6 apps allowed them to iteratively set short and long-term goals. Action taking was supported by providing guidance on how to perform a stress management activity (7 apps), by providing information on the health-behaviour link (18 apps), and by visualising the before and after effects of a stress management activity (6 apps). An additional 12 apps allowed the user to set reminders to perform stress management activities.

3.4.5.1 In-depth Review: Supporting Action

The Remente app (Remente 2018) included the most advanced planning and goal setting features in comparison to all other reviewed apps. The app is primarily focused on improving wellbeing, including activities and psychoeducation related to stress management. The users can set an overarching goal to manage their stress. Once the goal is set, they can specify additional steps for achieving this goal, such as meditating or going for a walk. Each step can be further edited by indicating how frequently a given activity needs to be performed and when, and set reoccurring reminders. One of the more distinct features included in Remente is a field dedicated to taking notes initially displaying a question “How can you make this goal more tangible for yourself?”. The intention here is to facilitate planning on how to approach the selected task.

Several apps include goal setting features designed to improve the users perceived self-efficacy (i.e., their belief that they are capable of performing a given behaviour) (Bandura 1977). This is done by drawing on past-success or helping people avoid failure through dynamically adjusting goals to their current capabilities. For example, Pacifica allows for comparing subjective evaluations of how difficult a user predicts a task to be with how difficult that task was in practice. Most people overestimate how challenging a given activity will be. By prompting their users to reflect on how challenging the activity they performed actually was, users of Pacifica can improve

their self-efficacy when performing the same behaviour in the future (Bandura 1977; Ryan and Deci 2000). Exist takes a more automated approach towards goal setting, where goals are dynamically adjusted based on a user's past activities. Instead of focusing on arbitrary goals that may not suit an individual user's capabilities, Exist aims to encourage people to perform better than their past selves, where higher performance in the present translates to more challenging future goals.

3.5 Feature gaps

The missing features that may create barriers to reflection and action include:

- Lack of support for short-term reflection. Most apps are based on self-reported levels of stress, meaning that the users do not gain any information in the short-term that is not already obvious to them.
- Lack of flexibility to customize the items being monitored alongside stress. This can create barriers to identifying the potential triggers of stress as these can vary across individuals.
- No or very little guidance on how to reflect on self-tracking data. Users are presented with graphs lacking even the basic legends. There are no guidelines on how the graphs should be interpreted or the types of information that the users can discover from those graphs.
- Unclear or inappropriate visualisations used to represent how stress may relate to other wellbeing indicators. As an example, it can be challenging to identify correlations between two variables in a line chart.
- No clear guidelines on how to use the identified insights for behavior change. Most systems assume that upon seeing their data the users will adjust their behaviors accordingly. But this does not frequently happen in real life (Sniehotta 2009; Sniehotta, Schwarzer, et al. 2005).

3.6 Discussion

Stress management apps reviewed in this study were shown to adequately support reflection but not action taking. This finding suggests that most apps enable their users to identify what their stress levels are but provide little support in addressing this issue. One of the main shortcomings identified in the reviewed apps was that even though most included guidance on how to perform a given stress management activity, they failed to provide adequate features to support self-regulatory BCTs other than self-monitoring.

We also found that by applying the REACT method we were able to establish whether and how stress management apps support reflection and action and identify related feature gaps. Unlike the app evaluation methods based on behavior change taxonomies (Michie, Ashford, et al. 2011), the REACT method goes beyond assessing whether a behaviour change app includes evidence-based techniques. For example, Christmann et al. (2017) used a taxonomy to identify the behaviour change techniques included in stress management apps. They could identify that 19 apps included self-monitoring features. However, they could not discuss to what extent and how self-monitoring features were supported. This is because the taxonomy that they had used does not consider personal informatics concepts. By considering concepts such as reflection and action, the REACT method was able to provide detailed insights into how stress management apps support self-monitoring and action taking during the different stages of self-tracking.

We next translate our findings into design implications for further improvements. The discussion and the design implications presented below follow the format of the REACT evaluation method and are therefore structured around app features and functions that can facilitate long-term and short-term reflection and action. This is done to demonstrate how specific app features can be used to support the users in generating insights about stress and support them with coping during the different stages of self-tracking.

3.6.1 Supporting Short-term Reflection

Short-term reflection can help people become aware of what their stress levels are and use this knowledge to prompt action (Li et al. 2010a; Pesseau et al. 2014). All the apps included in this review, except for Welltory, relied on monitoring self-reported levels of stress. Self-report data is not well suited for short-term reflection as it does not offer any new information that is not already obvious to the user. Therefore, several weeks or months of data collection is needed for patterns and trends to emerge from the data before users can gain insights.

3.6.1.1 Design guidelines for Short-term reflection

Reflection without the use of long-term self-tracking data

Apps such as Welltory work around not having access to long-term self-tracking data by using sensor inputs and rich in-app content to encourage users' reflection and engagement with the app during the initial stages of self-tracking. Welltory also provides actionable advice for stress management based on each HRV stress reading. Pacifica sustains user engagement through its *Thought Tools* that can help people identify a more adaptive outlook. Both apps are examples of how stress monitoring and management apps can use sensor data, rich content, and journaling features to encourage reflection during the initial stages of self-tracking.

3.6.2 Supporting Long-term Reflection

Long-term self-tracking data can be used to highlight the trends, patterns, and relationships in people's wellbeing. For example, visualisations displaying correlations can help people identify behaviour-health links, such as the one between exercise and stress. This helps forming outcome expectancies with regards to how a given behaviour may effect wellbeing, which can in turn motivate future behaviour change (Bandura 1977; Consolvo et al. 2008; Dijk et al. 2017b). Seven of the apps included in the functionality review displayed correlational visualisations of stress with another

variable. However, only two of these apps (Welltory and Pacifica) allowed for full customization of what that additional variable was. Finally, most apps over-relied on using graph-based visualisations to represent long-term self-tracking data.

3.6.2.1 Design Guidelines for Long-term Reflection

Use Tags to Personalise the Variables Being Monitored

Considering the highly individual and subjective nature of stress, it is essential that stress self-management apps allow users to personalise what context factors to monitor alongside their stress levels (Kelley, Lee, and Wilcox 2017). For instance, the apps Welltory, Exist and Pacifica enable this by using fully customisable tags (see Figure 3). Upon collecting the data, the Welltory and Exist apps perform additional correlational analysis between the tags and related sensor data to help users discover what factors are affecting their stress. Even though most apps included in this review allowed for monitoring one or more factors related to wellbeing and users' daily activities, only three apps allowed their users to customise what those additional factors were (see Figure 17). Ultimately, apps that enable their users to track multiple context variables, such as sleep, diet, and/or physical exercise, help ensure that their users have the means to gain insights into how different aspects of their daily lives and behaviours affect their stress levels (Li et al. 2011).

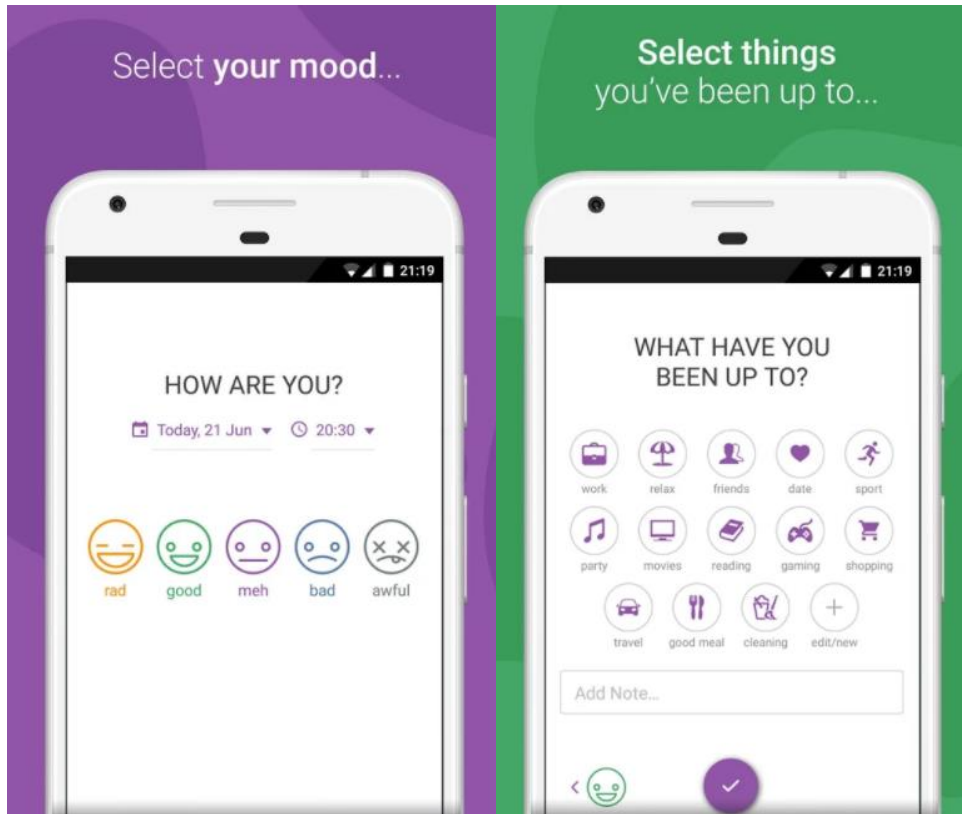


Figure 17. After collecting information on the user's mood (left), The Moodfit app allows the users to type in one or more activities that they were performing (see right). These activities can be selected from an extensive list of pre-defined tags or added as a new customised tag by clicking on a plus/add sign (see bottom right).

Use Text to Communicate Correlational Information

Using text alongside or instead of graphs that represent correlational data visualisations can help users better understand the relationships present in their self-tracking data (Bentley et al. 2013). For example, Welltory represents correlational information by using text-based tags, where each tag can either fall within the negative or positive categories, representing the sign of the relationship between the tag and the outcome measure (see Figure 15). Alternatively, text-based interpretations of the correlations can be used to demonstrate the direction of the relationship between two variables (i.e., You track Stress more when your Step Count is lower) (see Figure 16). Both methods are faster to interpret than the traditional bar and line charts as they do not require prior knowledge on how to read graphs (Bentley et al. 2013; Jones and

Kelly 2018). It is important to note, however, that graphs are well suited for visualising trends or how a trend in one variable relates to a trend in the second variable. Combined, insights gained from exploring correlational and trend visualisations can help people uncover what triggers their stress and when.

Provide Guidance on how to Reflect

Before presenting users with data visualizations, it can be beneficial to provide guidance on what relationships or patterns to look for in such visualizations. This can be done by providing examples on how trends in mood can vary depending on sleep or diet, or how to spot correlations between several wellbeing measures (Fleck and Fitzpatrick 2010). For example, the app Welltory provides links to their website containing several examples of what wellbeing measures the users should track and how these measures might influence one another (see Figure 18). Users can also benefit from interacting with more varied types of visualizations as this broadens the types of questions they can ask when reflecting on their data (Li et al. 2011). For example, the Pacifica app (Pacifica, 2017) represents trends in mood by visualizing these on a line plot. This allows the users to ask questions such as “Does my mood go up over time?”. Additionally, calendar views, such as the one used by the Daylio app (Daylio, 2017), can indicate periodic patterns in peoples’ moods, allowing to identify days of the week when a person might be experiencing more or less stress and when action should be taken to prevent this from happening in the future (see Figure 19).

Productivity

For example, you can see here that energy levels are higher when you get 8+ hours of sleep. And productivity plummets when stress levels are high.



Figure 18. Welltory's website provides information on what variables could be measured by its users, sample visualizations and their interpretations. Similar information is given for nutrition, sleep, and exercise monitoring.



Figure 19. The Daylio app displays mood patterns on a calendar view, where the users can identify what days of the week they might be struggling and use this insight to make adjustments on those days. The colour coding of the emoji's and highlighting of the days makes it visually easy to interpret the data at a glance.

3.6.3 Supporting Action-Taking

There were several ways in which the apps included in this review supported action taking. Most did so by enabling their users to monitor the relationships between stress and other aspects of wellbeing. Some apps also allowed users to complete a pre-set plan or goal. That being said, the major issue with these approaches is that they lack flexibility in terms of what can be monitored via the app. For example, only two apps allowed for customizing the types of variables being monitored alongside stress and only six apps allowed the users to specify their own goals. This makes it challenging for users to discover which aspects of their lives may impact their stress and how this relates to their overall wellbeing goals.

Additionally, even if people were able to gather such insights, apps included in this review did not guide their users in creating strategies for responding to a potential stressor. The users were instead offered pre-specified plans, usually involving daily meditation or breathing exercises. Such emotion-focused coping techniques can help lower the sensation of stress, but they cannot guarantee to resolve the specific causes of stress, such as not taking regular breaks or spending too much time on social media. As we mentioned earlier in this thesis, a combination of emotion- and problem-focused coping techniques are needed to successfully manage stress (Aspinwall and Taylor 1997; Christmann et al. 2017). Without incorporating functions for monitoring context factors or helping users to develop appropriate coping strategies based on their insights, the users of these apps will find it challenging to come up with appropriate coping strategies. If the users receive support in forming stress management strategies, the impact of these apps would be expected to improve (Aspinwall and Taylor 1997; Carver et al. 1989; Lee and Hong 2018).

3.6.3.1 Design Guidelines for Action Taking

Much work is needed to improve on the ways in which existing stress management apps support action-taking. The main feature gap identified in the present review was that none of the apps adequately supported their users in transforming their insights into stress management strategies. Implementing app features that support strategies

such as goal setting and planning can help to address this gap (Lee and Hong 2018; Sniehotta, Schwarzer, et al. 2005).

Help users transform their insights into actions

The least incorporated features by apps that were reviewed in this study were self-regulatory BCTs, specifically, goal setting, planning, using reminders and prompts (Rhodes & de Bruijn, 2013). Nevertheless, there were several apps that implemented one or more of these functions well. For example, the app Remente instructs its users to first set a long-term goal and then to create an action plan consisting of multiple short-term goals that will contribute towards the longer-term goal. This is presented in a form of a visual roadmap comprising of daily achievable goals that can be conveniently monitored and ticked off when completed (see Figure 20, left). Afterwards, a history is displayed of how such micro practices contributed towards the long-term goals. This allows the user to compare their current state with their goal state, identify discrepancies, and decide whether any behaviour adjustments are needed. To ensure that people will follow through with their intended behaviour goals, the app Pacifica allows its users to set reminders for when they would like to be prompted to do stress management or recreational activities, as well as when they would like to be reminded to report on their levels of stress (Li et al. 2010a). Combined, the practices incorporated into the Remente and Pacifica apps can help people form goals and plans for engaging in stress management behaviours.

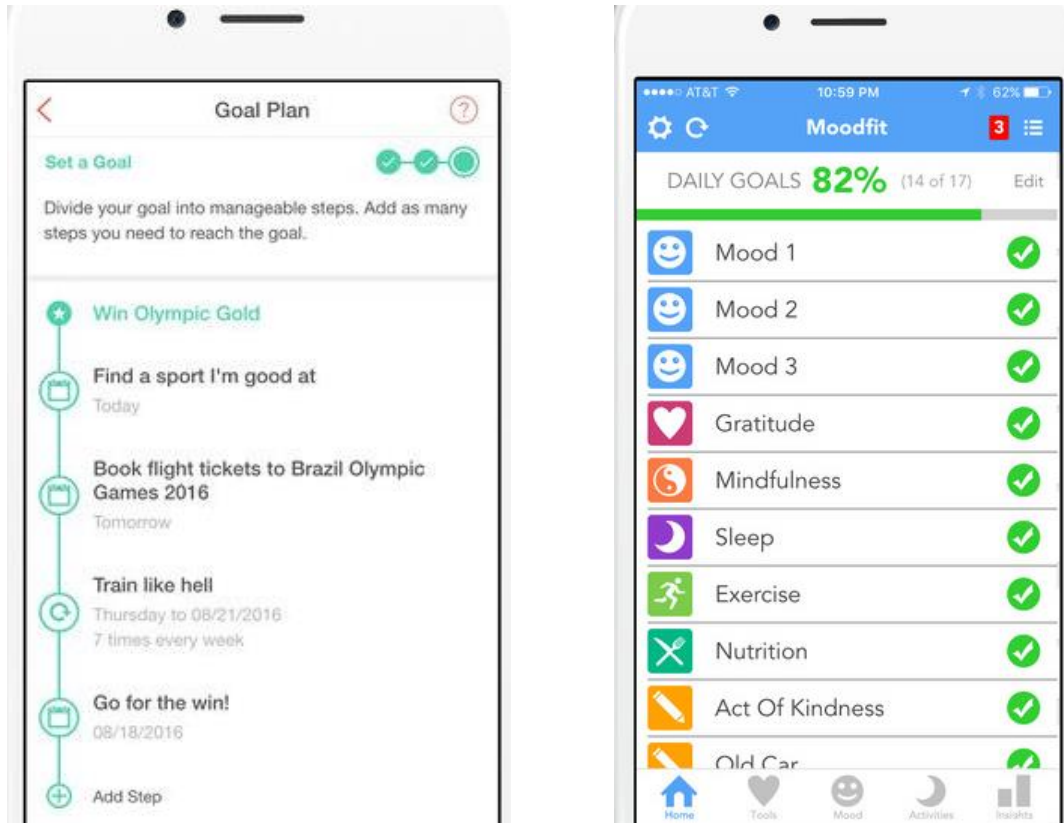


Figure 20. Remente and Moodfit goal displays. Remente (left) displays a roadmap where new short-term goals can be added at any time to achieve the long-term goal (indicated by a star at the very top). Moodfit (right) displays the percentage of how many of the daily goals were completed, along with a list of completed and uncompleted goals. Both apps allow the comparison of the goal state with the current state.

3.7 Limitations and Consideration for Future Research

There are several limitations to this study and the REACT method. Firstly, the study itself uses a small sample size. The number of actual stress management apps on the app store is relatively small and it is nearly impossible to estimate the exact number due to the limited search functions offered by the Google Play store. Every search has a 200 apps cut off, where most of the apps provided by the search results will not be stress management apps per se but will contain the keywords “stress” and “stress management” in the app description (e.g., a trivia minigame that promises stress reduction). Additionally, the apps and their position on the list are reshuffled the second time the same search term is used and there is no function to exclude the apps

that were already reviewed. This makes it challenging to identify all the available apps. Secondly, there is a possibility that there are more apps allowing the measurement or recording of occurrences of stress, however, the descriptions of these apps did not include keywords such as stress and were therefore overlooked as they were not displayed in the search results. Finally, because of the initial inclusion criteria, namely, for the apps to allow for self-monitoring and include ways of visually exploring stress related data, this study likely overlooked apps offering different types of reflection, specifically those that include similar guidance as Remente, where the users are prompted to reflect on their daily activities, experiences, stress management practices and how these impact them.

There are also several noteworthy limitations and future research considerations with regards to applying and refining the REACT method. Specifically, the REACT method has not been validated against other methods. Even though we were able to demonstrate REACT's ability to reveal more in-depth insights (e.g., identify the nuances of how apps implement features such as self-monitoring) than those offered through using a BCT taxonomy, it is unclear how our method would translate to evaluating apps other than those that met the inclusion criteria for this study. This is because we chose to develop the Likert scale item descriptions iteratively, based on the examples that we found incorporated into existing apps. On the one hand, this enabled us to develop concrete evaluation guidelines based on real-world examples observed in commercially available stress management apps. On the other hand, the REACT scale items may require updating when reviewing another subset of apps that incorporate techniques not included as part of our Likert scales. As such, the validity of the results would depend on how the Likert scale items were defined (i.e., what constitutes an app that supports self-monitoring or goal setting well). This is an important consideration to make given the fast-paced release, update, and innovation cycles associated with commercially available apps. Relatedly, research findings made by applying our method cannot be directly compared with app review studies using a complete behaviour change technique taxonomy. This is because the REACT method is not based on a complete behaviour change technique taxonomy (Michie, Ashford, et al. 2011). Future researchers may want to include a wider variety of coping-relevant behaviour change techniques than what is currently included in the REACT evaluation heuristics (e.g., time management or problem-solving).

3.8 Conclusion

This study systematically reviewed and evaluated how well stress management apps and visualizations generated by such apps support reflection (understanding) and action (managing). To achieve this, we have developed the REACT app evaluation method and applied it to investigate how stress management apps support reflection and action. Our method provided detailed insights into how the evaluated apps work to help their users better understand and manage their stress and how they could be additionally improved. Specifically, we find that even though most apps can adequately support reflection, they did not include functions to support action-taking. By applying the REACT evaluation method, we were able to additionally propose the following design guidelines for increasing the impact of stress management apps: by combining flexible data collection, visualisation, and exploration methods with features that support action taking, stress management apps can increase the likelihood that a behaviour will be initiated and maintained.

Apart from ensuring that existing stress management apps include relevant theory-informed features, it is also essential to understand how these features should be incorporated into apps to take full advantage of their benefits. While app functionality reviews can help highlight potential feature gaps and provide initial guidelines for improvements, field studies investigating how people use such apps in practice help to additionally reveal whether the theory-informed features meet peoples' stress self-management needs (Klasnja, Consolvo, and Pratt, 2011; van Turnhout et al., 2014). This will be explored by the two studies presented in Chapter 4.

4 Self-monitoring and Goals Setting to Help People Understand and Manage their Stress

4.1 Introduction

Our previous review of stress management apps (Chapter 3) indicated that most apps do not provide adequate support for problem-focused coping, as they lack in features that incorporate coping relevant BCTs. However, before we can start demonstrating how to appropriately integrate such features into apps, we still need to understand how people use, experience, and apply BCTs delivered via mobile apps and what their associated needs and barriers to use are. Having this understanding can help inform how to incorporate such techniques into mobile stress management apps in a way that enables users to leverage their full potential (Klasnja, Consolvo, and Pratt, 2011).

To gain an understanding of how existing apps support people with stress self-management using coping relevant BCTs, we ran a 3-week field study with follow-up focus groups that explored the following research question:

RQ1 Do existing apps support people with implementing coping-relevant behaviour change techniques in a way that helps them to understand and manage their stress?

Following the guidelines for HCI research aimed at investigating behaviour change interventions (Klasnja et al. 2011), our first task is to determine whether the intervention and its individual active components (BCTs) lead to significant short-term changes in stress. This is done to verify whether the intervention is acting as expected. We achieve this this by answering the following questions:

RQ 1.1: Does a digital intervention that supports reflection and action on self-management of stress correlate with stress reduction?

RQ 1.2: Which features of the intervention are correlated with stress reduction?

To adequately answer the above questions, we additionally investigate whether our participants experienced higher than usual stress levels and if so, whether this influenced the stress outcomes associated with using the apps and their features. As discussed in our background review (Chapter 2, section 2.3), there are different types of stress that people may experience (Aspinwall & Taylor, 1997; Skinner & Zimmer-Gembeck, 2016). We designed this study to primarily help inform how apps support their users with problem-focused coping. Consequently, people who experience higher than usual stress levels caused by point in time events outside of their control may benefit less from the present intervention. Therefore, to help disentangle whether our intervention was effective for the intended user group, we also account for whether our participants reported experiencing higher than usual stress levels during the study:

RQ 1.3: Does experiencing excess stress moderate how the apps and their features aimed at supporting problem-focused coping impact the change in perceived stress?

The apps selected for this study were Welltory (Welltory, 2018) and Coach.me (Coach.me, 2018) as they include complementary and non-overlapping features. Welltory was among the highest-ranking apps identified in our previous study presented in Chapter 3, specifically in the reflection category, containing rich materials to facilitate both short- and long-term reflection. Because Welltory does not include a broad range of features for supporting action, the Coach.me app was used for investigating how people use goal setting features.

Our initial analysis revealed that the intervention was effective in lowering stress. This was particularly evident in those individuals who did not report experiencing higher than usual levels of stress, despite both groups of participants showing similar engagement with the apps and their individual features. Specifically, our correlational analysis revealed that context monitoring and goal-setting correlated with a significant reductions in stress, but that this was only the case for those participants who did not report experiencing unusually high levels of stress.

Our follow-up focus group findings had additionally revealed that, for self-monitoring and goal-setting features to be maximally effective, they need to be better adapted to fit within a stress self-management context. Participants reported not yielding sufficient

data to gain insights into which factors affect their stress during 3-weeks of self-tracking. Relatedly, even though goal setting, monitoring, and reminders delivered via Coach.me encouraged people to engage in more frequent stress management behaviours, the lack of flexibility and guidance in their implementation had the adverse effect of inducing unnecessary stress. These findings highlight the need to support people with gaining insights into their stress during the early stages of self-tracking and to support them with flexible and guided strategies that promote engagement in stress management behaviours.

Drawing on our findings, the work presented in this chapter makes the following contributions:

- Demonstrating and explaining how context monitoring and goal-setting features incorporated into existing apps can support their users with better understanding and managing their stress;
- Using the insights gained from the focus groups, we highlight feature gaps relating to self-monitoring and goal-setting.

4.2 The Self-tracking Study

The following section describes the 3-week self-tracking study using the Welltory and Coach.me apps. We present the quantitative and qualitative findings stemming from our questionnaire responses and peoples' use of the apps, specifically focusing on how the participants' use of the apps affected their stress levels. We finish this section with a short discussion of our main findings and apply these to inform the questions for the follow-up focus groups.

4.2.1 Method

4.2.1.1 Participants

Thirty-eight healthy adults between the ages of 18 and 37 were recruited through an online recruitment system open to both students and professionals. The inclusion

criteria were to own a smartphone device and not be diagnosed with a clinical stress disorder as our study primarily focused on evaluating the value of mobile apps as an early intervention that could be targeted to people before they got to the point of a clinical diagnosis (see Appendix 1 for the associated consent form and participant information sheet). Eight of the participants had used self-tracking apps before, whereas 30 participants had never used a self-tracking app. The participants were rewarded for their time with a £20 voucher and a free one year's access to the Welltory app worth £60.

4.2.1.2 Design

The self-tracking study used a mixed methods research design, with the aim of identifying which app features/coping relevant BCTs (IVs) could be linked to change in stress levels (DV) between the beginning and the end of the study. This was achieved by measuring the frequencies associated with using individual app functions such as context monitoring by using tags, taking stress measurements, setting goals, and logging completed activities. Qualitative analysis was used to investigate qualitative questionnaire responses on how participants reflected on the data presented via the Welltory app and the insights that they gained.

4.2.1.3 Measures

Table 2 summarises the types of data that were collected during the self-tracking study and their measurement frequency. Each measure type will be explained in more detail when describing the Welltory and Coach.me apps. The participants were instructed to measure their stress via the Welltory app twice a day, once in the morning and once in the afternoon or evening and received reminders to do so. This was done because the Welltory app uses the morning measurement to set a baseline. Any subsequent measurements taken after 12 noon on the same day are then compared to the morning baseline to help the users gauge how the activities they have performed throughout the day affected their stress levels.

Measure Type	How the Measure Was Taken	Frequency
<i>Stress (Q)</i>	People's subjective stress based on the perceived stress scale.	Days 1, 14 & 21
<i>Number of Welltory stress measurements (W)</i>	W: Number of stress measurements taken.	At least one measurement in the morning and one in the afternoon.
<i>Tags/labels (W)</i>	Number of tags (e.g., work, exercise, meditate) used in Welltory.	After each stress measurement.
<i>Goal type and completion (C)</i>	Number and types of goals set, activity completion rate.	As many as the participants wanted.
<i>Excess stress (Q)</i>	Question on whether the participants experienced higher than usual levels of stress and why.	Day 21

Table 3. Names of the variables collected during the study, how and how frequently it was collected. The letter W next to each data type indicates that the data was collected by the Welltory app, C - Coach.me app, Q – Questionnaire (see section 4.2.1.5 for a description of each questionnaire).

4.2.1.4 Materials and the Intervention

Welltory – Stress monitoring and reflection

The self-monitoring aspect of this study was investigated by using the Welltory stress monitoring app. Welltory was selected as our previous stress management app review (Chapter 3) indicated that it includes rich data collection and exploration features (see Figure 21). Among these features are context monitoring and correlational visualisations. Welltory enables context monitoring by using fully customisable text-based tags. The stress measurement itself is inferred from a smartphone measured

PPG signal. Using PPG to measure stress helps ensure that reflection will be triggered during the 3-week intervention period. This is primarily because, unlike completing subjective stress reports, the PPG measurement reveals additional information that is not immediately obvious to the users, e.g., HR, HRV, inferred stress and energy levels. As this provides people with access to different types of data, such as context tags representing stress triggers and physiological data representing the body's response to stress, people should have more opportunities to reflect and reach deeper levels of reflective thinking. Finally, the combined use of PPG and context tags enabled us to observe and study how people use self-monitoring to better understand their stress.

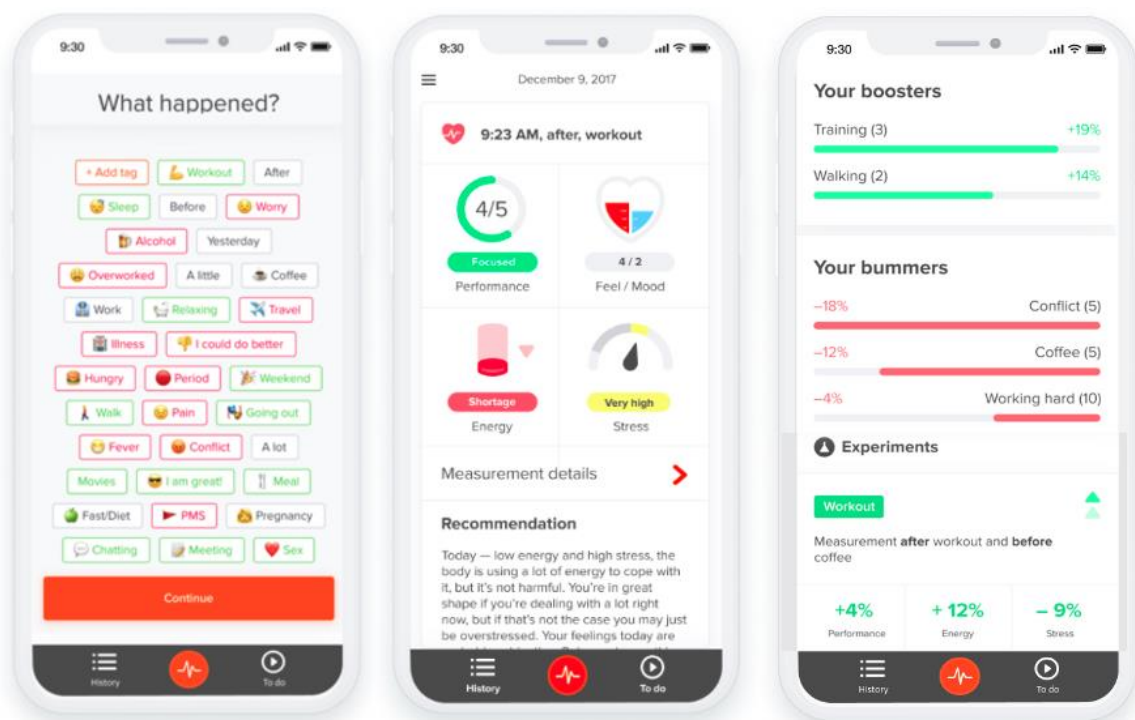


Figure 21. Welltory context monitoring and data visualisation features. The users can label each stress measurement with tags (left screenshot). After the measurement is taken, the users are presented with a summary of their results in the form of score and icon-based visualisations (middle). If the users selected tags after taking their measurement, these will come up as either Booster or Bummers in a dedicated app section (right). This represents correlations between stress and the context factors monitored by using tags.

Even though Welltory uses self-monitoring and data visualisation to help users better understand their stress, the app is limited in features designed to facilitate stress self-management. Notably, as we found in the research presented in Chapter 2, existing

stress management apps in general do not incorporate features that can adequately support their users with both reflection and action taking. Considering that research on behaviour change highlights the importance of including features that directly support action taking (Munson & Consolvo, 2012; Sniehotta et al., 2005; Sniehotta, 2009), we asked our participants to additionally use the Coach.me app. This allowed us to investigate how features such as goal-setting and reminders to engage in goal-related behaviours can help people manage their stress. Importantly, the Coach.me app was selected because it included complementary and non-overlapping features to Welltory. It is expected that the features incorporated across both apps should support people with understanding (Welltory) and managing (Coach.me) their stress.

Coach.me – Goal-setting, monitoring, and reminders

The goal-setting, monitoring, and reminders aspect of this study was investigated by using the Coach.me app (see Table 3 for parameters measured). For the present study, we define goal-setting as the process of identifying the desired outcome and establishing a timeframe and the necessary steps to achieve it (Austin and Vancouver 1996). The goal-setting features implemented in the Coach.me app aligned with both of these definitions. Notably, the Coach.me app's goal setting feature is similar to the features implemented in stress management apps that were reviewed and evaluated in Chapter 3.

The Coach.me app also acted as a catalogue of emotion-focused stress management activities. This feature helped us research whether goal-setting can add value in terms of directing people to activities that they can do to relax, and whether goal monitoring encourages action taking. The participants could set as many goals as they liked. A goal may be to exercise 5 days a week. If the user exercises on any given day, they can tick that goal as completed for that day. Each individual tick can be used as a measure of activity completion. The app allows to set reminders for participants to manually input whether they completed their selected activity on a given day.

4.2.1.5 Study Questionnaires

The participants were instructed to complete 3 questionnaires in total during weeks 0 (day 1), 2 (day 14) and 3 (day 21) (see Figure 22 and Table 4). The questionnaire given right before beginning the study contained items on general demographics and

the Perceived Stress Scale (PSS) (Cohen, Kamarck, and Mermelstein 2014) to measure baseline levels of stress (see Table 5). PSS is a widely used 10-item scale that measures peoples’ perceived ability to cope with stress. Its scores range between 0-40, with a lower score representing lower levels of stress. The first week was skipped so that the users could collect enough data about themselves and gain insights from their data before reporting on their stress and the insights gained.

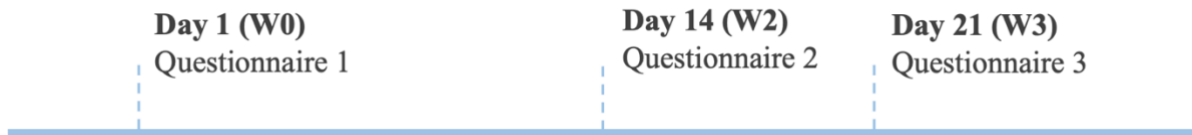


Figure 22. Study timeline indicating when each questionnaire was sent.

Name	Items measured	When
Questionnaire 1	Demographics, PSS	Day 1, Week 0
Questionnaire 2	PSS, report on insights gained, share data from Welltory and Coach.me	Day 14, Week 2
Questionnaire 3	PSS, report on insights gained, excess stress, share data from Welltory and Coach.me	Day 21, Week 3

Table 4. List of questionnaires, their aims and when they were administered during the study.

For each question choose from the following alternatives:
0 - never 1 - almost never 2 - sometimes 3 - fairly often 4 - very often

1. In the last month how often have you been upset because of something that happened unexpectedly?

2. In the last month how often have you felt that you were unable to control the important things in your life?

3. In the last month how often have you felt nervous and stressed?

4. In the last month how often have you felt confident about your ability to handle your personal problems?

5. In the last month how often have you felt that things were going your way?

6. In the last month how often have you found that you could not cope with all the things that you had to do?

7. In the last month how often have you been able to control irritations in your life?

8. In the last month how often have you felt that you were on top of things?

9. In the last month how often have you been angered because of things that happened that were outside of your control?

10. In the last month how often have you felt difficulties were piling up so high that you could not overcome them?

Table 5. The perceives stress scale (Cohen et al. 2014).

The questionnaires that were sent after 2 (day 14) and 3 (day 21) weeks of self-tracking included the PSS scale to measure perceived levels of stress at the end of each week and a field for sharing the data from Welltory and Coach.me apps. These questionnaires additionally included an open-ended question asking the participants to reflect on the insights that they had gained whilst using the apps. The question was worded as follows:

Write a summary about what you discovered from your self-tracking data and what you did about it.

The third and final questionnaire was also used to account for whether people experienced excess stress. This was done by using a binary questionnaire item which measured whether the participants experienced any unusual point-in-time events that caused higher than normal levels of stress, including specifying what those events were. The question was worded as follows:

Where there other external factors that might have affected your stress that were outside of your 'normal' daily activities (e.g., a holiday) and/or were outside of your immediate control (e.g., new job, moving homes)? If yes, what were these?

4.2.1.6 Procedure

This study was conducted during the summer of 2018. The participants were first sent a file containing information on how to participate in this study, including how to use each app (see Appendix 1). They were then instructed to complete the baseline questionnaire. Upon completing the questionnaire, each participant was given access to Welltory PRO (free subscription for 1 year) and Coach.me (free) apps and were instructed to use them as often as possible within a 3-week period. During the second and final weeks of the study the participants received an email asking them to fill out a questionnaire on their levels of stress (PSS), share their self-tracking data and their insights about stress as well as describe their experiences of using the apps.

4.2.2 Results

We begin this section by providing an overview of peoples' use of the apps and their respective features. We then split our Results section based on our qualitative and quantitative analysis performed on the questionnaire responses and the quantitative data representing the frequencies at which people used specific app features that incorporated coping-relevant BCTs.

4.2.2.1 Engagement with App Functions that Support Problem-focused Coping

As seen in Table 6, the participants reported being engaged with the Welltory app more than they were with the Coach.me app during the 3-week period. Most people adhered to taking one or even several Welltory stress measurements a day and used tags alongside their measurements. Upon closer investigation of the data, we found that most users set several types of goals on the Coach.me app, which were not necessarily related to the study. We therefore categorise the goals set into exercise,

relaxation, and self-improvement goals (e.g., learning a new language/skill, diet, writing/journaling) as these were the major categories of activities offered via the Coach.me app. Categorising goals enabled us to gain a better understanding of how each type of goal contributed towards stress outcomes. Finally, the activity completion measure (Coach.me check-ins) was unreliable as participants indicated frequently forgetting to report their completed activities on the Coach.me app. It was therefore excluded from further analysis.

<i>Welltory</i>	
<i>Welltory measurements taken</i>	Mean = 48, SD = 23.7, Min = 3, Max = 118, Median = 44
<i>Tags used (overall)</i>	Mean = 143, SD = 115, Min = 8, Max = 534, Median = 100.5
<i>Distinct tags used</i>	Mean = 20, SD = 9.65, Min = 5, Max = 45, Median = 18.5
<i>Coach.me</i>	
<i>Coach.me check-ins</i>	Mean = 42, SD = 35.8, Min = 1, Max = 153, Median = 34.5
<i>Goals set on Coach.me</i>	Mean = 4.8, SD = 3.46, Min = 1, Max = 15, Median = 4
<i>Self-improvement goals</i>	Mean = 2.8, SD = 2.8, Min = 0, Max = 11, Median = 2
<i>Exercise goals</i>	Mean = 1.7, SD = 0.98, Min = 0, Max = 5, Median = 2
<i>Relaxation goals</i>	Mean = 0.4, SD = 0.67, Min = 0, Max = 3, Median = 0

Table 6. An overview of how frequently our participants used a given app function during the study (average per 3-weeks across all participants).

4.2.2.2 Approach to Qualitative Analysis

The questionnaire responses were qualitatively analysed using thematic analysis (Braun and Clarke 2006). The interview recordings were transcribed and iteratively coded using Nvivo. We took a top-down (deductive) approach to code our data and organised our codes into themes that were more specifically aligned to our research question. Like Choe et al. (2017), we also drew on Baumer's (2015) and Fleck and Fitzpatrick's (2010) reflection frameworks (describe in details in Chapter 2, section 2.5) as a way of capturing the types of reflection people engaged in to gain insights from their personal data. However, our own investigation focused explicitly on capturing how people reflected on data relating to their stress and how people took action in self-managing their stress.

More specifically, if a participant reported that:

“Sleeping less seems to cause me more stress the next day”,

this would be considered R1 level of reflection. Here, the individual is simply restating what happened, without any alternative interpretations or more detailed reasoning as to why sleep is associated with them feeling stressed. In contrast, a statement such as:

“Sleeping less seems to cause me more stress the next day. Or I might be struggling to fall asleep when I’m feeling stressed”

would evidence R2 level of reflection. Finally, the following statement would be considered as R4/transformational reflection:

“Sleeping less seems to cause me more stress the next day. Or I might be struggling to fall asleep when I’m feeling stressed. I now see how on the weeks where I take more time for active rest I also sleep better. This really reinforces the importance of taking time off on a regular basis. I should schedule in more relaxing activities into my day if I want to get more sleep and feel less stressed”.

This statement evidences that the participant discovered a relationship in their data, considered an alternative interpretation, which led to a fundamental change in their stress management approach.

4.2.2.3 Do Welltory's and Coach.me Features Aimed at Self-monitoring, Reflection and Goal-setting Support People with Understanding and Managing their Stress?

Our qualitative analysis led to identifying two over-arching themes and three sub-themes (see Figure 23) that captured the types of reflection people engaged in, what their insights were and how they responded to those insights. We present our findings below.

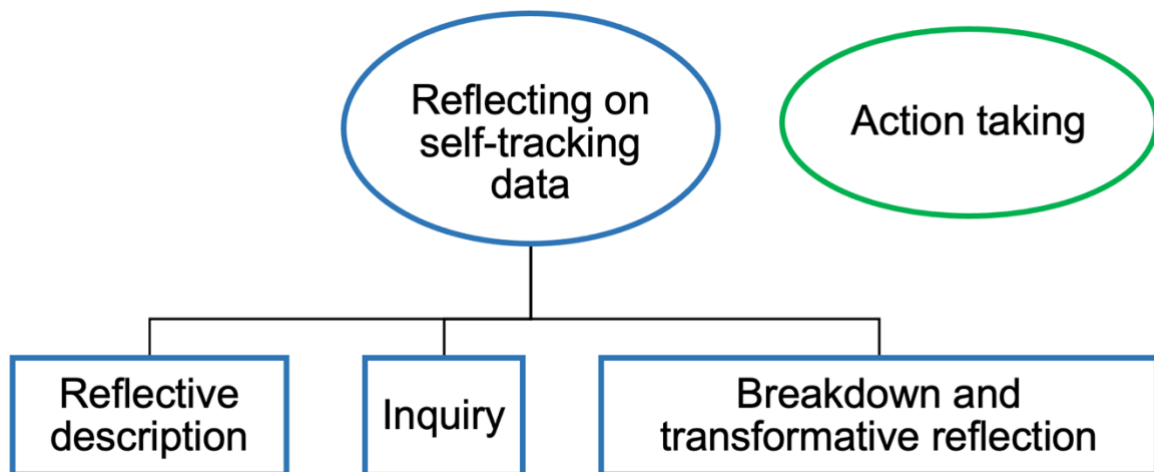


Figure 23. Themes derived from the thematic analysis performed on the questionnaire responses. The circles represent the two over-arching themes and the squares represent the three sub-themes. Themes with a blue border represent reflection/understanding concepts and the theme with a green border represents action taking/management.

4.2.2.4 Reflecting on Self-tracking data and its Visualisations

The first overarching theme encompasses the different levels of reflection that were captured in our participant's questionnaire answers. Most participants reported engaging in descriptive reflection, primarily focusing on how different factors affected

their levels of stress. Far fewer of our participants' responses evidenced engagement in transformative reflection.

Reflective Description

Most participants reported engaging in descriptive reflection (R1). Their reports were primarily focused on how different factors related to their stress levels. However, most responses did not evidence deeper level of analysis, interpretation, or change of perspective. For example, the reports primarily stated the following reflections:

P(7): *"Less than 6 hours sleep causes my stress levels to increase"*.

P(21): *"My stress goes down after allowing myself short breaks during the day and taking time out to reflect on my day"*.

Inquiry

Six of the survey responses evidenced Inquiry, whereby the participants engaged in active self-experimentation and hypothesis testing. For example, P(4) reported using Welltory to check how coffee was affecting her stress levels:

"I then take different readings throughout the days. Sometimes to check how I'm doing, other times for experiments. I've done a few for 'coffee' [experiments] as I'm starting to think it makes me feel way worse than better. I normally don't drink caffeine at all, but started a few weeks ago. I think this app is helping me remember why I stopped in the first place."

For P(22), self-experimentation led to challenging her existing practices and reasoning over alternative ways of exercising:

"Overall I found out that physical activity influences my life, my stress levels go down after it, the energy sometimes is the same sometimes goes down depending on the exercise (with Zumba tends to decline, with gym floor tends to remain stable/increase). Overall workout declines my performance of 0.50%,

increase my energy of 0.25% and maintain the same stress level. This makes me wonder whether I should change the workout routine and make it more difficult or, on the contrary, decrease my exercise level.”.

Breakdown and Transformative Reflection

There were instances (6 participants) where our participants reported being surprised by receiving unexpected measurement result from Welltory, which encouraged deeper levels of reflective thinking (R2-3). In other words, receiving an unexpected result prompted a “Breakdown” of the participant’s existing knowledge, which, in some cases, lead to a change in one’s thinking and acting. For example, P(6)’s account evidences that she is now considering whether she is exercising at the right intensity level:

“I am surprised about the somewhat contradictory information about how exercise affects my body. I do have quite intense workouts so I can understand that it may increase my stress in the short-term, but I think it has such a good impact on my physical and mental health and like I mentioned earlier I'm just trying to reconcile the bumper and experiment section. I've not tried doing lower impact exercises like yoga (I either go boxing or lift weights), so I'm not able to comment on whether doing a less intense activity influences my stress levels differently.”.

For P(35), receiving an unexpected result prompted him to re-evaluate how work affected his stress levels:

*“I was also surprised to see that work lowers my stress levels. Thinking about it, I guess this is because it's the *thought* of work (and how much work I have to do) that makes me stressed, whereas when I work productively, I feel more on top of things.”.*

Difficulty Interpreting Graphs

Our participants reported experiencing difficulties when trying to interpret their data using graph-based visualisations. For P(30), this was due to a lack of clear labelling of the graphs:

“The graphs on the analytics page were difficult. There was no key to show you what each part of the graph was showing so it was sometimes hard to work out what was what.”

There was also evidence to suggest that the difficulty arose from not having collected sufficient self-tracking data, primarily because the data visualised by the graphs lacked variability:

P(16): “It [The Graphs] was quite difficult to understand and it all seemed non variable.”

Six of our participants commented that they felt that they could have gained more from the apps after longer use:

P(2): “I tended to look more at individual measurements and advice than at the trends/charts - but again, maybe this would change if the charts became more useful with more data over time.”

In fact, this was not exclusive to the “My Graphs” section of the Welltory app, but also the text-based data visualisations that displayed which tags were associated with lower or higher stress and energy levels. The lack of variability in the data made it challenging to detect any meaningful trends and patterns in peoples’ stress levels:

P(8): “There are no events on my booster/bummer section even though I have put on tags every time I measured. I guess the reason is that I have a lot of unexpected measurement results. Say I did yoga and I felt relaxed, but the app says I was in high mental stress. It seems that an activity trend has yet to be found.”

4.2.2.5 Action-taking

The second over-arching theme – action taking – captures our participants' attempts to self-manage their stress as a result of using the apps. Unsurprisingly, their accounts evidence that self-monitoring acted as a motivating factor in encouraging self-care. For some participants, this was stimulated by their curiosity to discover how their behaviours affected their levels of stress:

P(33) *"I do feel more inclined to do more physical activity because I am interested to see the effect on my body and according to the data it seems to improve my stress levels."*

For others, the measurement results directly influenced their subsequent actions:

P(18) *"I'd usually work out after getting a low score and straight after the score would rise up so much higher, so it seems that exercise (yoga) has a positive impact on me. Doing the measurements and getting a low score was often a motivator."*

There were also reports indicating that our participants used the complementary features of both the Welltory and Coach.me apps to help them achieve their desired behavioural outcomes. For instance, P(11) reported that she used Welltory's self-monitoring and self-experimentation features to help her achieve goals that she had set via the Coach.me app:

P(11) *"It is very pleasing to inspect the data and to conduct the experiments on myself. It has specifically helped me to achieve my goal of completing the Couch to 5K programme in which I need to run at least three times per week."*

Other participants commented on how setting goals via Coach.me helped motivated them to change and adjust their health behaviours in a way that would help them regulate stress. Notably, people considered even small changes in their behaviours as an achievement:

P(5) *"I bunked all my PE lessons in school and have been to the gym only once in my life. So I decided to set a goal of walking. I think I would usually get the bus everywhere or I wouldn't leave the house much. Having this app reminded*

me to walk vs taking the bus, and one of my goals was to take more walks outside. While that's not the biggest exercise goal to most people, it was a big step up for me. And I think by walking so much more my stress really had gone down a lot! (And by walking I mean walking at a fast pace so actually get my heart racing)."

Besides motivating behaviour change, achieving goals generally made people feel better about themselves. It imparted them with a sense of competence:

P(20) "I found that when I achieved my goals such as walking 10,000 steps or drinking my minimum amount of water that I generally feel better about myself. I feel like I've done well which gives me a positive outlook."

However, there were also participants who commented on barriers to engaging in self-care activities for stress self-management. For instance, P(34) reported being reluctant to take time out for self-care before finishing work:

"When I am experiencing lots of mental stress, even if the app tells me to get rest, I am still reluctant to do it due to work not being finished."

Similarly, P(12) attributed her lack of action to a busy schedule:

"It seems that my stress levels might be slightly higher as my goals are less achieved due to increasingly busy schedule. I have been unable to do much stress reducing activity, so there doesn't seem to be much change in my data."

As P(28) explained, she did not feel that she had enough control over her daily schedule to be able to follow Welltory's measurement results:

"In general though, I tended to just carry on doing what I would have done before I had the app. One of the limitations of the app is that it assumes you have complete control over what you do that day - but you can't always avoid physical exertion (e.g. if you need to walk to the shops or to work) or intellectually-challenging tasks (e.g. if you have a deadline to hit!)."

Finally, P(2) did not find the apps helpful as they did not provide her with support during times when she was finding it challenging to be productive or engage in self-care:

“I can see from the data that I often have a run of 2 or 3 'bad' days (i.e. when I don't get much done, don't exercise etc) but I knew that already and I don't think the apps really help me to address that.”.

4.2.2.6 Approach to Quantitative Analysis

IBM SPSS Statistics version 23 was used for quantitative analysis. We measure the changes in perceived stress by calculating the difference between Perceived Stress Scale (PSS) scores taken at the beginning and the end of the study. Lower (negative) values represent a greater decrease in stress levels. We refer to this change as the *change in the PSS score* throughout the rest of the chapter.

Changes in Perceived Stress

The mean baseline levels of perceived stress for this sample was 18.63 (SD=5.97). The scores ranged between 9-28 (PSS scores can range between 0-40). By the end of the 3-week period, people who participated in this study experienced a reduction in their levels of perceived stress (PSS score) by an average of 3.13 points (16.8%). A Wilcoxon signed-rank test was used to assess whether there was a difference between the PSS scores measured at the beginning and the end of the study. There was a significant difference between the PSS scores taken at the beginning (M=18.63, SD=5.89) and end (M=15.50, SD=5.84) of the 3-week self-tracking period for the overall sample ($Z = -3.4, p = .001$); (see Figure 24). The effect size was $d = 0.53, r = .26$; $CI = [0.64 \text{ to } 0.9]$.

Effects of Experiencing Excess Stress on Change in the PSS Score

We next investigate whether the change in perceived stress was moderated by whether the participants experienced excess stress. To achieve this, we split our sample into two stress groups: the regular stress and the excess stress groups. The groupings were based on a Questionnaire 4 item asking whether the participants experienced any events that resulted in them experiencing higher than usual levels of stress during the study. The most common reasons for experiencing such stress were attributed to moving homes, changing jobs, visiting relatives, and exams. This type of

stress can be considered similar to acute stress as it was caused by a point-in-time event (McGonagle and Kessler 1990). The regular stress group included 17 participants, whereas the excess stress group included 21.

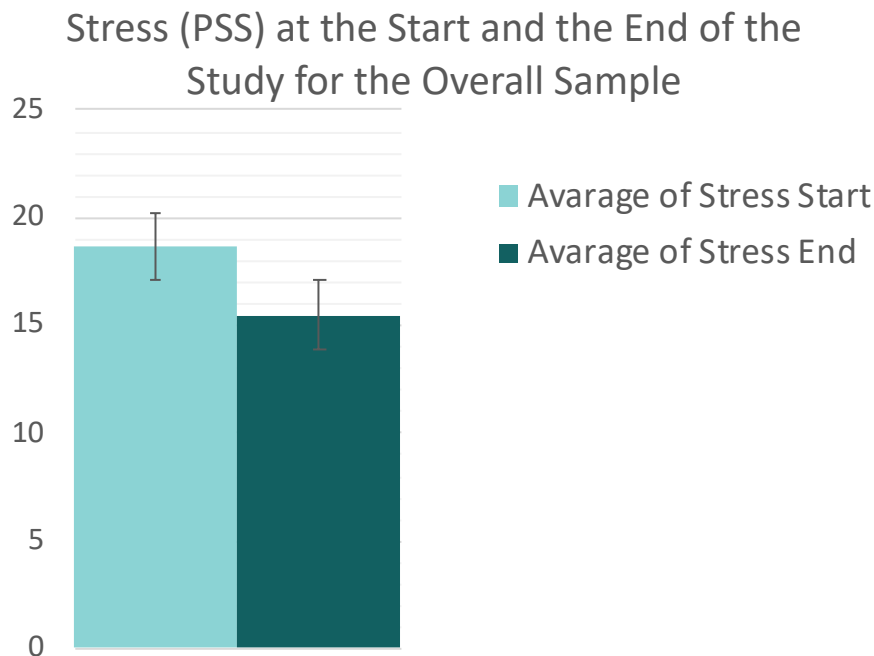


Figure 24. PSS scores taken at the beginning and end of the study and the difference between the two measures (bars represent standard error).

A one-way MANOVA was performed to investigate whether the starting levels of stress and the change in the PSS score (DVs) were depended on whether the participants experienced excess stress (IV, two levels). This was done to check whether 1) both groups for stress included participants with similar baseline levels of stress and 2) to investigate whether the efficacy of the intervention was associated with whether people experienced excess stress (RQ 1.3).

The multivariate results indicate that there was a significant difference between the two stress groups, $F(2, 35) = 4.586, p = .017; Wilk's \Lambda = 0.79, partial \eta^2 = .208$. The univariate ANOVAs indicated that both stress groups included participants with similar baseline levels of stress, $F(1, 36) = .031; p = .861; partial \eta^2 = .001$. However, we found that there was a statistically significant interaction between stress group and change in the PSS score (i.e., the outcome of using the apps), $F(1, 36) = 8.03; p = .007; partial \eta^2 = .182$. This indicates that the apps were shown to be more effective

for those individuals who did not experience excess stress over the course of this study, lowering their stress by an average of 5.35 points (28.43%) (N = 17, SD=3.46), effect size $d=1.05$, $r = .46$; $CI = [0.65 \text{ to } 0.95]$. This is higher than the changes observed for the individuals who experienced acute stress, lowering their stress by an average of only 1.33 points (7.25%) (N = 21, SD = 4.76), effect size $d=.22$, $r = .11$; $CI = [0.56 \text{ to } 0.93]$ (see Figure 25).

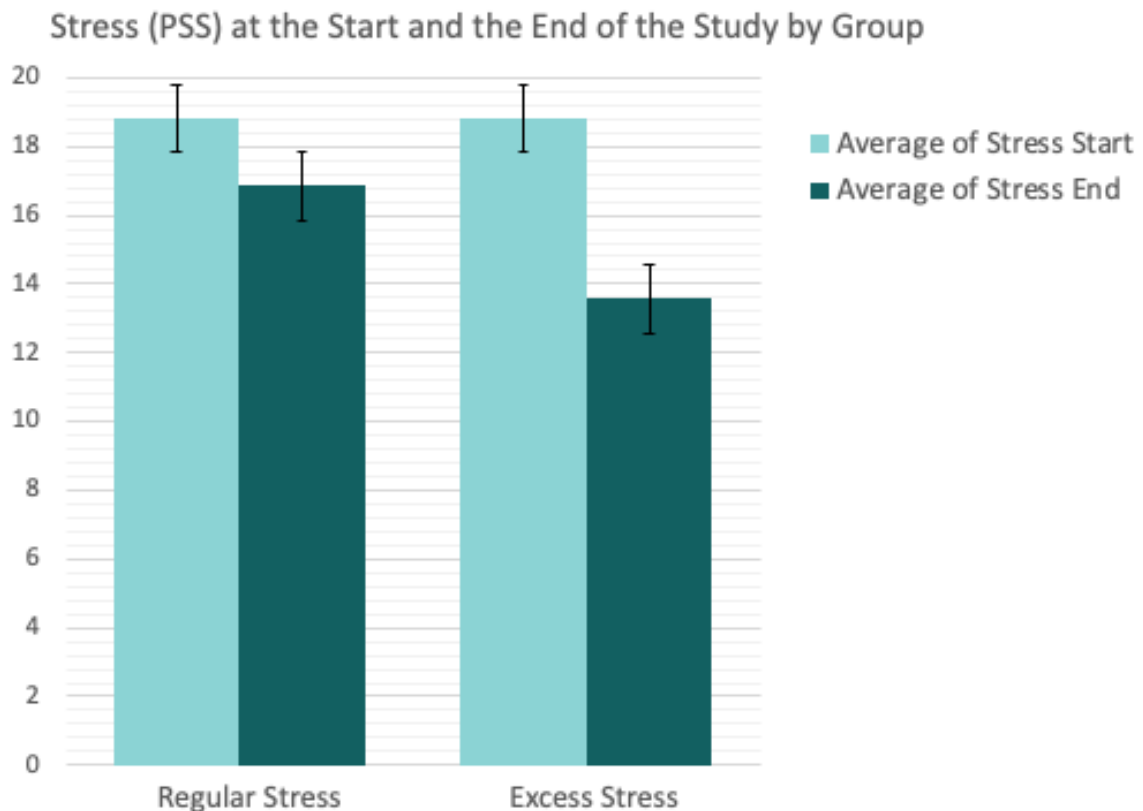


Figure 25. Difference in PSS scores between the start and end of the study by group (bars represent standard error).

Correlations Between the Change in PSS Score and App Features Supporting Problem-focused Coping

A correlation analysis was performed to help understand whether and which app features that incorporated coping-relevant BCTs were linked to changes in stress (see Table 7). The app features that were investigated included the number of Welltory measurements taken, the number of distinct tags used (i.e., distinct context variables monitored) in the Welltory app, and the number of goals set on the Coach.me app by their type (i.e., exercise, relaxation, self-improvement). There were no significant

correlations between change in the PSS score and the use of any of the functions of the apps.

	1	2	3	4	5	6	7
1. Change in the PSS Score	-						
2. Welltory Measurements	-.07	-					
3. Distinct Tags Used	-.073	.26	-				
4. Total Goals Set	-.13	.21	.62**	-			
5. Exercise Goals	-.22	.23	.42**	.64**	-		
6. Relaxation Goals	-.59	.41*	.24	.18	.02	-	
7. Self-improvement Goals	-.06	.09	.53**	.95**	.41**	.02	-

Table 7. Correlates of PSS scores. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Split Sample Analysis by Stress Group for Correlations Between the Change in PSS Score and Problem-focused Coping App Features

Our earlier analysis indicated that people who reported experiencing excess stress caused by point-in-time events were less likely to lower their stress than those who did not, despite exhibiting similar engagement with the apps (see Figure 26). This finding aligns with stress coping theory, namely that people experiencing acute stress will benefit less from strategies supporting problem-focused coping (Aspinwall and Taylor 1997; Taylor and Stanton 2007). We therefore performed additional analysis on both stress groups separately to have a more complete understanding of whether and for whom the selected problem-focused coping app features worked.

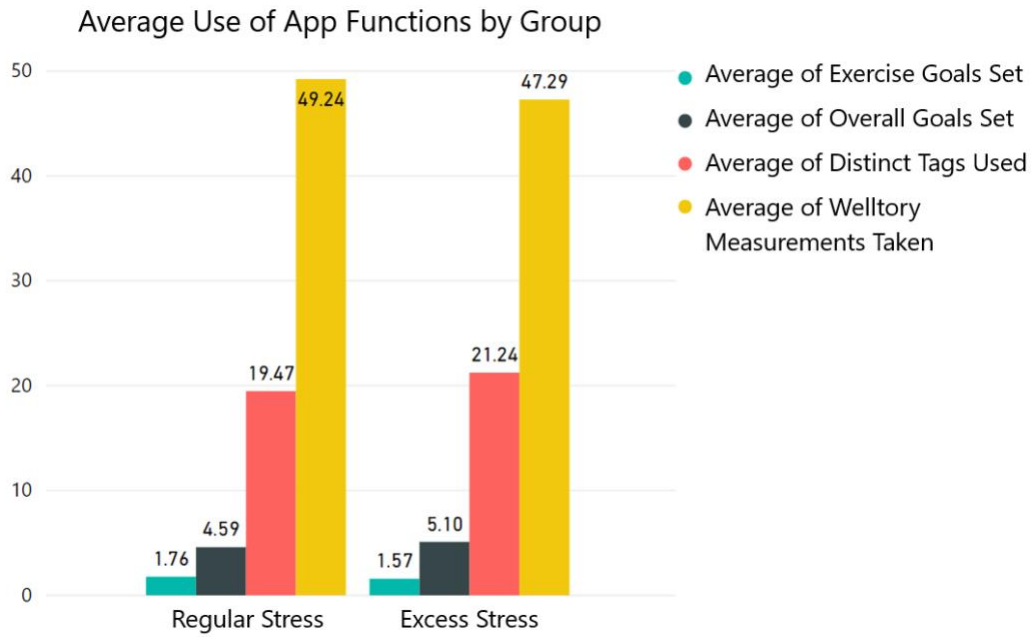


Figure 26. Use of different app functions for regular and excess levels of stress.

The correlational analysis for those individuals who did not experience excess stress revealed moderate negative correlations with the number of distinct tags used in the Welltory app, $r(15) = -.6$, $p=.023$ and the number of exercise related goals set in the Coach.me app, $r(15) = -.52$, $p=.034$ (see Table 8). There were no significant correlations observed for those participants who experienced excess stress (see Table 9).

	1	2	3	4	5	6	7
1. Change in the PSS Score	-						
2. Number of Welltory Measurements	-.370	-					
3. Number of Distinct Tags	-.546*	.296	-				
4. Total Goals Set	-.43	-.08	.41	-			
5. Exercise Goals	-.516*	.193	.25	.81**	-		
6. Relaxation Goals	.15	.39	.31	.14	-.05	-	

7. Self-improvement Goals	-.38	-.07	.28	.97**	.73	-.08	-
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Table 8. Correlates of PSS scores for participants who did not report experiencing excess stress (negative values indicating a larger reduction in stress). *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

	1	2	3	4	5	6	7
1. Change in PSS Score	-						
2. Number of Welltory Measurements	.066	-					
3. Number of Distinct Tags	.106	.251	-				
4. Total Goals Set	-.05	.28	.75**	-			
5. Exercise Goals	-.01	.26	.58**	.54*	-		
6. Relaxation Goals	-.07	.54*	.25	.33	.06	-	
7. Self-improvement Goals	-.05	.17	.68**	.96*	.32	.22	-

Table 9. Correlates of PSS scores for the excess stress group. *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

4.2.3 Discussion

Our participants reported engaging in R1-3 levels of reflection. Similar to Choe et al. (2017), we also find that most of our participants' responses were limited to R1 level of reflection, demonstrating recall and description of past events, behaviours, as well as psychological and physiological states. Some participants' answers evidenced deeper levels of reflective thought. For instance, it was evident that they reached R2 level of reflection as they explored alternative explanations of their data and engaged in self-experimentation. Similarly, some participants' answers demonstrated R4 level of reflection as they described a fundamental shift in their ways of thinking and/or behaving.

Albeit engaging in various levels of reflection, this did not necessarily stem from interacting with graph-based visualisations. In fact, it was evident that our participants found it challenging to interpret their data when it was displayed on a graph. This was primarily attributed to unclear labelling, lack of time required to familiarize with the graphs, and not having enough data for any obvious trends and patterns to emerge. In contrast, our participants' reports allude to them primarily gaining insights through relying on the measurement summary page displayed by Welltory after taking each stress measurement (see Figure 21, middle). Another interpretation of our findings is that the data captured via smartphone-based PPG could not be used to accurately infer peoples' stress levels. In fact, there is existing research discussing and addressing the limitation of PPG-based stress measurements (Cho, Julier, and Bianchi-Berthouze 2019). It is therefore possible that smartphone-based PPG could not fully capture variations in peoples' stress levels, which is why the Welltory app did not display correlations between PPG-based stress measurement results and the self-reported factors affecting stress (tags).

Our participants also commented on their stress self-management efforts. For some, seeing their data was enough to motivate behaviour change. For others, it was goal setting via the Coach.me app that encouraged them to take action. Nevertheless, our participants also reported facing barriers to engaging in stress self-management. These were primarily attributed to a lack of control over one's schedule and low perceived ability to cope with stress. The overall findings suggest that people were successful in their stress self-management efforts when they felt motivated and capable of coping with their stress. In these instances, even reflecting on the data alone could motivate action. In fact, other research has also found that people with higher perceived competence benefit more from engaging in self-tracking than individuals with lower motivational resources (Dijk et al. 2017b; Rapp and Cena 2014). However, when people are experiencing challenges, such as higher than usual levels of stress, they require additional support to stay on track with their stress self-management goals (Ellen A. Skinner and Zimmer-Gembeck 2016). Our findings suggest that existing apps do not cater for this user group.

4.2.3.1 Efficacy of the intervention

Our participants reported significantly lower levels of stress levels at the end of the 3-week self-tracking period (by 16.8%). This effect was particularly pronounced in those individuals who did not experience excess stress during the study caused by point-in-time events such as moving homes or changing jobs. Participants who experienced excess stress did not significantly benefit from using the apps. When comparing our finding to other research, the medium effect size of $d=.53$ (for the overall sample) is similar to that reported in other studies evaluating the effects of mental wellbeing apps on stress outcomes (see Table 10).

Authors	Description of the app evaluated	Effect size	Sample size
Flett et al. (2019)	Headspace Mindfulness meditation.	$d=.3$	N=67
Ly et al. (2014)	Viary ACT based audio and text psychoeducation, diary, ACT exercises, mindfulness, motivational messages.	$d=.62$	N=36
Ahtinen et al. (2013)	Oiva ACT based video and text psychoeducation, ACT exercises, mindfulness, diary.	$d=3.8$	N=15
Harrer et al. (2018)	StudiCare Stress CBT, psychoeducation, journaling.	$d=.69$	N=75
Moberg et al. (2019)	Pacifica CBT, journaling, mindfulness meditation, relaxation, self-tracking, goal-setting.	$d=.46$	N=253
Our results	Welltory + Coach.me	$d=.54$	N=38

Table 10. Effect sizes (Cohen's d) reported in other research evaluating the effects of mental wellbeing apps on stress. Cohen's d is interpreted as follows: $d=.2$ small effect; $d=.5$ medium effect; $d=.8$ large effect.

4.2.3.2 Experiencing Excess Stress on the Efficacy of the Intervention

As mentioned previously, we find that the apps were less effective for those individuals who experienced excess stress caused by point-in-time events. Participants who reported experiencing unusually high levels of stress attributed this to changing jobs, moving homes or dealing with visiting family members.

One possible explanation for why people experiencing excess stress benefited less from our intervention was because it primarily supported problem-focused coping. It is evident that what we defined as “excess stress” was primarily caused by temporary, point in time events. These types of acute stressors can be effectively managed through emotion-focused coping (McGonagle and Kessler 1990). The reason why this coping strategy can be more effective than problem-focused coping is because it helps people regulate the extent to which a given stressor affects them (Aspinwall & Taylor, 1997; Carver et al., 1989).

An alternative interpretation of our findings is that people who reported experiencing excess stress were generally more likely to appraise their stressors as something that was excessive or outside of their immediate control. In fact, there is evidence in the coping literature to suggest that people who appraise their stressors as something that they can control or change are more likely to engage in, and therefore benefit from, problem-focused coping (Aspinwall and Taylor 1997; Taylor and Stanton 2007). Similarly, neither Welltory nor Coach.me incorporated features designed to support their users in gaining more control over their stressors or changing the way in which they appraised stress. Consequently, users who appraised their stressors as something that was outside of their immediate control never received the right guidance on how to approach and cope with their stress, which resulted in them benefiting less from the intervention.

4.2.3.3 Self-monitoring and Goal setting for Stress Self-management

When looking at specific app features that incorporated coping-relevant BCTs, we found that context monitoring was associated with a greater reduction in stress. Specifically, this finding highlights that the short-term efficacy of our intervention was

not necessarily driven by how many Welltory stress measurements our participants took. Instead, we find that people who monitored a variety of distinct context factors were also more likely to report lower levels of stress at the end of the 3-week period. This observation is in line with past research reporting that people valued being able to monitor context factors and perform correlational analysis to gain insights into how different factors in their lives affected their behavioural goals and outcomes (Bentley et al. 2013; Choe et al. 2014a; Epstein et al. 2014a; Li, Dey, and Forlizzi 2012).

We also found that setting more exercise related goals was correlated with changes in stress levels. This is not surprising considering that exercise is known to have stress relieving properties (Bland et al. 2014). However, setting more self-improvement and relaxation goals was not associated with changes in stress. One possible explanation for this is that setting self-improvement goals such as learning a new language or improving one's diet may not directly lead to changes in stress. Additionally, because our participants had set .5 relaxation goals on average, there was simply not enough data for making any inferences about the efficacy of setting these types of goals.

Findings from the present study indicate that our participants engaged in reflection, gained insights into their stress levels and the factors affecting these. Similarly, they also reported making an active effort to self-manage their stress, albeit sometimes facing barriers in doing so. In line with the qualitative survey responses, our quantitative analysis revealed that context monitoring and goal setting contributed towards the short-term efficacy of the apps.

In an attempt to inform how and why did context monitoring and goal setting contributed towards positive stress outcomes, we take a look at research within the psychology and stress management literature. An occupational stress diary study by Alford et al. (2005) found that using a diary to write down how various stressors affected peoples' emotions and thoughts lead to improvement in their stress levels. In a related study, Clarkson and Hodgkinson (2007) asked university clerical workers to use a paper-based diary to record what their occupational stressors were, the effect that such stressors had on their feelings, emotions, and how they coped with their work-related stressors. Their qualitative analysis revealed that using this form of journaling provided deep qualitative insights into peoples' stress experiences and could be used to complement quantitative measurements of stress. What both studies

highlight is that context monitoring (even when administered in a form of a journal) can a) help improve stress outcomes, b) encourage reflective practices and c) enable users to gain insights into how different factors affect their stress levels. However, these studies did not investigate how successful people were in implementing and engaging with the assigned self-monitoring practices. Without this knowledge, it is challenging to apply the aforementioned findings to inform the design of app features for stress self-management. Relatedly, as Richardson and Rothstein's (2008) review of stress management interventions highlights, there is a gap in research investigating goal-setting interventions within a stress management context and that there is a lack of research that describes, in sufficient detail, how strategies such as self-monitoring and goal setting were implemented and disseminated to the intervention participants.

Consequently, it still remains unclear as to how and why did context monitoring and goal-setting help our participants to reflect and act on their data, and how these processes and the app features enabling them aided peoples' stress self-management efforts. On a similar note, there remains the need to gain a deeper level of understanding about the barriers that our participants faced when reflecting on visualisations of their data and/or trying to self-manage their stress. Having this knowledge is vital for informing the design of app features for stress self-management. To investigate this, we ran a series of follow-up focus groups during which we asked the participants from the original 3-week self-tracking study to discuss their use of the apps.

4.3 Focus Groups

The primary aim of the focus groups was to validate and extend the findings from the self-tracking study. The focus groups were therefore used to investigate how and why specific app features that incorporated coping-relevant BCTs included in the Welltory and Coach.me apps affected peoples' ability to better understand and self-manage their stress. We additionally investigated the longer-term efficacy of the apps and whether our participants were still using them.

4.3.1 Method

4.3.1.1 Participants

All the participants who took part in the self-tracking study were invited to attend the follow up focus groups. Nineteen participants agreed to take part in one of the 3 focus groups that were run 2 months after the self-tracking part of the study was completed and the quantitative results were analysed. The participants were compensated with £20 for their time in addition to travel expenses. Each group was formed of 6-7 participants, 19 in total. The dropout was due to the participants not being able to physically attend the location of the focus group or not responding to the invitation email.

4.3.1.2 Design

The follow-up study used a mixed methods research design, including a short questionnaire and three focus groups. We selected to run focus groups instead of other qualitative methods (e.g., interviews) because focus groups could be used to facilitate discussion around the use of the apps in a way that would naturally highlight the similarities and differences across our participants' experiences.

4.3.1.3 Materials

During the focus groups the participants were administered a questionnaire measuring their perceived levels of stress (PSS). The questionnaire additionally included two binary questions on 1) whether or not the participants were still using the apps and if yes, which ones and 2) whether or not they forgot to log their completed stress management activities on the Coach.me app. We additionally used printouts of Welltory data visualisations to help facilitate the focus group discussions.

4.3.1.4 Procedure

The duration of the focus groups was between 1-1.5hours. Each focus group consisted of 4 main parts. The first part was dedicated to introducing the aims of the focus group and for giving a quick overview of the findings from the 3-week self-tracking study.

Part two of the focus group looked at which app functions and features were the most informative and why. Part three was used to discuss how people decided to take action and whether self-monitoring of their levels of stress and goal-setting had influenced this decision. Part four looked at why the apps did not help as much for those individuals who reported experiencing higher than usual levels of stress (excess stress group) during the 3-week self-tracking study.

4.3.2 Results

The results from the 3 focus groups are presented below. The focus group questions were informed by the findings from the field study, with the aim of providing a deeper understanding of how people used the apps to understand and self-manage their stress. We again used IBM SPSS Statistics version 23 to analyse the questionnaire responses.

Change in PSS scores

A Friedman test was performed to test whether there was a change in our participants' stress levels between the beginning of the 3-week self-tracking study, end of the self-tracking study, and at the time of the follow-up focus groups (2.5 months after the original self-tracking study). The results indicate that there was no statistically significant difference between the three time points, $\chi^2(2) = 4.2$, $p = .125$ (see Figure 27).

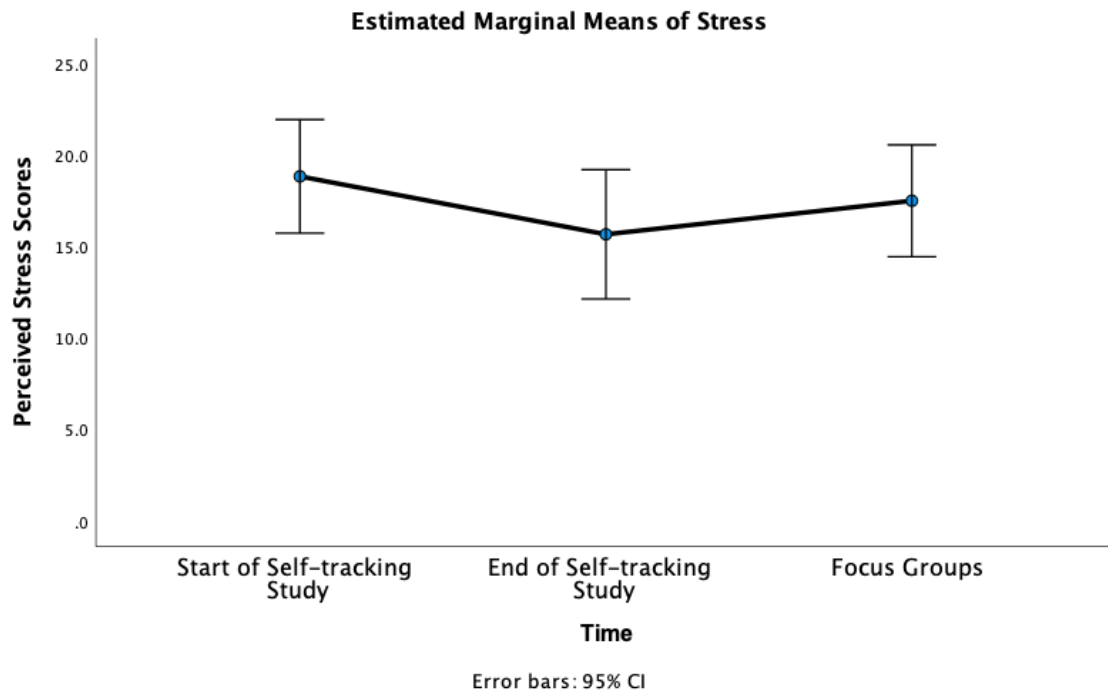


Figure 27. Change in perceived stress scores (PSS) between the beginning of the 3-week self-tracking study, end of the self-tracking study, and the follow-up focus groups (2.5 months). Even though there was an initial decline in stress levels at the end of the 3-week self-tracking study, our participants' stress levels returned closer to their baseline state by the time of the focus groups.

4.3.2.1 Qualitative findings

The focus group data was thematically analysed (Braun & Clarke, 2006). The qualitative analysis focused on how and why app features that incorporated self-monitoring and goal-setting helped our participants to reflect and act on their data, what their barriers to applying these strategies were, and where improvements could be made to help overcome those barriers. The focus group data was transcribed and iteratively coded using Nvivo. After completing the initial coding process, the codes were reviewed and, using a top-down approach, re-organised into two overarching themes and six sub-themes (see Figure 28). F1-3 refers to the focus groups 1-3.

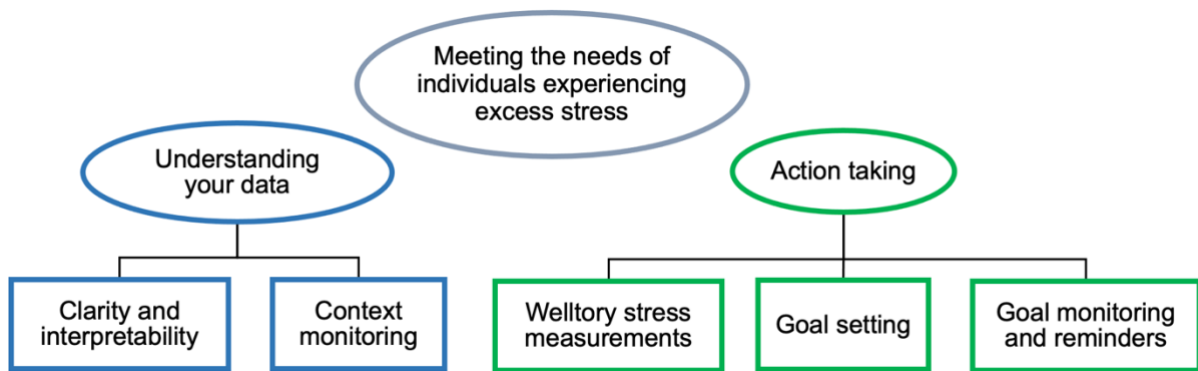


Figure 28. The three over-arching themes and five sub themes derived from the focus groups. Same as previously, the blue border is used to indicate themes related to reflection/understanding, the green border is used to refer to action taking/management. The grey border represents a theme discussing the needs of people who are experiencing unusually high levels of stress.

4.3.2.2 Understanding Your Data

Clarity and Interpretability

The convenience, clarity and interpretability of the format in which the data was presented proved to be crucial not only for ensuring that the users understood what their data meant, but also for encouraging future engagement with that data. Participants across all focus groups described regularly using data visualisations that were convenient to access (e.g., automatically popped up after taking a measurement):

F2P4 “...so I take my measure and I mostly just look at the things that's just right there. So like how much energy I have or how stressed I am.”.

They also reported benefiting from reflecting on score and icon-based data summaries representing their individual stress measurement results (see Figure 1, middle). These data summaries enabled our participants to make direct comparisons between their current and past measurement results (i.e., establishing what is a “normal” or “weird” result). In fact, they even reported memorising the meaning and advice associated with each score or colour coded icon:

F3P7 *"...and if you want to read more you can just tap on each icon for more information and just see what's going on with you today and see whether you should try and take it easy or if you should go ahead and do work. So it's very summarised. The first time I used it I looked at all of them but when I kept getting 4/5 in productivity I kind of knew what it means and If I see something weird I would look into it in more detail."*

Unsurprisingly (and in-line with our previous survey results), line and bar charts were used less frequently, if at all. For instance, in our second focus group, F2P3 described her challenges when trying to interpret the graphs provided by Welltory due to a lack of labels on the plots:

F2P3 *"I didn't learn anything new myself cause maybe I can't understand the graphs that well because I look at them and they plot different things and they don't necessarily tell you which plot is what and so I'm like there is a correlation but I'm not sure which ones which and I'm not really sure what's going on."*

This was followed by a discussion around the time required to adequately explore and interpret graphs. Notably, participants across all focus groups considered this process to be too time consuming, which resulted in them turning to icon, score and text-based summaries of their data instead:

F2P5 *"I probably looked at my charts once a week, once every two weeks. It was kind of when I remember. It's a little bit time consuming, a little bit involving. Whereas taking the measures, you take the measure look at the summary and get on with your day whereas with the charts I would have to log on via the web app, meaning I would need to be sitting at my computer and then remember..."*

Context-monitoring

It was evident from the focus group discussions that the Welltory's tag system helped our participants understand what factors were associated with their stress and wellbeing. As F1P1 explained, she used the tags to check how certain factors affected her stress:

F1P1 *“I think it helped to type in (tags) what I was doing at the moment, so I would see how it correlates with my stress levels. And then I could build a bigger picture in terms of which activities may increase or decrease my stress levels even if I didn’t know that they actually did.”.*

For P1, using Welltory to help her identify (and reflect on) the context factors associated with her stress resulted in her trying to avoid those stressors once she was in a similar situation/environment:

F1P1 *“When I finished arguing with someone I would input everything (tags in Welltory) as I was trying to test how I was feeling at the time and I did notice that conflict definitely did have an impact on my stress levels so I would try to avoid that as much as possible.”.*

Notably, instead of reflecting on visualisations designed to represent correlations between stress and context factors (see Figure 21, right), our participants explained that they primarily reflected on what factors were affecting their stress as they were taking their measurement. In other words, the process of taking a stress measurement acted as a catalyst for reflection:

F3P2 *“I did find Welltory very useful because when taking your pulse and you have to reflect on the activities you're done, it forces me to make that connection, oh hang on, I've been doing certain thing like being with family or commuting or had caffeine so I can connect this to how it's affecting me in my daily life.”.*

This was because the correlational visualisations either confirmed what the participants already knew:

F2P5 *“Having meals and sleeping were listed as my boosters, which wasn’t very surprising.”.*

Or no correlations were displayed yet by Welltory:

F3P2 *“There were no events on my booster/bummer section, even though I’ve put on tags every time I measured.”.*

However, even if no novel insights were gained, the act of self-reflection still led to improvements in self-awareness:

F3P1 *“I haven't really found any significant insights or correlations, I think that both setting goals and self-tracking made me more aware of my stress and what I was doing.”*

4.3.2.3 Managing Your Stress

Welltory Stress Measurements

Some of our participants described adjusting their behaviours immediately or shortly after taking a Welltory stress measurement. As F1P4 described, she would normally find it challenging to gauge what her stress levels were. However, using the Welltory app has helped her to become more aware of how she was feeling – information that she then used to adjust her behaviour:

F1P4 *“...but it did say that oh, you're really stressed or you're really low on energy, you're burning out. I thought that that was actually really helpful because then I thought that I should take a break and re-think what my next move is. Especially because when I get really stressed I don't really think things through very well and it kind of helped me to listen to my body a bit better.”*

However, most of our other participants reported changing their behaviours over time rather than instantaneously. F2P4 explained that she found it challenging to achieve instantaneous behaviour change because she did not always have the opportunity to engage in stress management activities after taking a measurement:

F2P4 *“But also, in the middle of the day if I then take my reading, I would eat lunch at my desk, I do not have time for meditation, so I would just keep going. It's nice that it's giving me all of this information, but I think it's really hard to apply it to anyone's normal working day causes everyone has a different working day weekly.”*

Some participants reported not wanting to have an app telling them what to do:

F2P1 *"If I'm really stressed and I know I'm gonna be unproductive...I don't need the app to tell me that. If I had a really bad day and I feel rubbish I would go home anyway...It would confirm that I'm not at my best but the decision to go home wouldn't be because of the app."*

And instead preferred making their own conclusions on what the next best action is, or took the measurement results as a warning sign:

F2P2 *"I always took it as a warning or as a heads up rather something to listen to."*

Even so, our participants expressed that they frequently followed the advice provided by the Welltory app, to the point where receiving a positive measurement result motivated them to be more productive:

F2P5 *"On the days it (Welltory) was saying that you're gonna have high productivity motivated me to get stuff done."*

However, as, F2P3 pointed out, this created issues when the measurements indicated low energy levels, which by the same means could decreased motivation to be productive:

F2P3 *"It does depress me sometimes when it says you're productivity is 1 out of 11 and I'm like oh no, what I'm gonna do now? Nothing..."* or even made them more stressed: F3P2 *"When I started using it I actually got worried when I saw the results because I was very stressed, like 10 or 20 times higher than the normal range so I actually it got me even more stress after seeing it and I knew I had to do something about it."*

Goal-setting

Most of our participants reported having already identified the types of activities that help them manage stress before even beginning the study, which is why they had set those activities as goals on the Coach.me app:

F3P4 *"I kind of knew what worked for me and it was confirmed by the app in terms of my boosters logged by the apps. These were eating, sleeping or exercising so I kind of just stuck with those same things."*

However, the heightened awareness of the benefits that such activities bring acted as a cue to engaging in them more frequently:

F3P4 *"I think it was just the heightened awareness of your stress and this helped you to moderate your life subconsciously."*

As P4 explained, she was able to lower her stress without necessarily beginning a new exercise regime or setting new goals:

F2P4 *"I think it was more that I was more aware of my stress and so I did more of what I knew worked for me, like walking or working out."*

P3 added that using the apps encouraged her to take more opportunities to relax when she was in the right environment:

F3P3 *"...so if I'm at home, I take every opportunity to relax. And I actually did notice that my mood and my stress was lower cause I was making an effort to relax and not make anything burst my bubble at that point."*

Even though most participants did not perceive the Coach.me app as valuable for supporting them with stress management, they did appreciate the concept of goal-setting and reported actively using it even before beginning the study:

F2P3 *"But I've already set myself these same goals to basically just on a to-do list and not on that (Coach.me)...But my goals were very vague, it's something I want to do 3 times a week or I already do them."*

Goal Monitoring and Reminders

Across all three focus groups goal monitoring and reminders were quoted as stress inducing, unnecessary and nagging. As F2P1 explained, she wanted to take

responsibility for her own actions (or lack of), instead of having an app reminding her of the activities that she had missed:

F2P1 *"I just found the reminders nagging. I set my own goals in my mind if and I don't stick with them I have the consequences and I'm aware of that."*

Unsurprisingly, this was primarily attributed to the feeling of disappointment that came with not meeting a goal:

F2P2 *"...if I haven't done it then I'm looking at this 0. Cause then I'm getting a downer cause I haven't achieved things that are not essential and then it's affecting me more than it should so I don't know if its helpful all the time."*

Ultimately, having a phone remind people that they are not meeting their goal when they were already under time pressure left them feeling more stressed:

F2P3 *"So I found that when I didn't manage to do it and my phone kept telling me do this thing and I was like I don't have time and it ends up being more stressful."*

Similarly, reminders to perform a stress management activity sent via the Coach.me app or suggestions made by Welltory after taking a measurement were frequently ignored if they were sent at inopportune moments:

F3P3 *"If I'm at work there's nothing much that I can really do at that point. So even if it suggests to me go and take a walk but I can't do it at that point. So I try and make an effort to do that when I do have the time and when I'm out of that environment."*

Instead of relying on reminders, the participants preferred doing their selected activities as and when needed:

F3P6 *"It's quite easy to ignore the reminders. I'm so used to seeing the notification that I just swipe it off. I think it's (performing selected stress management activities) as and when."*

Interestingly, some of our focus group participants considered goal-setting and monitoring as an unnecessary function in stress management apps. For example, after

being asked whether goal-setting has a role to play in apps such as Welltory F3P1 responded:

F3P1 *“No as it's (a goal) not a measurement, it does not tell you anything about yourself.”.*

However, as F3P6 explained, even though goals added more pressure, they also helped motivate her to engage in stress management activities:

F3P6 *“I think that goal-setting adds a little bit of stress if you don't do it that day. You do feel a bit more motivated to do it but you also feel more pressured.”.*

Other participants argued that goal-setting is a necessary motivator to perform a given stress management activity and that they would not have performed these without setting goals to do so:

F2P5 *“I kind of liked the Coach.me app because of the goal-setting. Having somebody else motivating me to do something, cause I wouldn't wake up every morning otherwise to do 10-20 minutes of yoga and I would lie in bed instead. Whereas if I know that I have a goal or like that 30 day plan challenge I need to make sure I just tick it off. I wouldn't do it otherwise.”.*

4.3.2.4 Meeting the Needs of Individuals Who are Experiencing Excess Stress

To better understand why the quantitative findings indicated that the efficacy of the apps was moderated by excess stress, the participants were asked whether they would find an app such as Welltory useful when they were experiencing higher than usual levels of stress. Most participants referred to emotion-focused coping stress management techniques as their preferred way of managing this type of stress:

F1P5 *“If I feel stressed I would try to do something that I like, like walking, seeing London maybe other people, talking with friends, and because I like movies I would try to watch movies.”.*

The participants also reported that mobile apps or smartphones in general may not be the right solutions for dealing with this type of stress:

F1P6 “...sometimes when I'm really stressed I would sort of try to stay away from the phone.” and F3P3 “I think that when people are really stressed out they will be less likely to use the app in general because that's not on their mind”.

It is also the case that completing a given task and reducing the workload (i.e., getting things done) can help deal with managing stress:

F1P6 “If I'm doing something I would focus on trying to get it done and then that helps to reduce my workload which reduces my stress...it depends on what kind of stress you experience.”.

4.4 Discussion

The two primary aims of the follow-up focus groups were to: 1) investigate whether the initial reduction in stress was sustained at the 2.5-month mark and 2) expand on how techniques supporting problem-focused coping, in this case, self-monitoring and goal setting, could help people with better understanding and managing their stress. We finish the chapter by addressing the limitations of our work and discuss future research directions.

4.4.1 Change in Stress Levels at 2.5 Months

We found that, even though our participants had significantly lowered their stress levels after the 3-week self-tracking period, these effects were not sustained at the 2.5 month mark (at the time of the focus groups). The most likely explanation for this is that only 5 out of 19 participants who attended the focus groups were still using the apps. During the focus groups, our participants commented that they did find the Welltory app useful and interesting to interact with. However, they also noted that they had stopped using the apps after the initial 3-week self-tracking period, and only used Welltory occasionally after that. This is in line with Epstein et al's (2015, 2016) observations, detailing that users of personal informatics tools will normally go through

bouts of use and abandonment, depending on their needs at the time. Choe et al. (2017) also highlight that people disengage with self-tracking simply due to the burden associated with manual data collection. Relatedly, Dijk et al. (2017) argue that the primary mechanism of action behind most PI interventions can be narrowed down to gains in self-awareness. Our findings lend themselves to a similar interpretation, whereby, once people disengaged with self-monitoring, they became less aware of their stress levels and the need to self-manage these. Consequently, their stress levels returned closer to their baseline state.

4.4.2 Reflecting on Data Visualisations to Better Understand Stress

Our participants found Welltory particularly useful because it enabled them to better understand how different behaviours and events experienced in their daily lives affected their stress levels. In other words, they primarily valued the ability to monitor and reflect on context information relating to stress. This confirms the findings from the questionnaire results. Below, we expand on our initial questionnaire findings and add to the existing body of work on context monitoring (Bentley et al. 2013; Choe et al. 2014a; Epstein et al. 2014a; Li et al. 2012) by highlighting user preferences and the associated challenges when self-tracking for stress self-management.

When it came to the modality through which our participants preferred to explore and reflect on their data, colour-coded icons and scores were perceived as more useful than graphs in communicating information about stress (see Figure 21, middle). As expected, our participants explained that they could best understand their data if it was presented to them using easy to interpret score and icon-based data summaries. Rather surprisingly though, they found it more useful to reflect on data visualisations that represented single measurement results as opposed to graphs that were based on longer-term time series data. In fact, line and bar charts were reported being used less frequently or not at all. There are several explanations to this. Firstly, some of our participants commented that graphs took more time to explore and interpret and that they would need access to a computer to do so. Others admitted having challenges with interpreting graphs in general (low graph reading literacy). Secondly, our participants simply did not have enough self-tracking data for any significant patterns

to emerge. That is, the graph-based visualisations could not reach their full potential of conveying reliable trends and patterns given the 3-week self-tracking period. This is an issue that most personal informatics tools face by design: people need to wait several weeks before they can gain meaningful insights from their data (Choe et al., 2017; Li et al., 2011). What our findings signify is that the core features encouraging reflection in stress monitoring apps, which are graph-based data visualisations (see Chapter 3), are therefore of limited use during the first 3-weeks of engagement.

Based on our findings, we argue that the issue of not having sufficient data to facilitate long-term reflection is particularly pronounced when tracking mental wellbeing. Self-monitoring of physical activity, for example, can be done seamlessly via mobile and wearable sensors. These sensors can accumulate large amounts of data in relatively short periods of time and reveal information that is not immediately obvious to the users (Choe et al. 2017; Swan 2012, 2013). In contrast, it takes more time and effort to engage in continuous self-tracking using tools that are geared towards recording mental states as they are challenging to log automatically due to their subjectivity (Choe et al. 2017). Welltory's PPG-based stress measurement is a somewhat special case in that it reveals data that is not immediately obvious to the user but has a high data capture burden as the user needs to remain still for up to two minutes to measure their stress. Consequently, as far as sustained engagement is concerned, Welltory's objective stress measurement feature still suffers from the same limitations as does using subjective self-reports (Choe et al., 2017). To add to the issue, our focus group findings indicate that not having access to long-term self-tracking data creates further barriers to gaining insights since the users are less likely to find reliable trends and patterns in their data, making the overall practice of long-term reflection less viable and valuable to the users.

The above findings highlight the need to consider alternative ways of encouraging reflection during the early stages of stress self-monitoring. Incorporating a self-reflection strategy that does not rely on data collection into a stress self-monitoring app can help ensure that the users have the necessary resources to engage in beneficial behaviour change. This can be of particular value during the initial stages of using a wellbeing self-monitoring app, possibly whilst the users are still collecting data to reveal the less obvious trends and patterns.

4.4.3 The Role of Goal-setting and Implementation Intentions in Encouraging Stress Management

Findings from the focus groups revealed that our participants appreciated the concept of goal-setting for stress management, but only when the goals gave them flexibility to manage their stress as, and when, needed. This type of behavioural autonomy can contribute towards heightening peoples' perceived behavioural control, which increases the likelihood of people translating their intentions into actions (Hagger and Chatzisarantis 2014). But as we discovered in our focus groups, our participants found it challenging to implement the goals that they had set via Coach.me in their daily lives. Their described experiences evidenced that goal monitoring and reminders to perform a specific stress management activity decreased their autonomy and, in some cases, invoked additional stress. This is not necessarily because our participants perceived a given stressor as outside of their control (e.g., reported experiencing excess stress), but rather because the reminders were often sent at inopportune moments, which caused user frustration as they felt unable (or even unwilling) to take action at that time. People already feel overwhelmed and out of control when experiencing stress. Our findings demonstrate that features constraining user autonomy further reinforce their perceived limited capacity to cope with their stress (Nezu 2004). Based on this finding, we argue that there is a need to consider alternative approaches in designing app features that take into account peoples' stress self-management needs, especially when those features are geared towards encouraging self-regulatory behaviours.

Our participants' accounts with regards to goal-setting (see Section 4.3.2.3) suggest that their needs align more closely with the concept of action planning (also known as if-then planning or implementation intentions) rather than goal monitoring (Gollwitzer 1999; Pesseau et al. 2014; Sniehotta, Schwarzer, et al. 2005). In the present study, by monitoring how various context factors relate to stress outcomes, people could identify and become more aware of the context-dependent cues for engaging in stress management behaviours. Once in the presence of a given cue, such as an argument or a quiet place to relax, people can automatically activate the associated action plans and adjust their behaviour accordingly. This contrasts with the traditional goal monitoring and reminder procedure used by the Coach.me app, whereby the users can specify a goal, its frequency, and receive set reminders.

Even though several participants did not consider goal-setting and monitoring as necessary features in stress management apps, people who did set more goals lowered their stress to a greater extent than those individuals who set fewer goals. One possible explanation for this is that goal-setting provided people with more opportunities to form implementation intentions, known to guide peoples' behaviour in response to stress (Gollwitzer 1999). Therefore, if a given individual had a goal set to go to bed early, they would be more likely to enact this behaviour than if they would have not set this goal.

As highlighted by past research (Ayobi et al., 2018; Ayobi et al., 2017; Figueiredo et al., 2018), setting goals that are focused on activity completion and well-defined outcomes can be detrimental in some use cases. This especially applies to people with conditions where they might never reach and/or should not focus on reaching their desired state, i.e., being stress free or fully recovering from a degenerative disease. Based on our focus group finding, we argue that there is a need to consider alternative approaches in designing app features that take into account peoples' stress self-management needs, especially when those features are geared towards encouraging self-regulatory behaviours. Peoples' experiences with using Welltory and Coach.me apps suggest that strategies such as context monitoring together with action planning can direct peoples' attention away from the unrealistic outcomes, and instead allow them to focus on gaining self-knowledge on how to cope with their condition. We will investigate this proposition in more detail in later chapters of this thesis.

4.4.4 The Role of Context Monitoring and Awareness in Encouraging Stress Management

Our participants reported that instead of goal-setting, the strongest driver of action taking was the heightened awareness of what their stress levels were and the factors affecting these. The finding that context-monitoring and heightened awareness helps people with self-regulation is in line with similar research done on personal informatics tools (Bentley et al., 2013; Choe et al., 2014; Jones & Kelly, 2018; Kim et al., 2017; Li et al., 2012) and stress management apps (Bakker and Rickard 2018). The present research adds to the existing literature by demonstrating how people apply the app-

delivered BCTs into their daily lives and how such practices lead to improvements in awareness and self-regulation for stress self-management.

Context monitoring via the Welltory's tag function helped form behaviour-outcome expectancies, which subsequently lead to creating action plans (in the form of if-then rules) for engaging in stress management activities. By taking daily measurements, the participants could observe and reflect on the changes and patterns in their physical and mental states. They could additionally gain an understanding of how their mental and physical states were affected by various context factors monitored via the tags function. This helped the users form outcome expectancies ("I will feel better after exercising") and risk perceptions ("I will be more stressed if I do not get enough sleep") (Bandura 1977; Dijk et al. 2017b). Based on this, action plans were formed (Sniehotta 2009; Sniehotta, Schwarzer, et al. 2005).

Heightened self-awareness helps identify whether there is a need to invoke context-dependent action plans (Sniehotta et al., 2005). Self-awareness, which in our sample primarily stemmed from continuous self-monitoring and reflective practices (Bakker and Rickard 2018b; Dijk et al. 2017b; Rapp and Cena 2014), helps to direct attention towards oneself and identify whether there are any discrepancies between the individual's current state (stressed) and their goal state (being relaxed). Over time, this process of state comparison and behavioural adjustments becomes automated, without the need for deliberate consideration of actions and can be performed outside of the individual's immediate awareness (Gollwitzer, 1999; Pesseau et al., 2014; Sniehotta et al., 2005). In the context of the present study, the use of the two apps encouraged people to reflect on their short-term self-tracking data and become more aware of the need to do relaxing activities. Action plans were implemented once people felt that they had the need and the means to relax.

4.4.5 Limitations

The first limitation of our work relates to not having a control group. Even though we use qualitative data to support the observed changes in our participants' stress levels, future research should do a comparative study to support the validity of our findings. We provide a more detailed account of this limitation in Chapter 9, which presents the general discussion for the overall thesis.

A second limitation of our study is that we were using a combination of commercial stress management and behavior change apps instead of using a bespoke solution. We therefore could not study the app features of interest in complete isolation. Specifically, because the Coach.me app included a wide range of goals that its users could set, our participants chose to set goals that were not necessarily related to stress management. Therefore, instead of setting goals to do activities such as mindfulness, progressive muscle relaxation or visualisation (instructions for which were available on the Coach.me app), our participants instead selected to set self-improvement goals that were not directly related to stress management. It could be the case that, if Coach.me was primarily focused on providing content related to relaxation and stress management, we would have seen more participants set goals related to performing relaxing activities (e.g., meditation, deep breathing), which might have influenced our participants' stress levels.

Finally, we could not account for the quality of the data captured via Welltory's PPG measurements and the quality of the subsequent stress inferences, which is why we additionally capture peoples' perceived levels of stress.

4.4.6 Conclusion

Previous research on stress management apps has investigated what types of stress management and behaviour change techniques such apps include or focused on evaluating their overall efficacy. The primary aim of the work presented in this chapter was to investigate whether existing apps support people with implementing coping-relevant BCTs in a way that helps them to understand and manage their stress. We additionally investigated how experiencing different types of stress affected how much our participants could benefit from the apps and their specific features. Instead of reviewing what types of BCTs stress management apps include, we ran an intervention study to evaluate how successful people are in applying the app-delivered BCTs in their daily lives. Relatedly, where past research had focused on evaluating the overall efficacy of stress management apps, we were interested in examining how the different coping-relevant BCTs and related app features (e.g., data visualisation) contributed towards the short-term effectiveness of the apps. To investigate this, we ran a 3-week self-tracking study using Welltory and Coach.me apps together with

follow up focus groups. Our findings demonstrate that, even though the intervention was shown to be effective for our overall sample, the use of both apps were more effective for those individuals who reported not experiencing excess stress during the study. We also found that monitoring a variety of stress-related context factors lead to engagement in both reflection and stress self-management. Similarly, goal setting encouraged our participants to perform more stress management activities than they otherwise would. However, we also identified several barriers to use, which primarily relate to how existing apps incorporate self-monitoring and goal setting features. Based on our insights, we dedicate the rest of this thesis to propose and evaluate alternative approaches to how stress self-management apps can incorporate features aimed at supporting users with understanding and self-managing their stress.

5 Using Reflective Questioning to Help People Gain Insights About their Stress

In Chapters 3 and 4 we identified that the currently available stress management apps do not incorporate features that can adequately support their users with better understanding and regulation of their stress during the early stages of their use. This primarily stems from two feature gaps: the lack of data on which to reflect and gain insights from when first beginning to use the app, and a lack of guidance on how to apply those insights to better regulate stress. In the present chapter, our focus is on addressing the first feature gap, whereas the later chapters will be dedicated to addressing the second feature gap. The first feature gap highlights a problem whereby the apps are of limited value to the user until they have collected sufficient data for behavioural trends and patterns to emerge (Choe et al., 2017; Li et al., 2010, 2011). This can lead to disengagement and app abandonment (Collins et al. 2014; Lazar et al. 2015).

Our finding highlights that existing stress self-management and monitoring apps need to implement features that support reflection without access to self-tracking data. The findings from our and related research (Bentley et al. 2013; Choe et al. 2017; Jones and Kelly 2018) indicate that most relationships in peoples' self-tracking data are messy and challenging to uncover by referring to data visualisations alone. As we found in Chapter 4, this issue is particularly pronounced during the initial stages of stress self-tracking, when not enough data is yet collected. A self-reflection strategy that does not rely on data collection can help ensure that the users have the necessary resources to gain insights into how different factors, including their environment or behaviours, affect their stress levels. As we found in Chapter 4, having this understanding can help people engage in beneficial self-regulatory behaviours (e.g., exercise or avoiding conflicts with family members) for stress self-management.

A potential solution for enhancing reflection may come from other disciplines where reflective questioning has already been shown to facilitate user ability to self-reflect (Baumer, 2015). The practice has long been applied in areas such as teaching and psychological therapy and has been making its way into HCI research and practice

(Baumer 2015; Kocielnik, Xiao, et al. 2018; Mols, van den Hoven, and Eggen 2016). Reflective questioning works by encouraging people to actively consider and reason over experiences from their memory to gain a better understanding of those experiences. Within the personal informatics domain it has been used to encourage people to better personalise their plans and increase their physical activity (Lee et al. 2015), as well as aid them in recalling past events and the contexts and emotions associated with those events (Isaacs et al. 2013). These findings support the notion that asking reflective questions prompts people to recall and consider the knowledge they already have about themselves. In fact, Bentley et al. (2013) found that people already have substantial knowledge about the factors that may be affecting their wellbeing, though this knowledge lies outside of their immediate awareness unless it is called upon. Similarly, we argue here that reflective questioning has the potential to help people gain meaningful insights into their stress by drawing on their existing knowledge.

What is still unclear, however, is how to design digital stress management app features that can help people reflect on and gain insights into the factors that are affecting their stress, without the need for collecting long-term self-tracking data. The primary aim of the study presented in this chapter is to test the assumption that reflective questioning can help people generate insights about their stress during the early stages of self-tracking. To test this, we record the following characteristics of the insights reported: actionability, novelty, and their ability to reveal context information (i.e, information on factors affecting stress). This allows for better comparison with existing solutions as users of personal informatics tools would be expected to derive similar types of insights from reflecting on visualisations of their self-tracking data (Choe et al. 2014b; Choe, Lee, et al. 2017; Cuttone et al. 2014; Dijk et al. 2017a). We achieve our aim by answering the following research question:

RQ1: How does the combined use of a personal informatics app and reflective questioning help people gain insights about their stress?

We were also interested in expanding on our findings presented in Chapter 4. Considering that a significant number of our participants attributed their improvements in stress to gains in self-awareness (as opposed to self-regulatory strategies such as goal setting), there was additionally a need to examine whether personal informatics-

based tools that support reflection alone (e.g., Welltory) can lead to significant short-term changes in stress. Furthermore, we also wanted to investigate what types of self-regulatory techniques people preferred using to support their engagement in more frequent self-care activities. This is primarily because there is a lack of research investigating goal-setting interventions within a stress management context (Richardson and Rothstein 2008).

To gain this understanding, we additionally answer the following research questions:

RQ2: Can apps that focus primarily on supporting self-monitoring and reflective questioning lead to significantly lower levels of perceived stress during the first 3-weeks of use?

RQ3: What app features do people prefer using to ensure their engagement in stress self-management activities?

To answer these questions, we ran a 3-week field study looking at whether the combined use of the Welltory stress monitoring app and journaling-based reflective questioning could help elicit insights about stress. The contributions of the work presented in this chapter are:

- demonstration of how reflective questioning delivered through a digital journal can aid in understanding the factors affecting stress during the initial stages of using a stress monitoring app;
- evidence that apps supporting self-monitoring and reflection alone are insufficient for producing measurable changes in stress levels;
- provide insight into how people prefer to plan self-care activities into their schedules via an app.

5.1 Method

We conducted a three-week field study and follow-up interviews with 17 participants to investigate whether the use of Welltory and journaling-based reflective questioning can lead to gaining insights into stress and whether this results in significant short-term changes in stress levels. The study was conducted during the summer of 2019.

5.1.1 Participants

Seventeen participants ages 22-38 (15 females, 3 males) were recruited from our university’s participant subject pool for this study. The inclusion criteria were to own a smartphone device and not have a diagnosed clinical stress disorder. The participants were compensated with £30 cash and one year’s access to Welltory’s pro subscription.

5.1.1.1 Materials

Evernote

The Evernote app was used as a journal for the participants to record their daily observations and insights about stress and the factors affecting it (see Figure 29). The participants were additionally asked to record whether they perceived their insights as *actionable* or *descriptive*, and *novel* or *old*. Examples of different insight types were provided at the top of the journal.

Insights				Journal
Date	Insight	Type (select one)	Novelty (select one)	
23/05/19	(example) That half an hour of yoga really helped me to relax and lower my stress. I should keep doing this more often...	<input checked="" type="checkbox"/> actionable <input type="checkbox"/> descriptive	<input type="checkbox"/> old <input checked="" type="checkbox"/> new	Went for a short walk today because it was sunny outside. Met up with a friend in the evening.
24/05/19	(example) My stress levels are no different from yesterday.	<input type="checkbox"/> actionable <input checked="" type="checkbox"/> descriptive	<input checked="" type="checkbox"/> old <input type="checkbox"/> new	
		<input type="checkbox"/> actionable <input type="checkbox"/> descriptive	<input type="checkbox"/> old <input type="checkbox"/> new	

Figure 29. Evernote journal template that the participants were asked to complete. This form captures the date insight was made, free text description of the insight, the insight’s type and novelty along with an optional journal entry. Each form included example insights and their classification (highlighted in blue).

5.1.1.2 Design

This study used a mixed methods design, investigating how the use of the Welltory and Evernote apps affected changes in stress levels (PSS). We additionally used qualitative analysis to investigate the types of insights people reported on the Evernote journal and how they reflected and acted on their observations about stress levels and the factors affecting these.

5.1.1.3 Procedure

The participants were emailed a file detailing how to use the Evernote and Welltory apps, in which they were asked to set evening and morning reminders for using the Welltory app and an evening reminder to write in the Evernote journal for the duration of the study (3-weeks). The email also contained a link for completing the baseline questionnaire. The participants were also asked to complete the perceived stress scale (PSS) (Cohen et al. 2014) assessing their levels of stress before beginning the study. This was repeated at one and two weeks into the study and after it was completed (3-weeks) (see Figure 30).

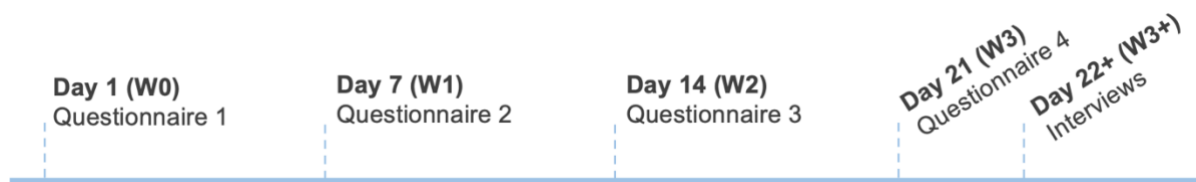


Figure 30. Study timeline indicating when each questionnaire was administered.

5.2 Results

In this section we describe our approach to analysis, followed by a description of the levels of engagement of our participants in the study. We also address our two research questions: 1) How does the combined use of a personal informatics app and reflective questioning help people gain insights about their stress? 2) Can apps that focus primarily on supporting self-monitoring and reflective questioning lead to significantly lower levels of perceived stress during the first 3-weeks of use?

5.2.1 Analysis

IBM SPSS Statistics version 23 was used for quantitative analysis. The insights reported on the Evernote app were qualitatively analysed to help record whether they contained information about the contextual factors that were affecting peoples' stress levels. For example, "*Drinking too much coffee makes me stressed*", where coffee represents a factor associated with stress. We additionally asked our participants to

indicate the actionability and novelty of their reported insights. This enabled us to measure the frequencies associated with the reported insight's perceived actionability, novelty and whether that insight conveyed information on context factors affecting stress (*yes/no*). We used this information to assess whether diary-based reflective questioning can help people generate insights into their stress. Thematic analysis (Braun and Clarke 2006) was used to analyse the post-study interview recordings. We used a top-down approach to code our data. The resulting codes were then organised into themes that were focused on investigating how people used Welltory and Evernote apps to understand and self-manage their stress.

5.2.2 Engagement

Our results indicate that people showed good engagement with both the Welltory and Evernote apps over the 3-week study period (see Table 11). People had taken an average of 2.3 measurements per day and reported an average of 0.6 daily insights about their stress on the Evernote app.

Measure name	Descriptive statistics
Welltory	Mean = 47.76, SD = 17.25, Median = 40, Min = 29, Max = 85
Number of insights	Mean = 12.12, SD = 5.8, Median = 13, Min = 5, Max = 21
Actionable insights	Mean = 6.65, SD = 5.47, Median = 5, Min = 1, Max = 18
Descriptive insights	Mean = 6, SD = 4.17, Median = 6, Min = 0, Max = 15
Novel insights	Mean = 6.41, SD = 4.89, Median = 5, Min = 0, Max = 18
Old insights	Mean = 5.29, SD = 4.66, Median = 5, Min = 0, Max = 21
Context factors	Mean = 10.65, SD = 5.43, Median = 8, Min = 4, Max = 21

Table 11. Summary of Welltory use and insights reported on the Evernote app.

5.2.2.1 Can Reflective Questioning Help People Gain Insights About Their Stress?

Analysis of the reports made on the Evernote app revealed that journaling-based reflective questioning led to people reporting insights about their stress. The reported insights were grouped based on whether they were labelled by the participants as actionable or descriptive, and novel or old. Insights that participants labelled as actionable, primarily focused on describing how specific activities or context factors affected their stress levels. This applied to insights that conveyed both novel and already known (old) information about stress:

P(11) *“As I know I sometimes start getting cranky in the afternoon because of accumulated stress, I tried taking a nap today, which I usually never do. I felt physically stronger after. I might do this again.”*. Insight type: Actionable, New.

P(15) *“Monday started again. Cycling after work made me relaxed. Keep doing it.”*. Insight type: Actionable, Old.

Insights that were labelled as descriptive primarily focused on observations made about stress levels:

P (18) *“Had a normal day, normal levels of stress (low to moderate).”* Insight type: Descriptive, Old.

Insights were also labelled as descriptive if they included information about something that was outside of the participants’ control, such as the weather:

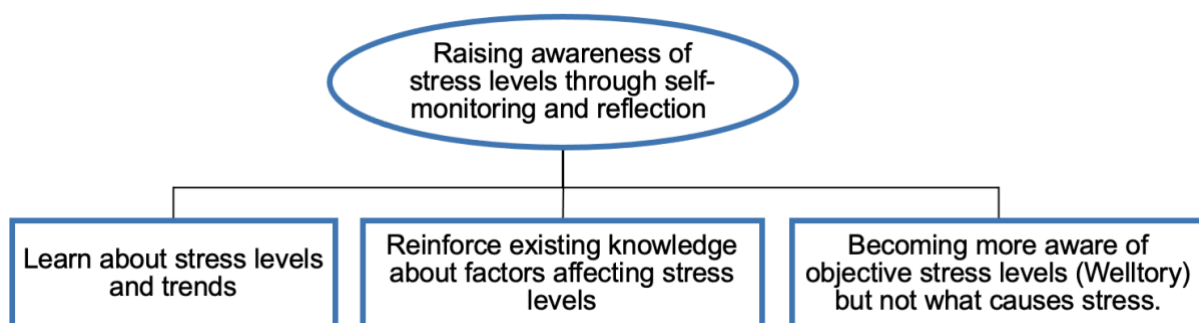
P(19) *“I walked in the morning, but it was a lot harder to do today as it was really hot. This also made studying harder and affected my stress, although I tried to actively remember that it was outside my control so I shouldn't dwell on it.”*. Insight type: Descriptive, New.

Overall, the insights reported on the Evernote app demonstrate that reflective questioning can lead to a) people reflecting on the factors affecting their stress, b) reinforcing their existing knowledge about such factors to motivate engaging in helpful self-regulatory behaviours, and c) observe changes in stress across different days. The content of these insights is qualitatively similar to those that people are expected

to gain by reflecting on visualisations of their data: identifying trends, patterns, and context factors associated with their stress (Choe et al. 2014a; Choe, Lee, et al. 2017; Cuttone et al. 2014).

5.2.2.2 How do Existing Stress Monitoring Tools Affect how People Understand and Manage their Stress?

The qualitative analysis of the interview recordings was primarily focused on how people used existing stress monitoring tools to better understand and manage their stress (see Figure 31). The aim of this investigation was to validate and extend the findings discussed in Chapter 4. Findings from the study presented in this chapter validate that, through objective self-monitoring, people became more aware of what their stress levels were. Similarly, we again find that people primarily engaged in short-term reflection and were less likely to reflect on graph-based visualisations of their data. We expand on our previous findings presented in Chapter 4 by additionally identifying that, instead of reflecting on graphs, our participants reported relying on their memory of past measurement results to find trends and patterns in their data. Our findings regarding stress self-management practices indicate that, even though some of the participants reported trying to eliminate or alter the sources of their stress, most preferred to avoid thinking about their stressors or felt unable to eliminate or cope with them. When planning in self-care activities, people preferred to plan a day in advance as opposed to committing to longer-term goals. Finally, instead of making any specific changes to how they were coping with their stress, most participants reported engaged in more of the same activities that they were confident would help them relax.



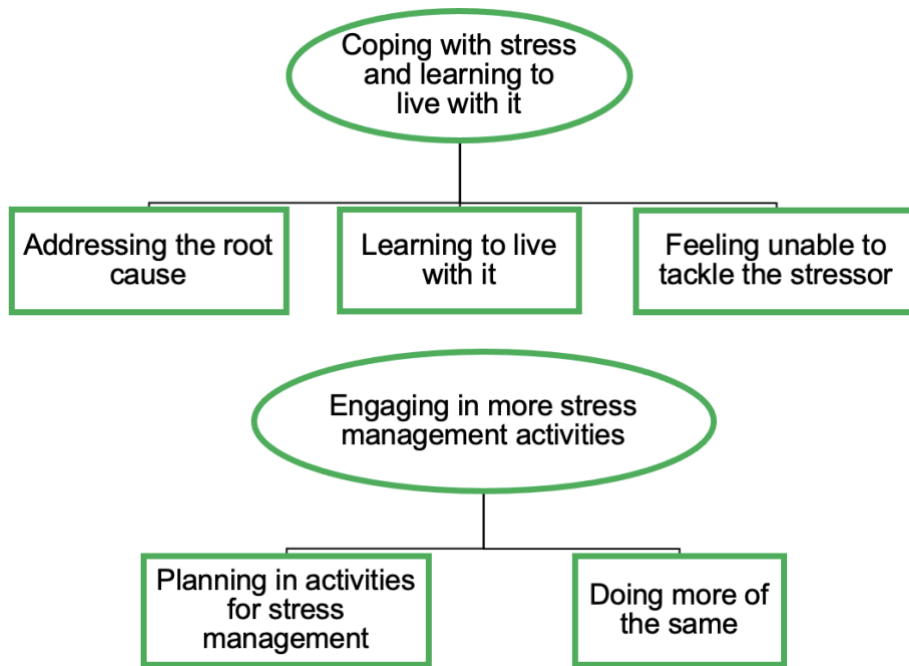


Figure 31. The three over-arching themes (circles) and eight sub themes (squares) derived from the semi-structured interviews. The blue border is used to indicate themes related to reflection/understanding and the green border is used to refer to action taking/management.

5.2.2.3 Raising Awareness of Stress Level through Self-monitoring and Reflection

Learn about stress levels and trends. When asked about the types of information that our participants learned from using Welltory, most of them answered that their primary and rather surprising, insight was that they were more stressed than they initially thought they were:

P(11) *“It made me reflect on whether I was stressed more than maybe I thought I was.”.*

For P(24), this realisation encouraged him to engage in stress self-management:

P(24) *“Actually, I used to think that I was stressed out and I didn’t really know for sure...But now the app (Welltory) made me realise that I’m actually stressed out and need to take steps for that so that was really helpful.”.*

Echoing the findings presented in Chapter 4, our participants again reported facing challenges with interpreting graph-based visualisations of their data:

P(6): *“I looked at the graphs a bit but not too much. The graphs were a bit confusing and not many trends had showed up yet. I usually relied on my memory to remember past measurements.”*

Instead of looking at graphs that visualised long-term trends, our participants preferred to reflect on their daily Welltory measurement results because a) the daily measurements enabled them to more immediately adjust their behaviours and b) the lack of variability in long-term data made it less valuable in informing these types of decisions:

P(7) *“I found looking at the day to day stuff more interesting compared to looking at weekly trends. I found that it was easier to manipulate what I was doing during the day, and I found that it looked relatively the same from day to day from what I was interpreting in it. So, I didn’t look at my weekly data.”*

Because people did not find any noticeable variability in their longer-term (e.g., weekly) measurement results, they reported primarily relying on their memory to make comparisons between their past measurements. As P(5) explained, this process was made easier by the fact that Welltory used scores and colour coded icons to aid peoples’ memory when reflecting on weekly trends:

P(5) *“I would try to remember my stress and productivity scores, generally what was displayed on the panel. And usually, they were around the same level. There was not that much variability.”*

Reinforce existing knowledge about factors affecting stress levels. Instead of learning new information about stress and the factors affecting it, our participants reported the Welltory app confirming their pre-existing knowledge about stress:

P(18) *“It kind of just confirmed what kind of things stressed me out or the things that helped me to relax.”*

For P(8), this helped to reinforce her prior beliefs about stress and motivate continuous engagement in helpful behaviours:

P(8) *"It was almost like a reassurance that I was doing the right thing. Because sometimes when you do mindfulness and yoga and if you think it goes particularly badly or you're just not in the mood...but then you get the confirmation that your heart rate had come down and generally your numbers looked better then I would be motivated to keep on doing that."*

Becoming more Aware of Objective Stress Levels (Welltory) but not what Causes Stress. Our participants reported becoming more aware of what their stress levels were and when they should act to self-regulate these:

P (11) *"I'm more aware of when I feel changes in my body or that I can keep a lot of stress and then blow at some point...But now I am more aware, I feel when that's about to happen and so I can intervene before it does."*

Some participants (2) even reported that the practice of self-monitoring and reflection on their self-tracking data representing stress led to them realising that they have the capacity to successfully manage their stress. This was driven by the observation that they were able to successfully manage their stress in the past:

P(18) *"I feel that I can do something about stress and documenting it really reinforces the idea that stress will not last forever and I can really de-stress."*

However, most of our participants' reports did not refer to them becoming more aware of what specific factors affected their stress levels – a process which is central to problem-focused coping. Instead of taking steps to mitigate potential stressors, most of our participants reported making reactive changes in their behaviour based on their stress levels at the time:

P(6) *"It was more oh my body is in stress right now I should do something right now. It made me more aware of the bodily aspects of my stress."*

5.2.2.4 Coping with Stress and Learning to Live with it

Addressing the root cause. As mentioned in the previous section, only two of our participants reported trying to address the root cause of their stress. For instance,

P(18) explained that, even though procrastinating and ignoring her issues might be easier, she understood the importance of tackling her issues head-on:

P(18) "Like sometimes I watch Netflix when I'm stressed but that doesn't really work to help me de-stress and address the root cause. It's more like procrastinating and avoiding the problem but when I actually sit down and think that I really need to do my dissertation and that is more addressing the root cause and that helps."

As P(8) explained, whether she engaged in problem-focused coping primarily depended on whether she felt that the stressor was worth approaching or could be resolved:

P(8) "If it's just bad day at work then there is no point in digging in to them deeper, but if it's something like friend dramas then you're gonna sort that out."

Learning to live with it. The participants (2) who reported already knowing what the sources of their stress were explained that they simply wanted to learn how to live with those stressors so that they have a minimal impact on them:

P(12) "I worry so much in my life and I already know what causes my stress. I think the best thing for me is to learn how to live with it and find out a way for it to have a minimal effect on you."

This was particularly the case when people felt that they could not remove the root source of their stress:

P(27) "I can't really do anything to help with the root of my stress. Because the thing that is causing you stress cannot be removed, you have to do it."

Feeling unable to tackle the stressor. There were also people (4) who felt unable to tackle their stressor:

P(5) "I don't think I can do that much about it because it's related to my work and deadlines."

For some, thinking about their stress resulted in them becoming even more stressed:

P(30) *“I would try to avoid and distract. Because I think it would be even more distressing for me. I feel that I already know what the stressor is and if I engage with whatever it is, it will make me even more agitated.”*

For others, this was simply due to a lack of resources at hand:

P(7) *“I do like confronting my stressors, but just that at times when you have so many different kinds of stressors that are in my face all the time, it’s hard to manage all of them all at once.”*

5.2.2.5 Engaging in more Stress Management Activities

Planning in activities for stress management. Some of our participants (6) reported that they would plan in more relaxing activities and set aside more time for themselves. As P(15) highlighted, intentionally setting aside time for herself was what helped her to engage in self-care:

P(15) *“I would plan. I would mainly realise that I am stressed when I’m back home and then I couldn’t be bothered to go back out. But if I realise I’m stressed today then I would hit the gym, go play football...Time management is important, setting some time aside for myself.”*

When asked about the types of app features they would prefer using to schedule-in relaxing activities, most of our participants referred to a flexible approach, which contrasts with the goal setting features incorporated into most stress management apps (e.g., specify the activity type and frequency and set a recurring reminder to perform the goal-directed behaviour, see Chapter 3). Participants in this study preferred making plans that were flexible (i.e., gave them autonomy) and focused on doing relaxing activities in the short-term (on the same or the next day):

P(18) *“I usually do breathing or try meditating...But I would try to do it during that day. I would not plan too far in advance. Say if I plan to run and then my friends would invite me for dinner I would not run. But it’s (dinner with friends) also equally a de-stressing activity.”*

Doing more of the same. For most people, using the Welltory and Evernote apps did not result in an uptake of new stress management activities. Instead, people reported engaging in more relaxing or helpful activities that they knew had worked for them in the past:

P(30) *“So I did used to go to the gym, but I just went more often, same with walks...So I did do the same activities but more frequently.”*

It was evident that continuous self-monitoring helped our participants to become more aware of when they needed to engage in stress self-management:

(P6) *“After the study I became more aware...It was more oh my body is in stress right now I should do something right now.”*

Similarly, we also find evidence that in addition to self-monitoring, being reminded and becoming aware of the benefits associated with engaging in self-care activities that people used to do in the past motivated further engagement in those activities:

P(11) *“I picked up yoga and reading again. It made me more conscious about how stressed I am. I now am more motivated to do this as I now realise how important it is for me.”*

5.2.2.6 Can Apps which Primarily Focus on Supporting Reflection Lead to Significantly Lower Levels of Perceived Stress?

The difference between perceived stress (PSS) scores taken at the beginning and the end of the study was used to measure the level of change in perceived stress over the 3-week study period. Lower (negative) values represent a greater decrease in stress levels.

The mean baseline levels of perceived levels of stress for this sample was 21.24 (SD=9.28). The scores ranged between 6-39 (PSS scores can range between 0-40). By the end of the 3-week period, the participants of this study reduced their levels of perceived stress by an average of 2.24 points (10.5%). A Wilcoxon signed-rank test was used to assess whether there was a difference between the PSS scores measured at the beginning and the end of the study. There was no significant difference ($p=.143$) between the PSS scores taken at the beginning ($M=21.24$,

SD=9.28) and end (M=19, SD=7.08) of the 3-week self-tracking period (see Figure 32. Change in stress (PSS scores) between the beginning and the end of the study (bars represent standard error).Figure 32). The effect size was $d=0.27$; $CI = [-0.41 to 0.94]$.

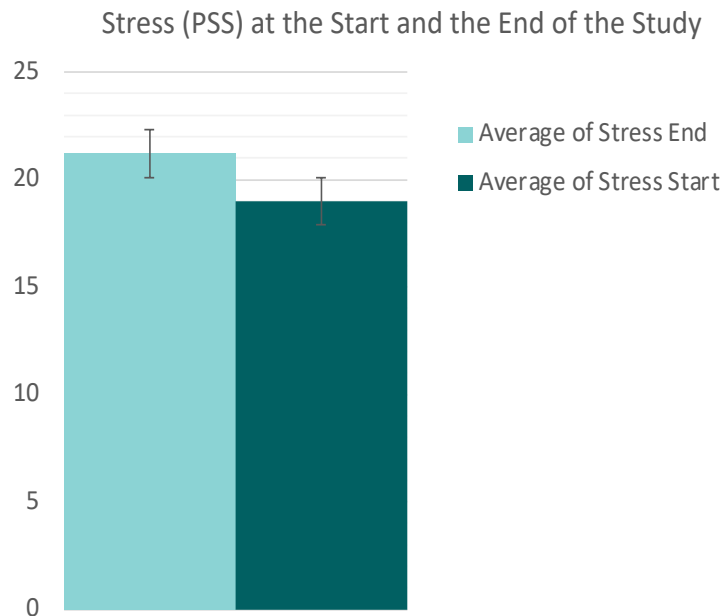


Figure 32. Change in stress (PSS scores) between the beginning and the end of the study (bars represent standard error).

5.3 Discussion

The research presented in this chapter demonstrates that the use of reflective questioning provides people with meaningful insights into their stress, even during the initial stages of using a self-tracking app. However, this does not translate to significant short-term improvements in stress levels. We also find that, instead of setting goals, people preferred to engage in flexible short-term planning to schedule in relaxing self-care activities for the following day. Below, we briefly discuss our findings in relation to past work. A more detailed interpretation of our findings is provided in Chapter 7, where we present a study aimed at evaluating the combined use of reflective questioning and self-regulatory BCTs adapted to better fit users' stress self-management needs.

Findings from the present study demonstrate that our participants' insights were qualitatively similar to those that people reported gaining in related research

investigating how people reflected on and gained insights from their data visualisations (Choe et al. 2014b; Choe, Lee, et al. 2017; Cuttone et al. 2014; Huang et al. 2015). Specifically, the insights reported in our study and that of others (Choe et al. 2014b; Huang et al. 2015; Li et al. 2011) both included identifying information such as trends, patterns, and context factors associated with a target behaviour or outcome measure (e.g., stress). For example, in their study of how quantified-selfers collect and explore personal data, Choe et al. (2014) noted that people often used descriptive statistics to make comparisons between different data points and relied on correlational analysis to find relationships between variables that they monitored. We similarly found that our participants valued comparing different Welltory measurement results to understand and keep track of changes in their stress over time (trends). However, we additionally identify that, in our study, people primarily relied on their memory instead of graphs to make comparisons across different measurement results. In fact, even though most of the insights reported on the Evernote journal focused on identifying relationships between stress and another factor, such as sleep or diet, none of the text entries referred to tags or scores displayed on the Welltory app. It is therefore possible that people gained these insights through introspection rather than from reflecting on correlational analysis results or graphs presented via Welltory – a finding that will be further investigated in Chapter 7.

Even though our participants reported gaining meaningful insights about their stress and displayed good engagement with both apps, no significant changes in stress levels were observed. This finding is unsurprising as neither the Welltory app nor the Evernote journal included features designed to explicitly support action taking for stress self-management. Self-monitoring can help people become more aware of the factors they are monitoring (Choe et al. 2014a; Dijk et al. 2017a; Rapp and Cena 2014). As we found in Chapter 4, having this awareness makes people more sensitive to recognising their stress levels and the need to engage in self-care. In some cases, this process alone can lead to action-taking (Dijk et al. 2017a). Yet, the lack of short-term changes in stress levels reported in the present study help reinforce the proposition discussed in the behaviour change literature: people looking to change their behaviour, including behaviours relating to stress self-management, can benefit from using self-monitoring in conjunction with other self-regulatory BCTs (Sniehotta 2009; Sniehotta, Scholz, et al. 2005). For instance, findings from our studies presented

in Chapter 4 indicate that people can also experience gains in awareness by engaging in goal setting. This finding suggests that people need to become aware not only of what their stress levels and the factors affecting these are, but also be cognisant of what types of activities can help them manage their stress. As explained in our previous chapter, setting goals to do stress management activities can help people keep those activities front of mind. In line with the literature on behaviour change, specifically that which focuses on the intention-behaviour discordance (Hagger and Chatzisarantis 2014; Sniehotta 2009; Sniehotta, Scholz, et al. 2005), we provide preliminary evidence that incorporating self-regulatory BCTs (e.g., goal setting) has the potential to help improve on the short-term impact of stress self-monitoring apps.

In our previous study we found that, even though goal setting can help with encouraging engagement in beneficial stress coping activities, there is still space for improvement in terms of how such BCTs are implemented into existing apps. The aim of the rest of the work presented in this thesis is to address the second feature gap identified during studies 1-3: the way in which existing stress management apps incorporate features intended to support people in applying their insights to regulate stress. We address this feature gap in the next two chapters of this thesis by 1) informing the design of alternative app features used to promote self-regulation in a stress self-management context (Chapter 6) and 2) evaluate whether the designed features can help people to self-manage their stress in a need fulfilling way (Chapter 7).

6 Designing a Chatbot Prototype for Stress Self-management

The primary aim of this chapter is to inform the design of novel app features that can better support people with action-taking when self-managing their stress (e.g., action planning). We begin with an overview of the work and the findings relating to this thesis thus far. This leads us to contend that our previous approach, which was primarily informed by research on personal informatics and behaviour change, did not fully meet people's stress self-management needs. To devise a more appropriate solution, we make the decision to pivot our original design approach to design practices outlined in the positive computing literature. We therefore review the literature on positive computing and link it back to practices relating to stress coping. Based on our findings from the literature, we present design guidelines on how apps can incorporate coping-relevant BCTs. In doing so, we identify that a chatbot-based interface lends itself particularly well in supporting people with both implementing coping-relevant BCTs and addressing their needs relating to stress self-management. The final section of this chapter outlines the conversational designs used to implement Reffy - a stress self-management chatbot prototype.

6.1 Challenges with Existing App Features that Incorporate Coping-relevant BCTs to Encourage Engagement in Stress Management Behaviours

Before describing the process by which we inform our design guidelines, we present a brief overview of the finding from the research presented in this thesis that motivated our efforts to explore new approaches of incorporating BCTs into stress management apps. As we found through our research presented in Chapter 3, the currently available stress management apps fall short of their potential effectiveness to support people trying to understand and manage their stress. In Chapter 4 we report Studies 2-3 in which we additionally discover that, even when users are given apps that include features and techniques shown to benefit people in therapy settings, they still face

difficulties when implementing the associated techniques in their day to day lives. This is due to two feature gaps: 1) the lack of data upon which users can reflect upon, particularly during early stages of use, and 2) inadequate guidance on how to practically apply the insights they have gained to regulating their stress. We address feature gap 1 in Study 4 (Chapter 5) by demonstrating how journaling-based reflective questioning can overcome the initial barrier of not having access to self-tracking data. Specifically, due to the inclusion of reflective questioning, our participants were able to gain insights that were qualitatively similar to those reported by people after longer periods of self-tracking in domains such as sleep and physical activity (see Chapter 4, also Choe et al., 2014; Cuttone et al., 2014). Our study also confirmed the long-standing notion that self-monitoring and reflection alone are insufficient to elicit change (Dijk et al. 2017a; Sniehotta 2009).

However, as we find in Chapter 4 (Study 3), the broader issue lies in how existing stress management apps incorporate features intended to support people in applying their insights to regulate stress (feature gap 2). For example, the goal-setting feature implemented in the Coach.me app lacked flexibility and guidance – two attributes that we found to be essential for helping people adhere to selected stress management behaviours. Based on these findings, we identify that people have express needs related to their use of stress management apps for implementing coping-relevant BCTs: 1) being able to initiate stress management behaviours without undermining their sense of autonomy, and 2) receiving guidance on how to apply their insights about stress to form effective stress management strategies. Therefore, our aim in this chapter is to inform how to design novel app features that can help people translate their newfound insights into stress coping strategies whilst still promoting their sense of autonomy (i.e. addresses feature gap 2).

6.2 Benefits and Challenges of Using Goal Setting to Encourage Engagement in Stress Management Behaviours

To inform the design of app features for supporting people with stress self-management, the following section provides a brief evaluation of the benefits and challenges of using goal setting and automated reminders in a stress management context. We will draw on this evaluation in the later sections of this chapter to inform novel solutions for supporting action-taking to encourage stress-self management (address feature gap 2). Notably, here we use the Coach.me app to illustrate how apps incorporate goal-setting features. We do so because findings from our app functionality review (Chapter 3, section 3.4.5) indicate that Coach.me includes a representative example of how stress management apps incorporate features that support goal-setting.

6.2.1 Goal Setting can Motivate more Frequent Engagement in Stress Management Behaviours and Activities

In Chapter 4, we found that our participants appreciated the concept of goal setting for stress management and reported previously using goal setting as a method for motivating engagement in beneficial health behaviours. Additionally, findings from Study 2 indicate that people who set a higher number of goals were more likely to lower their stress to a greater extent than those participants who set fewer goals. However, the procedure by which people implemented goals outside of using the app was more flexible than the goal-setting procedure incorporated in the Coach.me app.

6.2.2 Goal Setting and Monitoring Features Incorporated into Existing Apps Impair People's Sense of Autonomy

In Chapter 4, we find that even though goal setting did encourage engagement in stress management activities, the way in which it was incorporated into Coach.me undermined people's sense of autonomy. This is because Coach.me, and other apps that include goal setting for stress management (see Chapter 3), ask their users to

specify an activity they would like to perform alongside its frequency and time. The app then sends automated reminders at the specified times. As we found in our third study, this procedure can inadvertently diminish people's need to exercise autonomy. Participants in Study 3 reported disliking the reminders sent by the Coach.me app as missing a planned activity would make them feel even more stressed. Similarly, Study 4 participants reported that they would feel guilty if they missed a planned activity.

Based on the above evaluation, the following section presents a study that investigates approaches other than goal setting to support people with adhering to various stress management behaviours.

6.3 Personal Informatics and Behaviour Change: Informing the Design of Novel App Features to Encourage Engagement in Stress Management

The study reported below was an MSc dissertation project completed by Annika Schmid (2018) at UCLIC and was supervised by the author of this thesis.

Schmid (2018) draws on theoretical models of personal informatics (Li et al. 2010a) and behaviour change (Sniehotta 2009) to inform new ways of incorporating coping-relevant BCTs that support action-taking into an app interface. In her work, Schmidt (2018) described the design of a stress self-management worksheet, the aim of which was to help people identify the factors that affected their stress levels and formulate strategies for managing them (Schmid, 2018).

The worksheet builds on the processes that define the reflection and action stages in the stage-based model of personal informatics (Li et al. 2010a, 2011). Following the practices that people are expected to engage in during the reflection stage, the first section of the worksheet instructs people to 1) identify the sources of their stress, 2) note the times at which they are more likely to feel stressed, and 3) come up with activities they can do to relax. In doing so, it prompts people to recall and reason over the trends and patterns in their stress levels, as well as to think about the factors that will either cause them more stress or help them to relax. These are the types of insights

that users would be expected to gain after reflecting on long-term self-monitoring data using personal informatics tools (Choe et al., 2017; Dijk et al., 2017; Li et al., 2010a).

The second part of the worksheet draws on the action stage described in Li et al's PI model and the action planning procedure discussed in (Sniehotta 2009). The action planning component, which requires the users to specify when and how to act, was designed to mitigate potential barriers when transitioning between the reflection and action stages (Li et al. 2010a). This part of the worksheet therefore provided people with guidance on how they can apply the insights gathered from the previous reflection steps to form a stress self-management action plan. In doing so, it provides more guidance on forming coping strategies than typical goal-setting features do (Chapter 3) (Schmid 2018).

The effects of the combined use of the stress management worksheet and the Welltory app were evaluated in a 3-week intervention with 10 participants, followed by semi-structured interviews (Schmid, 2018). Although no significant short-term changes in stress levels were observed, it was found that people using Welltory tended to primarily confirm and become more aware of their pre-existing knowledge about stress. However, this did not lead to any drastic changes in the participants' behaviours.

The same study also indicated that the primary reason behind the stress management worksheet not leading to changes in stress levels was that people were only asked to complete it at the beginning of the self-tracking process. This resulted in people either forgetting what their stress management action plans were or the stressor that they had planned for did not re-occur during the 3-week study period. Some participants also found it challenging to think about their stress in such a structured manner (*identify a stressor → write an action plan to resolve it*). What these findings revealed was that, for people to create an effective stress management action plan, they need to a) be asked to provide a reoccurring stressor, b) complete the exercise more than once, and c) be provided with additional guidance on how they can resolve their stressor (Schmid, 2018).

The above findings indicate that relying on personal informatics and behaviour change research alone will be insufficient to inform the design of app features intended to

support people in implementing coping relevant BCTs. In light of these findings, we again shift our focus from the personal informatics and behaviour change literature to research and design that encompasses an area collectively known as *positive computing*.

6.4 Design for Wellbeing and Stress Coping: Informing the Design of Novel App Features to Encourage Engagement in Stress Management Behaviours

Positive computing focuses on wellbeing-supportive technology design (Calvo and Peters 2014). It provides a theoretical framework for designing and evaluating technologies aimed at increasing wellbeing determinants such as self-awareness, gratitude, mindfulness, motivation, compassion, and resilience, among others. More importantly, unlike most theoretical work relating to personal informatics and behaviour change techniques, research on positive computing pays greater attention to motivational antecedents of behaviour change (Diefenbach 2018; Peters, Calvo, and Ryan 2018; Wiese, Pohlmeyer, and Hekkert 2020) – a theoretical element that was largely overlooked in our previous field studies. As such, below we provide a brief summary of related work in the area of positive computing that we later apply to inform our own designs.

According to Diefenbach (2018), technologies designed for greater wellbeing need to reach an equilibrium between *demand* and *autonomy* promoting features and/or behavioural strategies incorporated into those features. A feature can be considered as demanding if it constrains flexibility. For example, a technique such as goal setting can be considered as more flexible and, therefore, less demanding than creating a specific plan that requires indicating when, where, with whom, and how to act. In their survey of 177 users of self-improvement technologies, Diefenbach et al. (2016) found that users benefited the most from technology that provided them with a clear call to action, but also left room for flexibility in how people should act to reach their wellbeing goals. What they also highlight is that features enabling greater user autonomy are perceived by users as more beneficial at the beginning of an intervention, whereas

demanding features add more value during the later stages of change. This is primarily because app features that command action can lead to negative experiences (as we have also found in our own Studies 3-4 presented in Chapters 4-5). However, once people become more accustomed to the change process (and the potential negative experiences arising from it), they become more accepting of features that *demand* change through discipline and challenge. Based on these findings, Diefenbach (2018) argues that technology should highlight opportunities for change by design. She also suggests that, to facilitate the process of change in a way that balances *demand* and *autonomy*, instead of highlighting faults in its users, technology should be designed to communicate the act of change as caring for oneself.

Relatedly, building on Diefenbach's (2018) call to frame the act of change as caring for oneself, Wiess et al. (2020) further conceptualises this by highlighting the value of designing technologies that promote engagement in positive activities as a way of improving on people's wellbeing. According to the authors, interacting with wellbeing supportive technologies and the features (e.g., self-monitoring, goal setting) that they include can promote engagement in positive activities. Wiess et al. (2020) define a positive activity as any evidence-based wellbeing enhancing activity that aligns with the individual's goals, needs, and values. Examples of such activities include developing coping strategies, committing to one's goals, taking care of one's body and mind. Engaging in technology-supported positive activities can in turn lead to positive experiences, such as positive behaviours, feelings, and emotions. These positive experiences are what ultimately leads people to greater wellbeing (Peters et al. 2018; Wiese et al. 2020).

Both Diefenbach (2018) and Wiese et al. (2020) highlight that, technologies aiming to support behaviour change should additionally consider motivational factors that mediate this process. Notably, our own finding that people required balancing autonomy and guidance when implementing BCTs aligns well with the self-determination theory (SDT) (Deci and Ryan 1985a). According to SDT, to sustain motivation and wellbeing, the following three basic psychological needs have to be met: 1) *autonomy*, including experiences of agency and acting in accordance with one's goals and values, 2) *competence*, which refers to feeling capable of carrying out a task or engaging in a given behaviour, and 3) *relatedness*, which involves feeling

connected to others. The stress management needs that we have identified in our previous work align closely with the concepts of autonomy (*need two*: ability to initiate stress management behaviours as and when needed) and competence (*need three*: receiving guidance on how to form stress management strategies). Because SDT has been successfully applied to inform and evaluate technology design (Hassenzahl et al. 2013; Jansen, Van Mechelen, and Slegers 2017; Yang and Aurisicchio 2021), it can similarly help guide our own efforts in developing app features that support people with both implementing coping-relevant BCTs and addressing their stress self-management needs.

Notably, Peters et al. (2018) draw on the core principles of SDT and positive computing to propose *the model for motivation, engagement, and thriving in the user experience* (METUX) (Peters et al. 2018). According to the model, wellbeing enhancing technologies should strive to address the needs for autonomy, competence, and relatedness within five spheres (levels) of individual user experience. The model begins with the *adoption* sphere, which entails the experiences and motivations relating to acquiring and adopting a new technology. The *interface* sphere encompasses experiences that arise from the direct interaction with the technology via its interface. For example, interface design that addresses users' needs for autonomy can translate into users' ability to easily navigate that interface. The *task* sphere concerns itself with experiences arising from engaging in technology-supported tasks. This includes actions such as self-monitoring and planning. The *behaviour* sphere aims to capture the experiences associated with engaging in a technology-supported behaviour. The *life* sphere describes experiences that pertain to the user's overall life, beyond interacting with the technology. Within the context of a behavioural intervention, the model suggests that for a technology to maximise positive impact on health and/or behavioural outcomes, it should aim to support the basic psychological needs of autonomy, competence, and relatedness at all five sphere levels (Peters et al. 2018).

Our subsequent work draws on the positive computing literature discussed above (Diefenbach 2018; Diefenbach et al. 2016; Hassenzahl et al. 2013; Peters et al. 2018; Wiese et al. 2020) as well as on the METUX model (Peters et al. 2018) to help inform design guidelines for app features that can better support people in initiating and

adhering to stress self-management behaviours. Following the call to support motivational determinants of behaviour change, we aim to design app features that promote the process of engaging in autonomous self-regulation and provide guidance to users on how they can self-manage their stress. To achieve this, we first draw on the METUX model (Peters et al. 2018), which suggests that the need for autonomy and competence can be influenced across different spheres of user experience. Specifically, as the research question addressed by this thesis aims to inform how technology can support people with applying BCTs to better understand and manage their stress, our design guidelines primarily focus on supporting the needs for autonomy and competence at the technology-supported task, behaviour, and life spheres (Peters et al. 2018). To design app features that can support autonomy and competence across the aforementioned spheres, we next build on Diefenbach's (2018) work, where she details how to design digital wellbeing interventions in a way that balances *demand* and *autonomy*. We aim to achieve this balance through 1) implementing features that provide people with structured frameworks/techniques upon which they can rely on to effectively self-manage their stress (demand/competence) and 2) designing and implementing these features in a way that leave space for flexibility in terms of how and when people can apply them to self-manage their stress (autonomy). In the next section, we outline a set of design guidelines based on our own findings and the insights drawn from the stress coping, behaviour change, and motivation literature.

6.5 Design Guidelines for App Features to Support Users with Autonomous Self-regulation and Guidance for Stress Self-management

In this section, we propose two design guidelines for addressing the second feature gap (supporting people with stress self-management). Each sub-section begins by defining the design guideline and outlining what it entails. This is followed by providing additional context and motivation for proposing each design guideline. Finally, each section finishes with a summary of the evidence that were used to inform that design guideline.

6.5.1 Design Guideline 1: Support Autonomy by Using Short-term Planning to Prompt Engagement in Stress Management Behaviours

Setting short-term plans instead of structured and rigid goals can encourage people to engage in more stress self-management activities than they usually would, without the negative connotations associated with missing a planned activity. Similarly, instead of sending automated reminders to perform a given activity, making people more aware of the different activities they can do to relax the next day (as a means of short-term planning) can lead to the same benefits as reminders.

Design motivation: In Study 3 (Chapter 4), we find that people expressed a need to engage in stress management behaviours of their own volition instead of having an app notification instructing them to do so. We also found that heightening people's awareness of their stress levels and activities they can do to relax encouraged more frequent engagement in self-regulatory behaviours for stress self-management. Therefore, we hypothesise that designing app features that rely on awareness instead of automated reminders can help support *autonomous self-regulation*.

More specifically, we aim to support *autonomous self-regulation* by using short-term planning prompts that encourage engagement in daily positive self-care behaviours. Because people can more accurately forecast their schedules a day in advance, it is expected that they should be able to plan in more realistic and attainable daily self-care activities. This, in turn, should help ensure that people can successfully enact those planned activities, which is what we hypothesise should intrinsically motivate people to continuously engage in and create positive and uplifting experiences in their day-to-day lives (Peters et al. 2018; Wiese et al. 2020).

Evidence for design: In Study 4, people reported that they preferred making flexible short-term plans to setting structured goals: P(18) "...I would try to do it during that day. I would not plan too far in advance. Say if I plan to run and then my friends would invite me for dinner I would not run. But it's (dinner with friends) also equally a de-stressing activity.". They also reported that this would help them avoid the feeling of guilt associated with missing a given activity: P(38) "...Whereas if I just plan a day

ahead knowing how I feel, it's more realistic for me and I won't feel so guilty if the plan doesn't fall through". What these findings additionally highlight is that, besides having control over when to perform a given activity, people should also feel that they can change the activity type itself. Relatedly, as was demonstrated in Studies 3 and 4, people engaged in more stress management behaviours not because of the reminders to do a given activity but because of the heightened awareness of their stress levels and the need to manage them: F3P4 *"I think it was just the heightened awareness of your stress and this helped you to moderate your life subconsciously."*

6.5.2 Design Guideline 2: Use Problem-solving to Help People Feel more Competent in Forming and Executing Stress Management Strategies

Where short-term plans can prompt people to engage in more frequent stress management behaviours the next day, using techniques such as *problem-solving* can provide people with guidance on how to create an action plan that outlines the steps they should take to manage or resolve a given stressor. Because the problem-solving exercise additionally involves a variety of cognitive-behavioural techniques, such as laddering and guided discovery (taking more than one attempt to find solutions to a given stressor) or cognitive restructuring (looking at a situation from an outsider's perspective to minimise biases in one's own ability to cope) (Leahy 2018; Overholser 2013), it can help people think more deeply about what steps they can take to address a given stressor, thereby leading to more informed and meaningful action plans.

Design motivation. Findings by Schmid (2018) indicate that people required explicit, step-by-step guidance designed to help them think about the ways in which they could manage a given stressor. That is, people needed a tool that would alter their perceived ability to control and cope with stressful experiences. They needed to feel competent in their stress management abilities. Notably, designing app features that address this need is particularly important because feelings of stress are oftentimes linked to a loss of control and inability to cope (Nezu 2004). Empowering people with the tools they need to improve on their ability to cope can help account for such deficiencies.

Stress coping literature discusses a therapeutic technique called *problem-solving* (Cox 1987; Lazarus and Folkman 1984) that has the potential to both help users form stress coping strategies and support their stress management needs with regards to competence. In general, the problem-solving exercise aims to accomplish very much the same outcomes as the self-monitoring, goal setting, and action planning techniques discussed in personal informatics and behaviour change domains (Li et al. 2010a; Sniehotta 2009). As the name implies, *problem-solving* is a problem-focused coping technique frequently applied in self-help and therapy settings (Cox 1987; Peters et al. 2018). The aim is to help people identify the problem or the stressor at hand, and try to come up with a set of solutions for how to address it. This exercise goes beyond simply identifying a stressor and creating an action plan, as was done in Schmid (2018). It additionally guides people through a series of steps designed to reveal unhelpful thought patterns and assist them in considering different solutions (action plans) for resolving their stressors. Only then are people instructed to evaluate and select one solution based on its pros and cons. These additional measures can promote people's sense of competence in managing their stress, primarily through improving their perceived control over a given stressor and providing them with a clear action plan for its management (Cox 1987; Nezu 2004).

Evidence for design: In Study 3, the participants' preferences with regards to goal setting aligned more with action planning (also known as if-then planning) than with goal monitoring: F3P3 "...so if I'm at home, I take every opportunity to relax.". Findings from Study 3 indicated that by monitoring how various context factors related to stress outcomes, people became more aware of context-dependent cues for engaging in stress management behaviours. In the presence of a given cue, such as an argument or a quiet place to relax, people would automatically activate the associated action plans and adjust their behaviour accordingly: F1P1 "*I did notice that conflict definitely did have an impact on my stress levels so I would try to avoid that as much as possible.*". Additionally, findings from Schmid (2018) indicate that, people sometimes find it challenging to create action plans for tackling given stressors without getting additional guidance on how a given stressor could be resolved first: P(14) "... So it was quite hard in a way to think about in such a structured way like, oh, this is what stresses me and this is how I can tackle it.".

6.6 Guiding People in how they can Manage their own Stress – a Case for Chatbots

We argue here that chatbots can act as a suitable interface for delivering coping-relevant BCTs in a way that addresses both the two design guidelines described above and the insights stemming from the positive computing literature. Firstly, a chatbot interface can be used to check-in with the users about how they are feeling and then prompt them to plan in relaxing activities for the following day (short-term planning). The primary way in which our proposed chatbot-based planning feature contrasts with the goal setting and planning features used by Coach.me, is that the former provides a more natural, conversational, and flexible way of inviting people to continuously update their planned activities based on their current schedules and needs, whereas the latter was designed to accommodate fixed activity schedules and types (e.g., doing yoga Monday, Tuesday, Friday at 8am). Secondly, a chatbot interface can provide an intuitive way of guiding people through various structured behavioural tasks (Fitzpatrick, Darcy, and Vierhile 2017; Kocielnik, Xiao, et al. 2018; Kocielnik and Hsieh 2017b), and should therefore also support users with problem-solving. These types of structured tasks can provide people with a framework that helps them clearly define what their stressors and their sources are and then guide them towards applying this information to form coping strategies (*demand/competence*) (Cox 1987; Nezu 2004). This type of flexibility and guidance afforded by a chatbot interface is what we anticipate will enable us to balance the *demand* and *autonomy* supporting features in our chatbot's conversational designs (Diefenbach 2018).

There are, in fact, existing examples of chatbots being used to support people with both stress coping and behaviour change (Fitzpatrick et al. 2017; Inkster, Sarda, and Subramanian 2018; Kocielnik, Xiao, et al. 2018; Kocielnik and Hsieh 2017b). For example, research evaluating the efficacy of Wysa (Inkster et al. 2018) and Woebot (Fitzpatrick et al. 2017) demonstrates the efficacy and acceptability of delivering self-help materials via a conversational interface. However, because the primary aim of these studies was to evaluate efficacy and acceptability related outcomes, they do not provide design guidelines on how evidence-based techniques can be translated and incorporated into a chatbot interface. Similarly, a chatbot incorporating motivational

interviewing techniques (e.g., asking people how a given stressor affected them and how they had coped with it in the past) has been shown to enable reflection on stress and facilitate conversations around change (Park et al. 2019). However, this study did not investigate the use of chatbot-based reflection within a self-tracking and behaviour change context.

Albeit focusing on physical activity rather than stress, Kocielnik, et al. (2018), have demonstrated how a conversational agent can help people notice and understand their behaviours and think of future actions in response to the gained insights. In their study, Kocielnik et al evaluate a chatbot that sends daily notifications to its users asking them to reflect on visualisations of their physical activity data (steps). The reflective questions follow three stages: noticing, understanding, and future actions. Like *problem-solving*, each subsequent stage builds on those prior to elicit deeper levels of reflection and understanding. For example, in the noticing stage, the chatbot asks the user whether they have met their step goal. In the understanding stage the questions are focused on helping users understand and interpret their own observations. Finally, in the future actions stage, users are asked whether they could do anything differently next time. Kocielnik et al find these dialogs to be successful in supporting reflection as well as awareness of goals and trends in behaviour. Their study additionally evidences that at least some of their participants (8/19) engaged in action planning to change their physical activity behaviours. Specifically, they reported forming concrete, small, and attainable steps towards making changes in their behaviour.

Finally, a chatbot interface can inherently mimic conversations that a therapist might have with a client (Fitzpatrick et al. 2017). This offers the added benefit of supporting people's need for relatedness, which can be achieved by taking conversational turns, asking reflective questions, acknowledging people's responses, and even using emojis to display empathy and care (Bae Brandtzæg et al. 2021; Peters et al. 2018; Schulman, Bickmore, and Sidner 2011).

Notably, in their METUX model (Peters et al. 2018) explain that it is not always necessary to focus on supporting relatedness at the interface level as not all interfaces require addressing this need. They define relatedness as "*feeling connected to others, a sense of belonging*". Following this definition, (Peters et al. 2018) explain that a designer might incorporate a button for sharing a personal digital journal entry with

others but that this can have a negative effect on user's sense of privacy. Looking at this from another perspective, supporting the need for relatedness at the interface level is important when designing chatbots within the wellbeing domain. However, instead of invoking the sense of "*feeling connected to other humans*", the designers aim here is to have the user feel connected to the chatbot. A good example of this is aiming to establish a therapeutic alliance between the chatbot and the user through the means of conversational design. Like in traditional face-to-face therapy with a human, the aim of such an alliance is to help people feel that they can open-up, be understood and listened to by the chatbot (D'Alfonso et al. 2020; Henson et al. 2019; Kim, Park, and Robert 2019).

Considering our above discussion, we highlight that, to truly design for meaningful experiences of relatedness (and even autonomy at the interface level), the chatbot requires holding conversations on a variety of topics mentioned by the users as this can help the users feel that they are being understood and listened to by the chatbot (Fitzpatrick et al. 2017; Yang and Aurisicchio 2021). The challenge here lies in that having this level of conversational design and data required to train a model that can handle such conversational capabilities requires designing and training chatbot conversations that span multiple wellbeing domains, which is beyond the scope of this thesis. Therefore, our conversational designs primarily focus on supporting peoples' sense of autonomy and competence in implementing coping-relevant BCTs in their day-to-day lives.

In summary, by leveraging the guidance and flexibility afforded by a chatbot interface in its ability to support people with implementing coping-relevant BCTs (Kocielnik et al, 2018), we implement the two design guidelines presented above as chatbot-based conversations. The resulting conversations incorporate features that support reflection and *problem-solving*, together with coping-relevant BCTs, including self-monitoring/reporting of insights about stress, short-term planning (in place of reminders), and action planning (in place of goal-setting).

6.7 Designing App Features to Promote Autonomous Self-regulation and Competence for Stress Self-management

The prototype was designed to support people's needs for autonomy and competence when implementing coping-relevant BCTs. It consists of 3 main conversational paths. The first conversation was dedicated to onboarding the participants onto the chatbot. The second conversation was a daily report, asking people about their stress levels and the factors affecting these. This element of the chatbot was informed by the approach used in Chapter 5 to help raise people's awareness of the factors affecting their stress (stress management need 1). The daily report also prompted people to plan relaxing activities for the next day (stress management need 1, design guideline 1). The third component of the chatbot was a *problem-solving* conversation, guiding the users through a series of steps designed to help them find ways of resolving their stressor (stress management need 2, design guideline 2).

6.7.1 Approach to Chatbot Architecture

Most chatbots found online are stateless, meaning that they do not keep any memory of the previous conversational turns (Shevat 2017). This type of chatbot architecture enables a user to ask questions about any arbitrary topic at any given point in the conversation. The chatbot is then expected to respond with a pre-defined answer to that particular question, provided it knows the answer. To achieve this, the chatbot needs to be trained to recognise a set of intents and entities that can be used to infer the appropriate response. This type of chatbot architecture lends itself well to developing generic frequently asked questions (FAQ) bots. However, it was decided that, instead of implementing a stateless bot, a tree and rule-based architecture would act as a more reliable solution for guiding people through structured therapy exercises. Firstly, unlike stateless chatbots, a rule-based chatbot does not require access to large amounts of prior training data used to train the intents and entities, based on which the conversational paths will be formed. Instead, it guides the users through a series of hard-coded conversational paths (Shevat 2017). Secondly, the stability afforded by a rule-based chatbot can help ensure that the users are guided through all the

necessary steps (e.g., laddering, cognitive restructuring) before they are asked to form a stress management action plan.

The key advantage of implementing a rule-based system is that it enables us to test the chatbot's value in delivering stress self-management exercises without needing to collect and annotate large amounts of conversational data. Relatedly, having access to such data becomes beneficial only once the chatbot has grown in conversational content and complexity. For example, a user may provide a response stating that they are feeling stressed from work. The chatbot can extract the keywords *stressed* and *work* from that message and use this information to direct the user to a conversational path that discusses work-related stress. As the chatbot that we are aiming to implement for our own research only contains an onboarding conversation, a daily report, and a weekly problem-solving exercise, having the ability to recognise multiple keywords would not add value at this stage of the implementation. There is simply no other conversational content available within the chatbot that the users could be guided to, and, as explained in the previous section, adding such content is beyond the scope of the present thesis. For our current intents and purposes, implementing the chatbot as a rule-based decision tree provides sufficient functionality to quickly and reliably test the feasibility of using a chatbot interface for providing people with access to stress self-management strategies.

6.7.2 Approach to Conversational Design

To design the conversations, we first defined the goal(s) of each conversational flow based on our previously identified design guidelines. For instance, the three primary goals of the daily report are: 1) to elicit information about the users' subjective stress levels, 2) what insights have they gained about their stress (reflective questioning, design guideline 1), and 3) ask them to plan in relaxing activities (short-term planning, design guideline 2). Once the goals of the conversation are identified, which, in our case, are to provide users with access to reflective questioning and short-term planning intervention components, we design the chatbot scripts that incorporate those intervention components (see Figure 47).

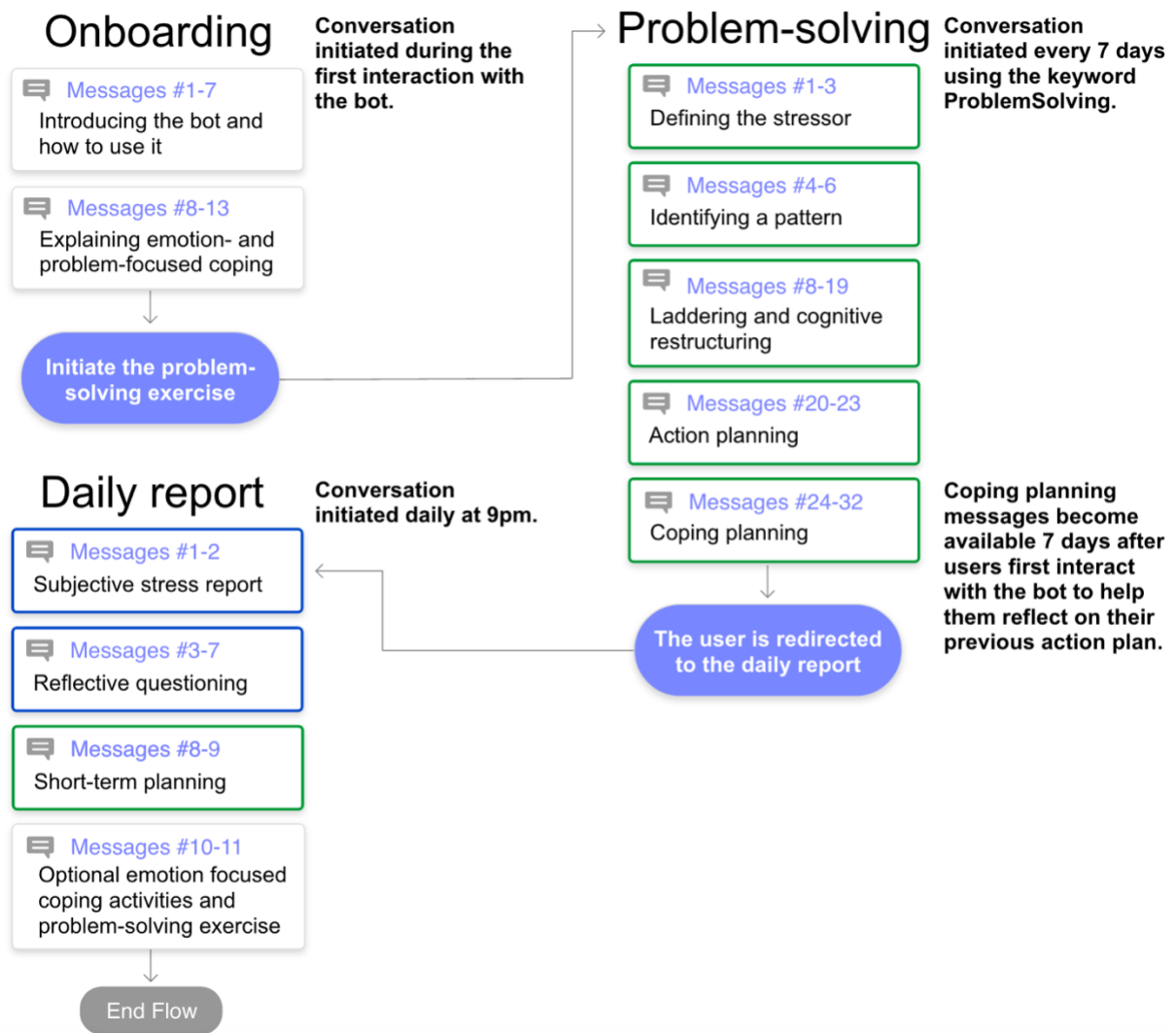


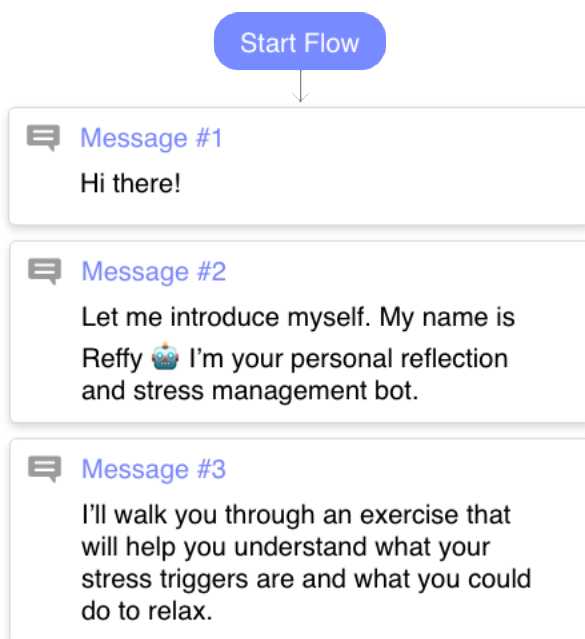
Figure 33. A summarised overview of the three conversations that constitute the Reffy chatbot: Onboarding, Daily report and Problem-solving. Each conversation is further split into smaller components, where each component includes a description of what the messages included in that component aim to achieve. Message boxes highlighted in blue represent intervention components related to reflection (design guideline 1), whereas intervention components highlighted in green refer to action taking (design guidelines 1&2). Full text included in the message can be found by referring to the message numbers and the conversations outlined in the sections below.

In the following sections, we describe and motivate designs for chatbot conversations which encompass the design guidelines and requirements that we have summarised previously, as well as describe the tools used to develop and deploy the chatbot. Where appropriate, we provide an overview of additional resources used to augment and transform evidence-based stress coping techniques into a chatbot conversation. The chatbot was designed by following the guidelines and best practices outlined in the Shevat (2017) designing bots manual.

6.7.3 Onboarding Conversation

In this section, we describe how the users begin interacting with our chatbot, which we call Reffy. Even though this part of the conversation does not include any of the intervention components (i.e., reflective questioning, short-term planning and problem-solving), it is essential that the users are instructed on how to use the chatbot and be introduced to its primary aims.

The users are first instructed to open up the Messenger chat with the Reffy chatbot and type in “Start”, which initiates the onboarding conversation (see Figure 34).



When designing chatbots, the primary aim of an onboarding conversation is to communicate to the users what the purpose of the bot is and how to navigate it. This step is essential in the implementation process because much of the visual cues that would normally be available to the users in a standard app interface, such as buttons or menu icons, are not available in a chatbot interface.

Figure 34. The Reffy chatbot introduces itself and explains how to use it.

The onboarding conversation is also the stage at which the chatbot begins to express its personality. This can be achieved through the means such as a distinct tone of voice, emojis, images, gifs and even the chatbot’s name. In this instance, the name Reffy was selected as it represents the primiray aim of the chatbot - to help people reflect.

The users are informed how long a given conversation is going to take. Buttons are used to collect simple binary responses from the user to quicken the conversation flow (see Figure 35).

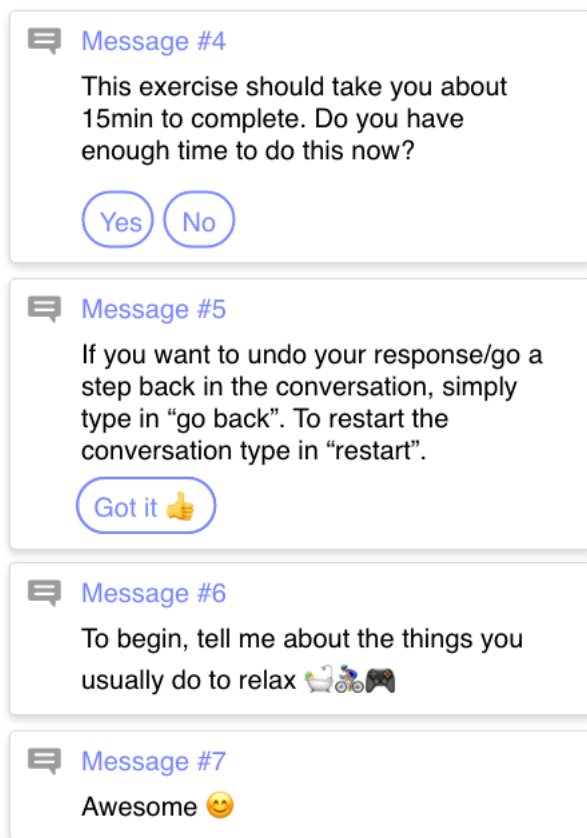


Figure 35. Messages #4-7 provide further information about the chatbot, its personality and its use.

Each conversational turn made by the bot is limited to no more than 3 messages at a time (with only very few exceptions), before a response is expected from the users. This helps to keep the users engaged by making them feel as active participants of the conversation.

To help support the need for relatedness, the chatbot uses emojis to display empathy and emotions, and by acknowledging each response provided by the user. Care is taken to use non-judgmental responses throughout the conversation.

This part of the onboarding conversation (see Figure 36Figure 37) introduces the

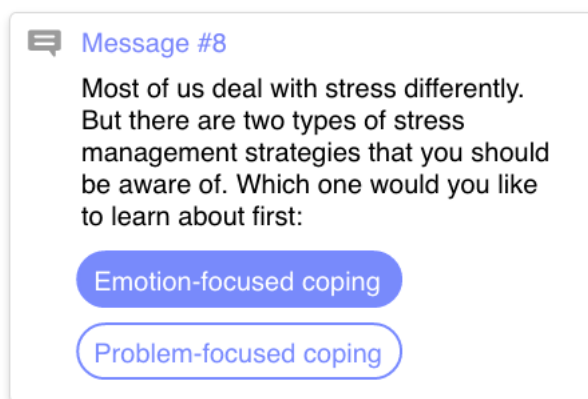


Figure 36. Message #8 introduces the concepts of emotion- and problem-focused coping.

users to the concepts of emotional and problem-focused coping, including when to use which approach. As mentioned previously in this thesis, people will experience different types of stress. It is therefore helpful to provide users with information on when they should engage in emotion or problem-focused coping.

The dialogflows below outline the rest of the conversation, which finishes by initiating the problem-solving exercise.

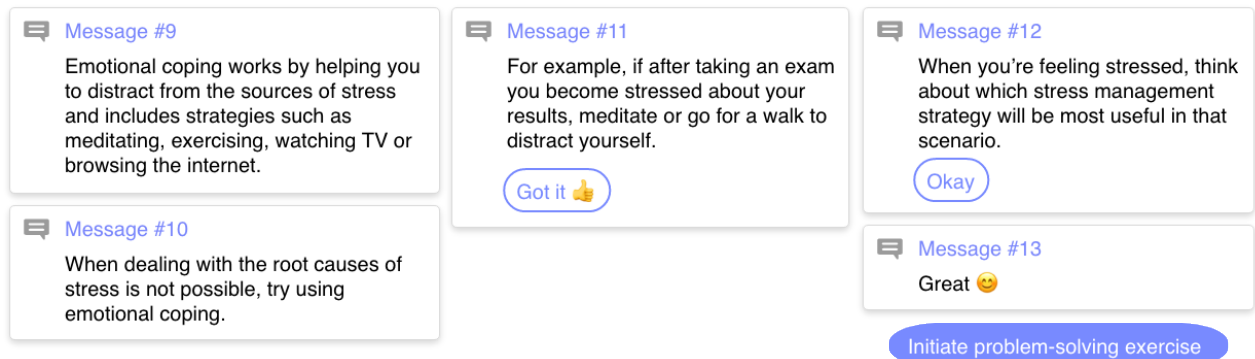


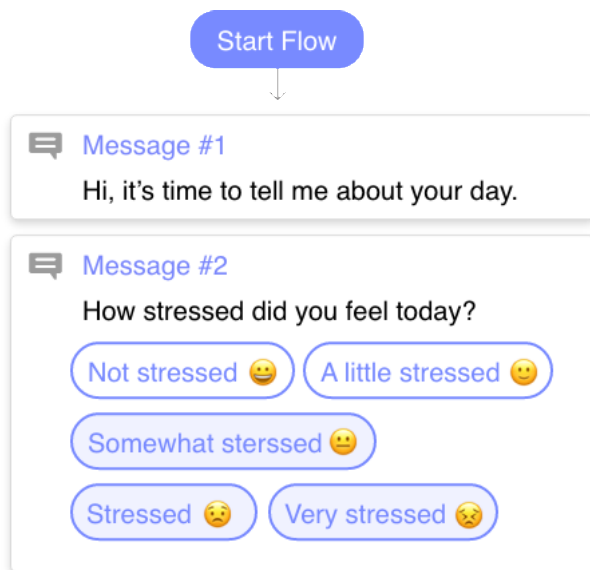
Figure 37. Messages #9-13 explain what emotion- and problem-focused coping entail and when to use which approach.

6.7.4 Daily Reflection Report: Reflective Questioning and Short-term Planning

In the following section, we describe the daily chatbot report. The daily report incorporates two features of our intervention: reflective questioning and short-term planning. Firstly, the daily report acts as a journaling feature designed to help users become more aware of how different factors are affecting their stress. Then, we demonstrate how we use the conversation to prompt people into thinking of the types of positive wellbeing activities they could do to self-manage their stress, which encompasses our short-term planning feature.

Reflective questioning

As we found in Study 4 (Chapter 5), people already have substantial knowledge about the factors affecting their wellbeing, though this knowledge simply lies outside of their immediate awareness unless it is called upon. We therefore argue that reflective dialogs can help bring peoples' existing knowledge relating to their stress back to their immediate awareness. This is because chatbot-based dialogues can be used to create the conditions for reflection to take place. Then, by reasoning over the knowledge that usually lies outside of their immediate awareness, people can become more cognisant of what their stress levels and the factors affecting these are.



Every evening at 9pm the users are sent a message asking about their stress levels (see Figure 38). The chatbot's response to message #2 varies based on how stressed the users are: Awesome/Glad you're doing well/I'm sorry to hear that/Better days will come etc.

Figure 38. Messages #1-2 used to greet the user and ask about their subjective stress levels.

The users are then asked to report what they have learned about their stress during that day (see Figure 39). This is done to highlight behaviour-outcome relationships, which can help provide users with a better understanding and awareness of how different factors affect their stress (Kocielnik and Sidorova 2015; Li et al. 2010b). The chatbot additionally asks about the novelty of a given insight, and whether or not the users feel that they can act on this information. This part of the conversation (Messages #3-7) replicates the reflective questioning procedure used in study 4 so that we can compare insights and their types with our previous findings.

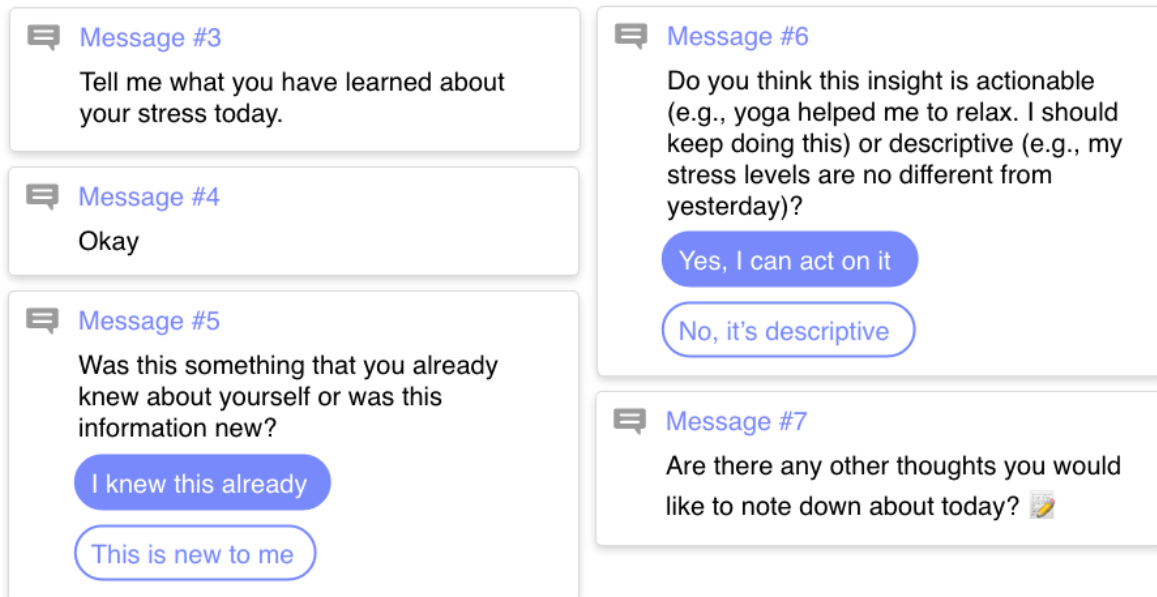
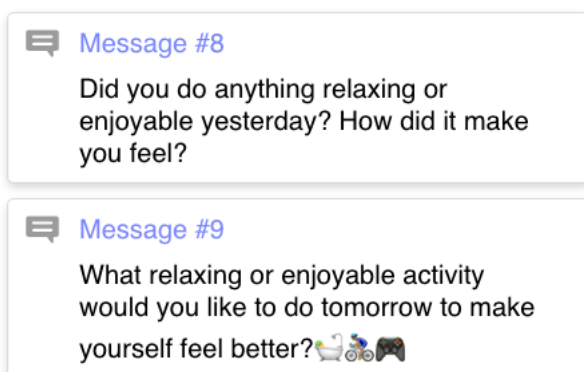


Figure 39. Messages #3-7 incorporate the reflective questioning element of the intervention by asking people to report what they have learned about their stress and indicate the novelty and actionability of this information.

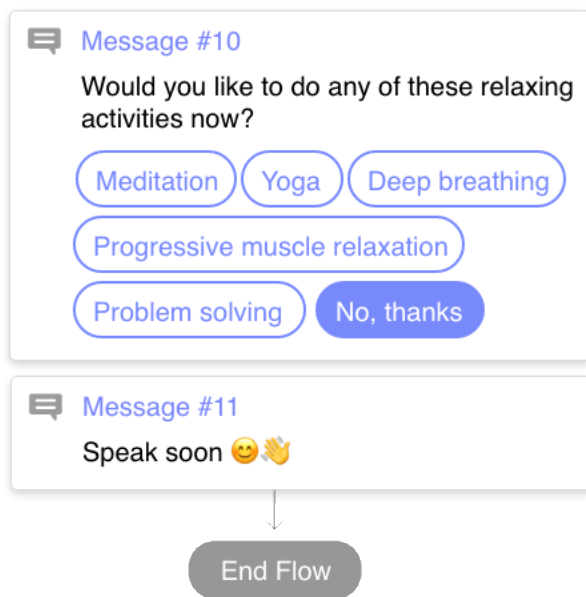
Short-term planning

This section describes the short-term planning feature, which is incorporated into messages #8-9 (see Figure 40). These messages were designed to invite people to continuously reflect on their self-care needs, remind them of the positive experiences associated with practicing self-care, and encourage them to create continuous positive and uplifting experiences.



Message #8 reminds people of the positive feelings associated with the activities done the day before, which is used to motivate and prompt people into thinking about what relaxing activity they could do tomorrow.

Figure 40. Messages #8-9 incorporate the short-term planning feature by asking the users to plan in relaxing activities for the next day.



The final part of the daily report offers the participants to engage in a set of emotion-focused coping activities or the problem-solving exercise (see Figure 41). Each button representing the emotion-focused activities presents people with a set of external links to videos that contain the selected activities. The length of the activities varied between 3-15 minutes.

Figure 41. Messages #10-11 mark the end of the daily report conversation.

6.7.5 Problem-solving Exercise

This chatbot conversation accounts for the problem-solving component of the intervention. The problem-solving exercise is commonly presented as a worksheet that people can complete using pen and paper, either on their own or with the help of a therapist. Figure 42 presents one way in which the exercise can be delivered, even though there are other variations (Leahy 2018).

Problem solving example

1. Identify the specific problem

The landlord is coming round tomorrow to fix the heating and collect the rent, but I don't have the money to pay the rent.

2. Brainstorm solutions

- Go out so I don't have to see him
- Give him half the rent and say I'll pay the rest next week
- Borrow £100 off Mum
- Threaten him to fix the heating and let me off the rent
- Say I'll fix the heating if he lets me off this month's rent
- Sell some jewellery to get the money
- Buy a lottery ticket

3. Evaluate the good and bad points of each

Give each possible solution a mark out of 10, giving higher marks for the best or worst points.

4. Choose the solution with the most good points

Give him half the rent.

Possible Solution	Good points	Bad points
Go out so I don't have to see him	I don't have to deal with it tomorrow (5) Total - 5	I'll still be worrying about it (5) He will come round again and be more angry (8) Only a temporary solution (9) Total - 22
Give him half the rent	He'll be happy to have some money (6) I'll feel better (4) He'll fix the heating (10) Total - 20	I'll still have to find the other half next week (5) Total - 5
Buy a lottery ticket	I could win the jackpot and buy my own house and never have to pay rent again (10) Total - 10	Odds are against me to win (10) If I don't win I'll lose £1 (2) and I'll still have no money to pay rent (10) Total - 22

13

5. Write down each step of the solution

Get the half of the rent ready before he arrives.

When he arrives, make him a cup of tea and explain why I have had difficulties getting the money this week, that I know it is important and that I will deliver the rest to him next week.

Decide with him a time and place to meet to pay the rest.

6. ACTION and evaluation

Try out this solution and later evaluate how it went. If this solution has not helped then review your list, try out another solution and evaluate.

Figure 42. Problem solving worksheet taken from (NHS Camden and Islington 2019). The exercise presented in the worksheet consists of six steps which entail asking the users to define their problem and formulate a structured solution to that problem.

To guide people towards formulating a solution to their problem, we additionally take inspiration from the problem-solving exercise included in the Wysa chatbot. Like Wysa, we also incorporate a set of CBT-based techniques, including *laddering* and *guided discovery*. We include these techniques to support our users in overcoming common cognitive distortions, such as catastrophising or feeling unable to cope, and this way help them formulate a less biased solution to their problem (Leahy 2018; Overholser 2013). Reffy's problem-solving exercise incorporates these techniques by initially asking its users to look at the problem from an outsider's perspective. It then asks them to evaluate the extent to which the problem affects them on a scale of 1-10, followed by a question on what they could do to reduce the impact of this problem by

2 points. Next, the Reffy chatbot instructs the users to imagine a future scenario where that problem no longer exists and what adjustments they would need to make between now and then for this to happen. At this stage, both the Wysa and the Reffy chatbot ask their users to come up with a solution to their problem. Wysa does so by asking the users “*How could you make this situation better for yourself?*”. In contrast, the Reffy chatbot asks the users to provide a concrete action plan (see Figure 43, message #21). This decision was based on Study 4 findings (Chapter 4), where our users reported engaging in action planning to cope with their stress – an approach which also aligns with the worksheet presented in Figure 43, step 5. Another essential overlap between the worksheet presented in Figure 43 and the problem-solving exercise incorporated into Wysa and Reffy is that they all aim to lead to the same outcome – a thoughtfully refined and elaborated solution to the problem (instead of having the users settle on their initial solution) (see Table 12 for a comparison).

Description of each step	Worksheet	Wysa	Reffy
<i>Define the problem</i>	✓	✓	✓
<i>Brainstorm multiple solutions to the problem</i>	✓	-	-
<i>Evaluate each solution and choose the most appropriate one</i>	✓	-	-
<i>Provide a single solution and gradually refine it</i>	-	✓	✓
<i>Cognitive restructuring and reframing to eliminate biases</i>	-	✓	✓
<i>Write out the solution to the problem</i>	✓	✓	✓
<i>Create an action plan for solving the problem</i>	✓	-	✓
<i>Evaluate the action plan after a set timeframe (e.g., a week)</i>	✓	-	✓

Table 12. List of steps included in different tools/modalities used for delivering the problem-solving exercise. Worksheet refers to the example given in Figure 42. Rows highlighted in a lighter shade of blue refer to the original steps used in the worksheet and rows highlighted in a darker shade refer to the new steps that were used instead of the originals to better accommodate a chatbot interface.

Finally, based on step six outlined in the worksheet (see Figure 42), the problem-solving exercise that the Reffy chatbot sends at weeks 1-3 additionally asks the users to evaluate their previous action plans (see Figure 43, messages #24-32). We included this step as findings by Schmidt (2018) identified that users frequently forgot what their

action plans were, or they found that their plans were no longer relevant. Designing a conversation that enables users to re-evaluate and revise their previous action plans should provide additional support with their implementation of those plans. This is primarily because the revised plans should be more closely aligned with the users' current wellbeing needs.

The users could initiate the conversation with the keyword *Problemsolving*. They were emailed a weekly reminder asking them to complete this conversation. After completing the problem-solving exercise, the chatbot automatically guided the users to the daily reflection report conversation.

Start Flow

Message #1

To begin, you'll first need to identify what causes you stress and when.

Message #2

So, tell me about something that regularly or significantly stresses you out.

Message #3

Fair enough.

Message #4

Is there any pattern that's reoccurring in terms of when you're more likely to feel stressed because of this?

Yes

No

Message #5

When is this more likely to happen?

Message #6

Okay

Message #7

Now that we've identified what the problem is, let's get to work on creating some coping strategies for you.

Message #8

First, try looking at your situation from an outsider's perspective. This helps minimise any negative biases you might have towards your ability to cope.

Message #9

Hint: it helps to put yourself in a friend's or a family member's position.

Message #10

What advice would you give yourself?

Message #11

Good 😊

Message #12

Next, we'll assign a number to your stressor based on how significantly it affects you.

Message #13

If 10 is a stressor that is so overwhelming that it stops you from doing your daily activities, and 0 means that this stressor is successfully managed, where would you place your stressor?

Message #14

I see.

Message #15

What would need to change for the impact of this stressor to go down by 2 points?

Message #16

Okay 😊

Message #17

Next, I would like you to imagine a situation in the future where your problem is resolved.

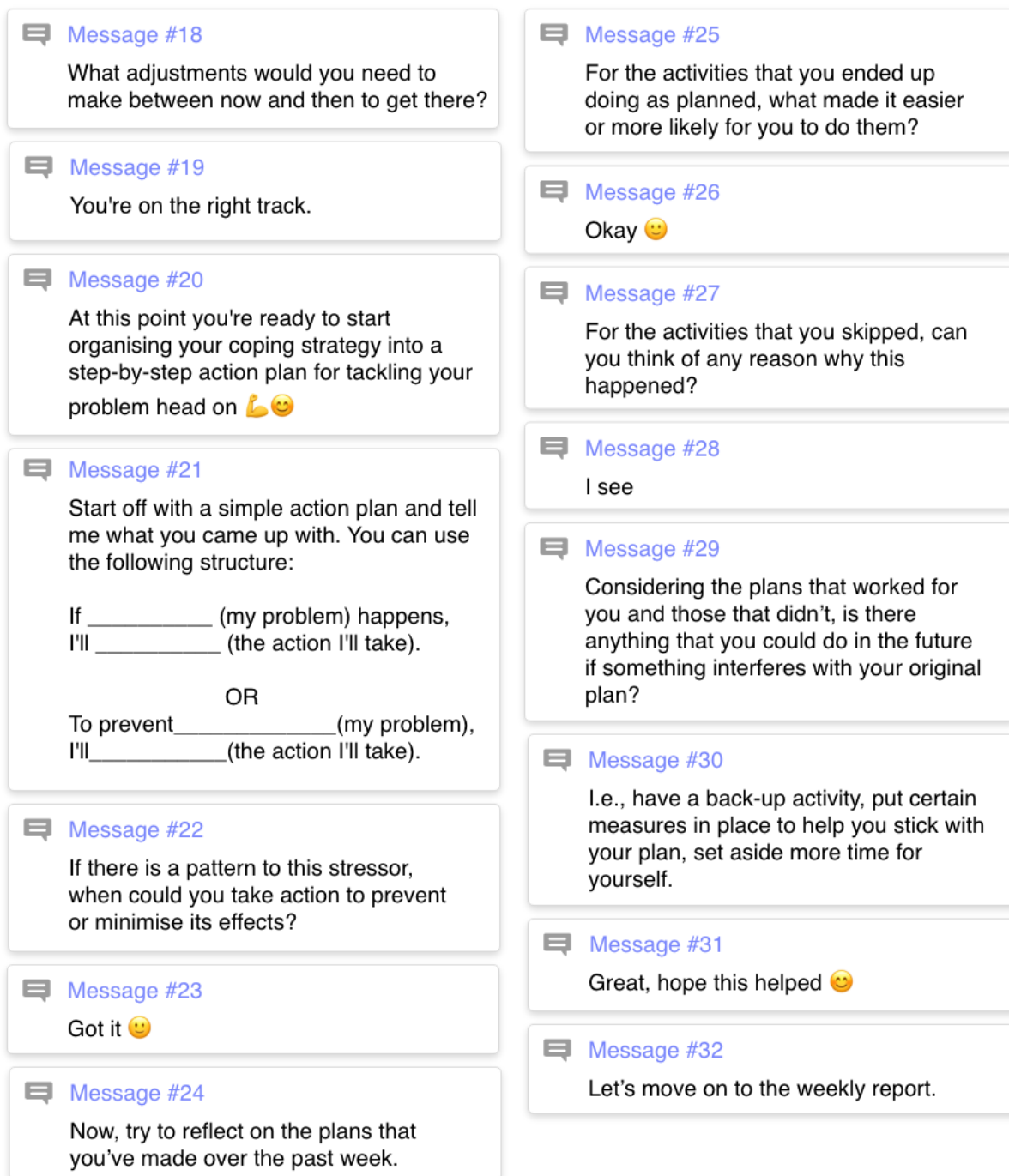


Figure 43. The chatbot-based problem-solving exercise included in our intervention.

6.8 Chatbot Implementation and Deployment

The chatbot prototype was developed by using the IBM Watson Assistant framework (Watson Assistant, 2019) and deployed on Facebook's messenger platform. There were several reasons as to why the Facebook Messenger app was chosen as a

suitable platform for deploying the Reffy chatbot. Firstly, the Messenger app provides an out of the box front-end user interface that can host the chatbot. Secondly, a chatbot developed via the IBM Watson service can be seamlessly deployed onto the Messenger app. Finally, due to the large user base of the Facebook platform, it is likely that the participants of the study would be using the Messenger app for purposes other than interacting with the Reffy chatbot. Because the Messenger app displays contacts based on recent messaging history, the participants would likely see the Reffy chatbot at the top of their contact list, making it more likely for them to remember to interact with the chatbot.

The content included into the chatbot was proofread and evaluated by one reviewer. Per Facebook standard procedure, the usability and functionality of the chatbot was assessed by 5 Facebook software testers, after which the chatbot was made publicly available to registered Facebook users. With regards to GDPR compliance, the chatbot conversation logs were automatically deleted from IBM's databases after one month's use – a procedure that is performed automatically as part of Watson Assistant Lite plan (see IBM, 2016). Users could also delete their conversations from their personal messenger apps themselves after completing the 3-week self-tracking period.

6.9 Conclusion

In studies two and three (Chapters 3-4), we found that people need support to help them gain an understanding of their stress, particularly in the early stages of using a stress self-monitoring app, and that they also need guidance on how to turn their insights into actions. In study four (Chapter 5), we began exploring how we might support people in gaining insights into their stress using reflective questioning. We found this method to be effective. Even though people did not report significantly lower stress levels, they identified gaining other benefits, such as their becoming more aware of their own stress levels. In this chapter, we expanded our focus to include not only the reflection, but also the action stage. Specifically, our aim here was to understand how coping relevant BCTs, including self-monitoring and action planning, could be incorporated into an app in a way that is both evidence-based, yet still meets

people's needs of autonomy and competence. In doing so, we concluded that chatbots have the potential to act as a suitable medium for helping people reflect on their wellbeing and form effective stress coping strategies.

Previous research investigating chatbots for mental health focused on evaluating their overall efficacy (Fitzpatrick et al. 2017; Inkster et al. 2018), leaving a gap in understanding of how new chatbot-based features could be designed to better support people with stress self-management. For example, an evaluation of the Wysa chatbot demonstrated that the app was effective in treating depression and anxiety related symptoms (Inkster et al. 2018). However, research that primarily focus on demonstrating efficacy are challenging to translate into concrete design guidelines for where improvements could be made (Klasnja, Consolvo, and Pratt, 2011). Relatedly, even though there is research within the HCI domain investigating the benefits of using chatbots for reflection and behaviour change (Kocielnik, Xiao, et al. 2018; Kocielnik and Hsieh 2017b), this research primarily focuses on physical activity behaviours. As discussed in Chapter 4, reflective practices and their associated outcomes will differ across domains. Similarly, we find that the usefulness of behaviour change techniques, such as goal setting, will be perceived differently by the users depending on which aspect of their wellbeing they are looking to improve upon. Therefore, there is still the need to investigate whether and how conversational interfaces can incorporate coping-relevant BCTs in a way that supports people with their stress management needs.

In this chapter, we have summarised a set of design guidelines to inform the design of novel chatbot-based features that can support people with implementing coping-relevant BCTs. To achieve this, we synthesised our findings from Studies 2-4 and related research on motivation and stress coping (Aspinwall and Taylor 1997; Cox 1987; Peters et al. 2018). In doing so, we identified short-term planning and problem-solving as suitable mediums through which apps could supporting people with stress-self-management and their needs for autonomy and competence. In the second half of the chapter, we described the design and implementation of Reffy stress self-management chatbot prototype. Instead of acting as a stand-alone solution, we designed Reffy to complement the functionality available in an existing, state of the art stress self-monitoring app – Welltory. The chatbot prototype acts as a complementary

add-on designed to fill in the feature gaps and barriers to use that were identified in our previous intervention studies using Welltory (Chapters 4-6). As mentioned earlier in this thesis, a mobile stress management intervention requires the inclusion of several active components to ensure its efficacy (Klasnja et al. 2011). Because it would have been impractical to re-implement a new self-monitoring app, we combined the use of both the Welltory app and the Reffy chatbot. In doing so, we could test our hypothesis on how people use specific features of these apps to help them implement coping-relevant BCTs, whether the design of these BCTs meets people's stress management needs and where improvements could be made. Our next chapter therefore describes a 3-week field study in which we evaluate the combined use of the two apps.

7 Reffy: Supporting Reflection and Stress Management via a Chatbot Interface

7.1 Introduction

There has been a call for improvements to existing health and wellbeing mobile apps, particularly towards incorporating more BCTs (Conroy et al., 2014). Our own review of prevailing apps and a 3-week self-tracking study of people using them revealed that existing stress monitoring and management apps do indeed fall short in supporting their users' efforts to implement coping-relevant BCTs. Guided by our findings and research on positive computing (Calvo and Peters 2014; Diefenbach 2018; Peters et al., 2018; Wiese et al., 2020), the final study of this thesis investigates how a chatbot can better support users' implementation of coping-relevant BCTs by including features that are designed to foster mindful self-reflection, autonomous self-regulation, and competence supported by explicit guidance for stress self-management.

In chapter 6, we focused on the process by which we informed the design of the Reffy stress self-management chatbot prototype, the aim of which is to address peoples' stress self-management needs that we identified in our previous studies. The Reffy chatbot aims to address these needs by 1) incorporating reflective questioning features to help people gain insight into their stress during the early stages of self-tracking, 2) using short-term planning prompts rather than automated reminders to encourage people to engage more frequently in stress management behaviours, and 3) integrating problem-solving exercise to guide people towards forming effective stress management strategies from the insights gained.

We now present a 3-week field study with 20 participants evaluating the combined use of the Welltory stress self-monitoring app and the Reffy chatbot. In doing so, we address the following research questions:

RQ1: How can chatbot-based reflective questioning, short-term planning, and problem-solving help people better understand and manage their stress?

RQ2: Can apps supporting chatbot-based reflection, short-term planning, and problem-solving lead to significantly lower levels of perceived stress?

In answering these questions, we identify the benefits and challenges involved with using chatbots for supporting coping-relevant BCTs. From our findings, we see that app features incorporating these techniques must also consider people's need for a sense of autonomy and competence in order for a stress-management app to successfully motivate them to incorporate coping-relevant BCTs into their daily lives. We demonstrate that chatbot-based reflective questioning helps people draw on their own self-knowledge. This in turn helps them identify and become more aware of how different aspects of their lives impact their stress without requiring them to access any prior and/or extensive self-tracking data. Our study also reveals that short-term planning encourages autonomous engagement in stress management behaviours without the necessity for automated reminders. Likewise, using a dialogue-based problem-solving exercise is shown to be effective in providing people with direct guidance on how they can apply their self-knowledge to self-managing their stress. We demonstrate how this leads to an improved sense of competence which then empowers them to cope with stressful experiences. In summary, our findings demonstrate that, to be effective in encouraging people's efforts to consistently include coping-relevant BCTs in their day-to-day lives, the apps must support users' needs for autonomy and competence.

7.2 Method

7.2.1 Participants

We recruited 20 adult participants (17 females, 3 males) between the ages of 19 and 29 through our university's participant recruitment website. The inclusion criteria were to own a smartphone device and not be diagnosed with a stress disorder. Sixteen participants had never engaged in self-tracking before, whereas two of the participants used apps and another two used pen and paper. The participants were compensated with a £30 voucher and a free one year's access to the Welltory app worth £60.

7.2.2 Materials

We used the Welltory stress monitoring app (full description in Chapter 4) in conjunction with the Reffy chatbot (full description in Chapter 6). The PSS questionnaire was used to measure pre and post study perceived levels of stress.

As in our second study (Chapter 4), we used the Welltory stress self-monitoring app in conjunction with the Reffy chatbot because the chatbot included features aimed at supporting action taking, which Welltory did not include. However, unlike the Coach.me app used in study two, the Reffy chatbot was designed to complement, as well as to address some of the limitations found in the Welltory app. Specifically, the Reffy chatbot was designed to enhance Welltory's objective self-monitoring features aimed at revealing correlations between people's stress levels and the context factors relating to stress. As we found in study two, it takes time for such correlations to emerge due to a lack of initial self-tracking data. The chatbot added an additional layer of subjective reflection as a way of overcoming this barrier. Consequently, there is an overlap between the two apps as they both support self-monitoring, reflection and insight generation. Yet, from a research evaluation perspective, the self-monitoring features incorporated into both apps should have clearly distinguishable effects on the reflection-related outcomes investigated in this study. Observing how people use both apps should also help reveal how both types of self-monitoring and reflection (objective via Welltory and subjective via the chatbot) help people to understand their stress.

7.2.3 Design

This study used a mixed methods design, investigating how the use of the Welltory app and Reffy chatbot affected changes in stress levels (PSS). We additionally used qualitative analysis to investigate the types of insights people reported gaining via the Reffy chatbot and how they reflected and acted on their observations about stress levels and the factors affecting these.

7.2.4 Procedure

Each participant was given access to the Welltory and the Reffy chatbot apps and was instructed to use them as often as possible within a 3-week period (see Appendix 2 for full participation instructions). They were sent morning and evening reminders to use the Welltory app. Every evening at 9pm the chatbot would initiate the daily reports. The participants were asked to complete 4 problem-solving exercises, one at the beginning of the study and the rest at the end of weeks 1-3. After completing the self-tracking study, the participants were asked to do a 30-minute semi-structured interview (see Figure 44). During the interviews the participants were asked about their use of both apps, focusing on whether people gained insights, took actions, changed their perceptions about stress and its management. The interviews were audio recorded. After completing the interviews, the participants were advised to delete the conversations from their Facebook messenger app. Upon copying the conversation logs for further analysis, these were also deleted from the researcher's side on the messenger app.

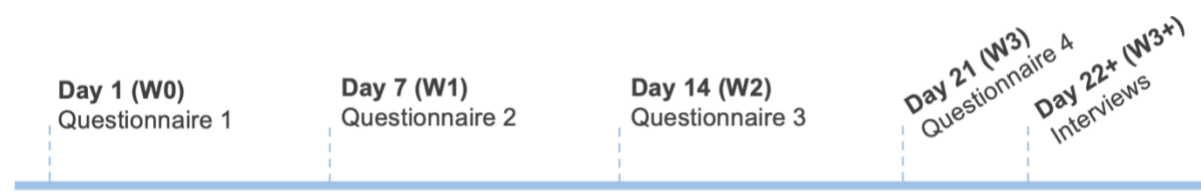


Figure 44. Study timeline indicating when each questionnaire was administered. The interviews took places during the 4th week of the study, after the 3-week self-tracking period was completed.

7.2.5 Data Analysis

IBM SPSS Statistics version 23 was used for quantitative analysis. The insights reported on the Reffy chatbot were qualitatively analysed. We used the same procedure to analyse the reported insights as was described in Chapter 5, section 5.2.1. Finally, thematic analysis was used to analyse the interview results (Braun and Clarke 2006). The interview recordings were transcribed and iteratively coded using Nvivo. The analysis process consisted of two steps:

1. The first step of the analysis investigated how people implemented the app-delivered BCTs to help them better understand and manage stress. To achieve this, we took a bottom-up (inductive) approach to code our data as we wanted to capture the nuanced aspects of how people applied the strategies delivered via both apps in their daily lives. After coding our data, we took a top-down (deductive) approach to organise our codes into themes that were more specifically aligned to our research questions. Therefore, we have organised our codes based on how people used the apps to understand and manage their stress, resulting in two overarching themes. As we used an inductive approach to code our data, we additionally identified a third overarching theme relating to the more general use of the two apps. Finally, we have organized our codes into ten sub-themes that were primarily based on how people used the various features and BCTs supported by the apps.
2. The aim of the second step of the analysis was to capture peoples' experiences relating to competence and autonomy associated with using the apps. To achieve this, we reviewed and coded our data again, however, this time using a top-down, latent approach. The resulting codes were compared to the ones from the first analysis step and were incorporated into existing sub-themes.

Using the above analysis approach, we were able to capture how people applied the app delivered BCTs in their daily lives and how these practices supported people's sense of autonomy and competence with regards to understanding and managing their stress.

7.3 Results

In this section we report on engagement with the Welltory app and the Reffy chatbot, followed by a presentation of our qualitative findings on how people used both tools to support their implementation of coping-relevant BCTs and the associated challenges when interacting with the chatbot.

7.3.1 Engagement

Our results indicate that people showed good engagement with both the Welltory and the Reffy chatbot over the 3-week study period (see Table 13). People had taken an average of 2.3 measurements per day, had an average of 19.55 active conversations with the chatbot, and reported an average of 0.6 daily insights about their stress.

Measure name	Descriptive statistics
Welltory	Mean = 36.2, SD = 8.36, Median = 36.5, Min = 22, Max = 58
Chatbot sessions	Mean = 19.55, SD = 2.9, Median = 21, Min = 9, Max = 21
Number of insights	Mean = 16.45, SD = 5.8, Median = 13, Min = 5, Max = 21
Actionable insights	Mean = 8, SD = 4.74, Median = 7, Min = 0, Max = 18
Descriptive insights	Mean = 4.8, SD = 4.34, Median = 4.5, Min = 0, Max = 16
Novel insights	Mean = 3.65, SD = 3.1, Median = 3.5, Min = 0, Max = 11
Old insights	Mean = 5.22, SD = 5.22, Median = 7, Min = 2, Max = 20
Context factors	Mean = 14.1, SD = 4.9, Median = 13.5, Min = 4, Max = 21

Table 13. Summary of Welltory use, number of active chatbot sessions, and insights reported on the Evernote app.

7.3.2 How can Chatbot-based Reflective Questioning, Short-term Planning, and Problem-solving help People with Understanding and Managing their Stress?

The primary focus of this analysis was on understanding how the use of dialogue-based short-term planning and problem-solving contribute towards stress management, and how experiences of autonomy and competence support this process (see Figure 45). Specifically, we were interested in understanding how people implemented the stress coping techniques delivered via the chatbot in their daily lives.

The findings outlining how people may gain a better understanding about stress and the factors affecting it are only reported briefly, as they align closely with the findings presented in Chapter 5 (Study 4). This is due to both studies using the same protocol to elicit reflection. As such, the findings from the present chatbot study help confirm that, at least during the initial stages of self-tracking, subjective self-monitoring and reflective questioning help people become more aware of what their stress levels are. We concluded by reporting people’s preferences associated with the use and functionality of the chatbot and how the chatbot’s lack in personalisation affected user engagement.

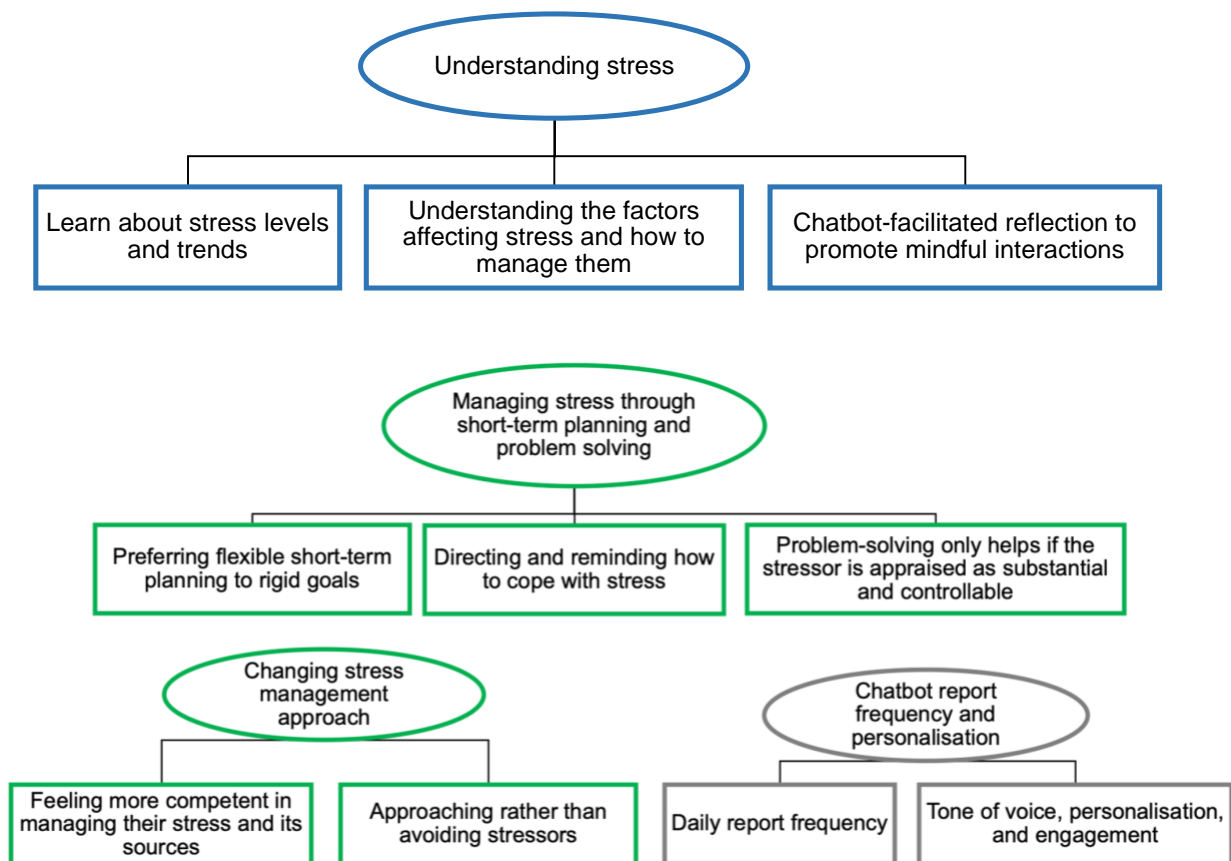


Figure 45. The three over-arching themes and seven sub themes derived from the interviews. The blue border is used to indicate themes related to reflection/understanding, the green border is used to refer to action

taking/management. The grey border represents a theme discussing chatbot-specific interactions and experiences.

7.3.2.1 Understanding Stress

Learning about stress levels and trends. For most participants, the only novel insights that they gained from the Welltory app were related to their stress levels:

P(12) *"It's kind of strange sometimes because I don't feel as stressed as it's saying."*

Most of the other information relayed by the app simply confirmed what they had already known about the factors affecting their stress:

P(2) *"It did more of the general things like how exercising reduces your stress or having more sleep is better for you. These were the kind of things that I already knew so there wasn't anything in particular new in that regard."*

Self-monitoring and self-reflection via both the Welltory app and the Reffy chatbot resulted in people becoming more aware of what their stress levels were:

P(13) *"Because of using the app, I became more aware of my stress, so now I don't just leave it there or ignore it."*

Finally, when asked whether the insights reported via the chatbot originated from their own observations or from interacting with Welltory, the majority (15/20) of participants reported that their insights came from their own observations. Fewer participants reported that these came from either a combination of both (4) or from Welltory alone (1).

Understanding the factors affecting stress and how to manage them. Perhaps the single most noticeable difference between Study four (Chapter 5) and the present study was that the participants' reports (in this study) indicated a deeper level of reflection and understanding around the factors affecting stress and how to manage it. Importantly, they reported becoming more aware of how they were dealing with their stress:

P(5) *"The apps helped me, kind of, to be more aware of how to deal with my stress. Before, I would just ignore it and not do anything about it. Now, I know if it's bothering me, I know I have to deal with it."*

They also became more cognisant of factors causing their stress:

P(10) *"The apps made me more aware of the activities that were making me stressed out. It helped me to create a set of patterns of what I should do before I'm stressed, when I'm stressed or after stress."*

as well as the activities that could help them lower their stress:

P(8) *"I'm now more aware that I need to actively work on my stress rather to occasionally take breaks from what is stressful. Do something like yoga or meditation."*

Some participants (2) additionally described engaging in introspective reflection, whereby they examined *why* they were becoming stressed, further evidencing the deeper levels of reflective thinking observed in the present study:

P(13) *"I think before the study I didn't really think about my stress that much. And now I actually started to think about it which is useful. I think that is more actively in my thought now. Now I would think: why am I stressed? Is it because of these people walking on the street slowly? Before I was just like: you people need to speed up. Now I'm thinking: why this is stressing me?"*

For P(4), the chatbot's prompting her to take time to think and reflect was what enabled her to gain novel insights into her stress:

"I think in my case, Welltory confirmed what I knew; and the chatbot gave me new insights because it forced me to think about things."

Chatbot-facilitated reflection to promote mindful interactions. The daily reports completed via the chatbot helped reveal everyday life experiences that would have otherwise gone unrecognised. For example, the chatbot encouraged participants to recall what they had experienced throughout their day, leading them to become more mindful of the impact that various events had on their stress. As P(1) explained:

“...it’s always asking you questions so it always makes you think, ‘Oh, that’s why, I forgot about this.’ So that was useful; it was something that Welltory didn’t have. Because it didn’t ask any questions, so you would not say the same things and would forget about them.”

What we found was that even though our participants appreciated having access to data and its visualisations, they felt that using data alone did not allow them to express the multifaceted nature of what they were experiencing. As P(8) acknowledged, stress can be difficult to quantify. She therefore valued the opportunity to use her own words to express what she was feeling:

“... the data wasn’t that helpful during the study. The chatbot was probably more helpful. Because stress is difficult to quantify ... it’s not like one thing and there are lots of variables. So I think it’s more useful to discuss it with words rather than examine it with graphs. Looking at graphs can be very passive, but if you’re forced to think about yourself through this chatbot, then it’s more interactive.”

Ultimately, our participants wanted to craft their own stories of what they experienced throughout the day. They achieved this by intertwining and mediating the objective stress inferences recorded via the Welltory app with the subjective reports made through the chatbot. This enabled them to paint a more complete picture of what they were feeling:

P(14)“...especially in the evening I would do the Welltory measurements and then go on the chatbot. But at the same time, if I did not agree with what Welltory told me, for example, that I’m super stressed but I’m actually fine, then I would go on the chatbot and say that I was not stressed today but actually this happened. So I was stressed but I really got through it okay...So I did the two together. I like to link data and my own insights.”

Managing stress short-term planning and problem solving

Preferring flexible short-term planning to rigid goals. Most participants preferred making short-term plans over having to follow structured goals to help them sustain continuous engagement in stress management behaviours:

P(17) *“I plan a few days in advance, because if I say I will do it 5 times a week, I will never do it. I just have to mentally prepare. Maybe it will happen if I will plan. I just have to think, ‘I’m gonna do it now’ and it might sum up to 5 times a week.”*

This was primarily because planning one day ahead helped people schedule realistic and attainable activities into their day. For instance, instead of setting ambitious goals, P(11) explained that he used the chatbot to plan relaxing activities that were easy to accomplish into his existing schedule, thereby making sure they would fit in and he would actually do them:

“I tried to do things that were simple and that I knew I could do. I know I’m gonna be by Regent’s Park tomorrow so I should take a walk then or go skateboard. I made a plan so I would know most of the time what I would do. I would do the things I said about 80% of the time because I didn’t come up with extravagant things that I knew I wouldn’t fulfil...So it really helped to think ahead about something that’s gonna be enjoyable.”

Similarly, our participants favoured short-term planning over following a set structure, as this empowered them to adjust their planned activities based on their current self-care needs. This is in contrast to negative experiences they may have had in the past, trying to plan activities for the future without the benefit of having any context about how they will be feeling at that time. Relatedly, creating a short-term plan imparted a sense of autonomy and flexibility, as opposed to the detrimental feelings of guilt people often experience from failing to stick to a longer-term plan:

P(5) *“For me, planning a day ahead is better than having a structure because if my plan falls through, if I said I would do yoga Monday, Tuesday, Friday and if I skip it then I would feel guilty. Whereas if I just plan a day ahead knowing how I feel, it’s more realistic for me and I won’t feel so guilty if the plan falls through because I’m aware that that’s how I felt, that’s what I needed the next day.”*

The daily reports made via the chatbot further illustrate just how varied people’s perceptions of self-care and relaxation are and that their self-care needs will change on a day-to-day basis (see Figure 46).

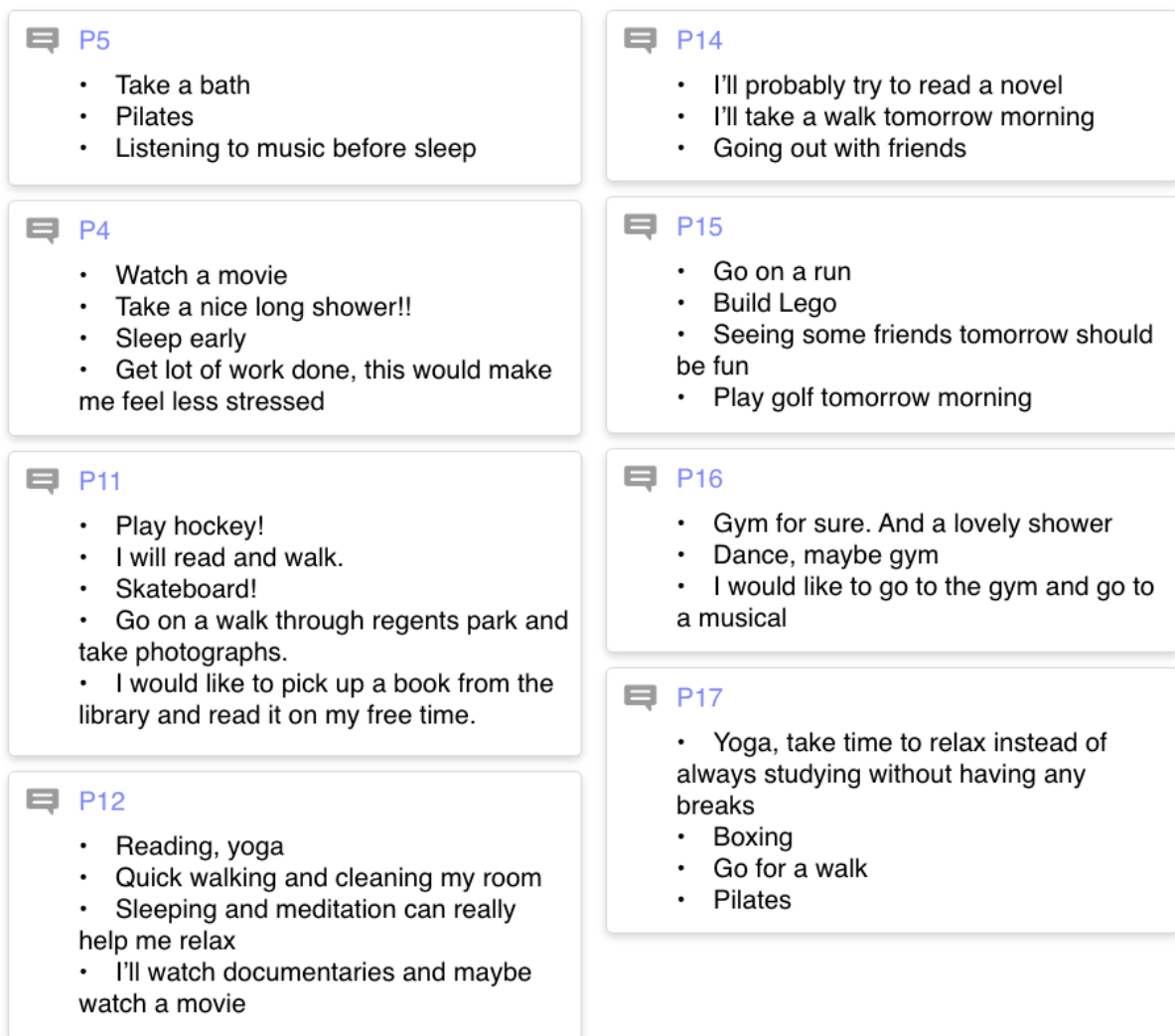


Figure 46. Example responses to a message asking about what relaxing activities the participants would like to do the next day. For some, self-care meant taking a bath and reading a book; for others, it was doing yoga or skateboarding in the park.

This was due to their recognising that the plans they had set were flexible:

P(20) *"I think it's nice to have a plan, just recognize that it's not set in stone."*

People also felt that using the chatbot offered them the freedom to make their own decisions as to what relaxing activity to do and when; and they appreciated that such choices were independent of what they had written in the chatbot the day before. Importantly, they came to understand that the priority was not *what* they did, but *that* they did:

P(2) *"So it has to be something like what can you do tomorrow about your stress. I don't think that I actually did the things that I wrote in the chatbot. But*

I did some of the activities in between. So not the ones I mentioned in the chatbot but other ones related to breaks and relaxing. So I was more conscious that I had to do something.”.

Another value added by the chatbot’s short-term planning feature was that it promoted engagement in autonomous self-regulation, whereby self-awareness, rather than prompts from an automated reminder, motivated people to engage in self-care. For example, when asked whether or not there were any changes in the frequency in which she engaged in relaxing behaviours, P(3) explained that:

“Definitely yes, because I would plan my day ahead with the chatbot and then the next day I would remember that this is what I wanted to [do], so I’ll do it.”.

Mindfully sharing plans for relaxing and enjoyable activities with the chatbot, not only inspired her to think about setting aside more time for herself, but it also gave her something positive to look forward to the next day:

P(3): “I remember it asked whether there were any relaxing things I wanted to do the next day and it sort of made me feel, I would look forward to the next day.”.

Having been encouraged by the chatbot to purposefully set aside more time for self-care and/or appreciate the positive activities they had done the previous day, our participants reported experiencing positive feelings of control, calm, relaxation, balance, happiness, and liberation, among others (see Figure 47).

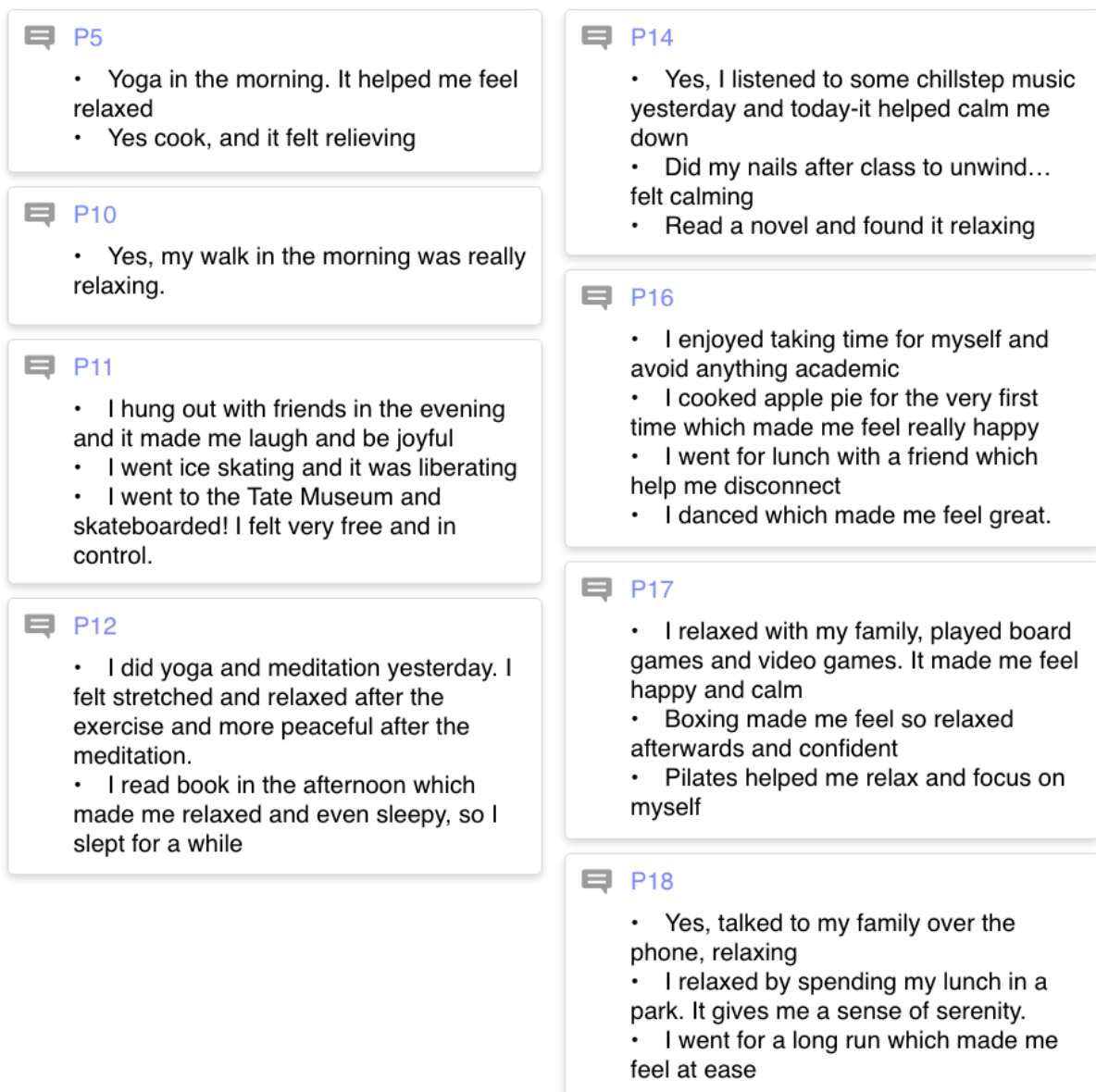


Figure 47. Example responses to a message asking about what relaxing activities the participants did the day before and how it made them feel.

Directing and reminding how to cope with stress. In responding to questions about the chatbot’s problem-solving exercise, many (12/20) participants commented on the guidance it provided. They noted in particular that it helped them recognise coping strategies that they could use when facing stressors and/or problems that they might otherwise have felt too reluctant or unsure about how to approach:

P(4) “I think both apps helped me to realise that there is a problem, but the chatbot helped to direct me on how to solve it.”.

The problem-solving exercise was especially useful for participants struggling to cope with recurrent stressors. For instance, P(19) described how using the chatbot helped her realise that rushing at the tube station was a consistent stressor for her. In recognising this, she realised she could control certain aspects of her own behaviour, such as those leading up to her being at the tube station (e.g., by engaging in time management), which, in turn, helped moderate her stress response:

P(19)“There is a lot of travelling involved in my job. So I would get stressed with the tube or I get stressed with people and I notice if I give myself a time constraint or I’m rushing even before I get to the tube, that results in me being really stressed out. So by recognising that that situation in the tube station is going to cause me stress, being able to work on not rushing to get there, and how I learned to respond to the stress at the tube station, I think that really helped me. So I guess it’s not necessarily about stressors that come up here and there, but it’s about focusing on stressors that come up consistently that I found really useful. And I think just being more aware of it in my day to day was helpful.”.

The problem-solving exercise consisted of several CBT-based and behavioural techniques (e.g., laddering, cognitive restructuring, action planning). We found that participants benefited from different elements, depending on their unique personal circumstances and experiences. For instance, working with the chatbot triggered P(3) to think about the kind of supportive advice friends or family members would give her, and to use those recollections to reassure and remind herself of how to cope when she was under pressure:

“Sometimes when I panic about my university work I think, okay, if a friend was telling me the same thing, then what should I do? Should I tell them to calm down? So, I would tell myself to calm down first and to think rationally before making any decisions. So it’s definitely helpful to sort of get a reminder on how to solve problems.”.

P(18) described how the exercise enabled her to break the negative cycle of worry about her future by helping her restructure her thoughts:

“A recurring theme of my worries is what I’m going to do after my graduation; and after my first interaction with the bot’s problem-solving exercise, I kind of figured out a way to cope with my stress. I was basically telling myself that there must be a solution for it, and that you should take action instead of immersing yourself in those negative worries. I remembered what I said to the chatbot. It’s like every time this question comes up, I would try to think in this way.”

The responses provided to the problem-solving exercise (see Figure 46) help further illustrate how people used the chatbot to a) define their problem, b) give themselves reassuring advice, and c) create an action plan for resolving that problem.

Message #2
So, tell me about something that regularly or significantly stresses you out.

P14
Class preparation, it's a lot of reading to get through each week

Message #5
When is this more likely to happen?

P14
Middle of the week when I know I already need to start preparing for the readings next week

Message #18
What adjustments would you need to make between now and then to get there?

P14
I need to use my time more effectively and break the work down into more manageable chunks

Message #21
Start off with a simple action plan and tell me what you came up with.

P14
To prevent cramming, I'll do an hour's readings every day and read in between classes

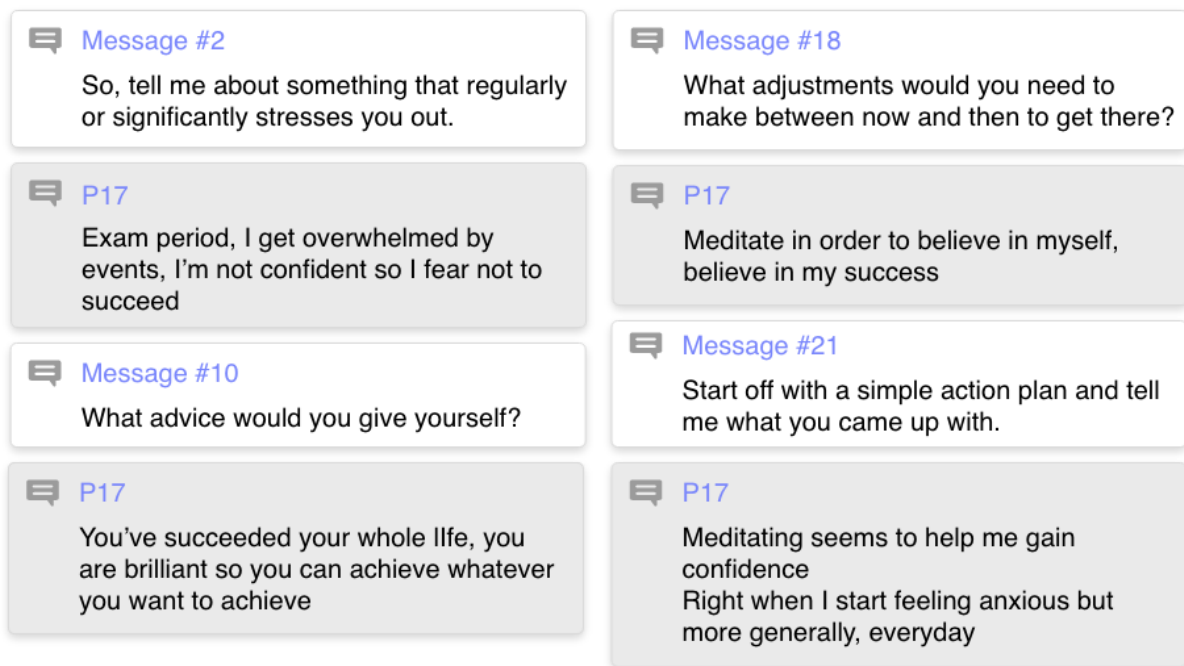


Figure 48. A summary of example responses provided to the chatbot's problem solving exercise.

Similar to what was observed with short-term planning, most participants did not always choose or remember to follow their action plans word-by-word. Instead, they approached their stressors by using the tools for coping, such as relying on the concept of if-then planning, that they had learned from their interacting with the chatbot. This in turn gave them a framework and the capacity to take the necessary steps to manage their stress themselves:

P(3) *"...it's quite difficult to remember that this is the problem and this is the solution. I didn't remember that, okay, this equals to this or that equals to that. But that generally, if this happens, I can do this or I can do that."*

As with any skill, people became better at remembering and acting on their plans with practice:

P(3) *"I have to remind myself of it more. Some days I worry so much that I would just not remember, but after I used the apps for a few weeks, I started remembering more of what the chatbot was telling me about problem-solving."*

Problem-solving only helps if the stressor is appraised as substantial and controllable. The problem-solving exercise did not add value for participants who were not experiencing substantial stress (2/20):

P(11) *"I could see how it could be helpful. But I don't think it was that helpful for me. I think if I was very stressed out it would have been more useful."*

It was also ineffective when the participants felt they could not address the root cause of their stress (3/20):

P(8) *"My main stressor was difficult to solve. It's job hunting, so it's always gonna stress me out. It's something that I just need to do. And it's tied to another stressor, which is money. So I don't think I could really do much about it."*

7.3.2.2 Changing Stress Management Approach

Feeling more competent in managing their stress and its sources. Our participants described experiencing a sense of competence, that is to say, feeling more confident in their own ability to take active measures to effectively cope with their stress. This primarily stemmed from their practicing introspective reflection with the apps, which many participants commented led them to question their previous approaches towards stress and its management. Specifically, they reported that the reflection process helped them become more aware of the effectiveness (or ineffectiveness) of their current and past strategies. P(8), for example, described her realisation that she needed to more mindfully manage her stress:

"I'm now more aware that I need to actively work on my stress rather [than] to occasionally take breaks from what is stressful. Do something like yoga or meditation."

Similarly, P(5) described reflecting on and becoming more aware of how she manages her stress:

"I feel that this application woke up my awareness of how to deal with my stress, which is something I didn't really think about. I was like, "Okay, I'm stressed. I'm stressed." Now it's like, "Okay, I'm stressed. How do I take better care of

myself when dealing with stress?" Before I used to ignore my stress and do mundane activities. But now I am more aware of how I'm dealing with my stress."

For most participants, this led to their feeling more confident in their ability to manage stress. Consequently, they became more proactive about it:

P(1) *"So, often when I have daunting tasks to do, I'm scared to even start it 'cause the thought of going through all the steps to finish the task scares me. When in fact, it's better to start and get [it] over with it. So I always write in the chatbot to just do it. Don't be scared of it and then you realise it's not as bad as you think it is."*

For P(4), engaging in problem solving in particular led her to realise that she had the capacity to cope with her stress. This motivated her to take action in managing it:

"So the chatbot would ask what I could [do] about solving this problem and then it made me realise that I could actually do something about it. So I think it sort of motivated me to take action which I wouldn't have done on my own."

Approaching rather than avoiding stressors. We found that most of our participants (12) reported becoming more likely to approach their stressors head-on rather than avoid them (2):

P(13) *"I would usually avoid it and pretend it's not there. Now I realise that I need to solve the problem if I want for the stressor to be gone. So now I try to not avoid the problem but just finish it, be done with it and I'll be fine. So it's a different approach."*

Some participants directly linked this change in their approach to the problem-solving exercise:

P(14) *"Generally, I would just try to do something relaxing...But at the same time, especially with the problem-solving exercise - it doesn't take that long and it's not that difficult - then maybe I should start thinking about it in the moment, rather than just running away from it. So, is there something I can do right now? So, it kind of changed my approach to stress management."*

A few of our participants additionally appreciated the utility of engaging in different stress coping approaches. As P(3) explained, she found different styles of coping useful for trying to tackle different types of stressful experiences:

“For things that could be solved, it would be nice to get to the root of it. If I have trouble with university work, I cannot just quit university. There is a mix between both. For things that can be solved, it’s nice to solve them. But for other things, I guess I just need to learn how to cope with them.”

7.3.2.3 Chatbot Report Frequency and Personalisation

Daily report frequency. For most of our participants, the length of the daily reflection conversations was “just right”:

P(4) *“The length of the interaction was really alright. I already waste so much time on my phone so 3 minutes isn’t really a lot.”*

However, they also expressed that the daily reports were too frequent, noting that they would prefer a two-to-three day reporting schedule:

P(18): *“Every 3 days would have been better, but also not too long, so that people wouldn’t forget what they learned.”*

This was primarily because people would not always experience stress or make observations about their stress on a daily basis:

P(13) *“...sometimes the questions do not really apply, so I don’t want to answer. For example, on the days when I’m not stressed, it asks me what I learned about my stress, but I don’t have any stress.”*

Tone of voice, personalisation, and engagement. The chatbot was generally perceived as caring and friendly:

P(4) *“It’s a bit weird, but I felt that the bot really cared about me, the way that the messages were structured. It was very friendly.”*

Moreover, through its emojis, the chatbot came across to some users as displaying empathy and understanding:

P(17) *“Overall it was very well done. I mean the smileys and stuff. That was actually really great because you had the impression that you are talking with someone who could understand your feelings.”*

These design elements were often overshadowed, however, by the chatbot's repetitiveness and a lack of personalisation, which had a negative effect on user engagement. As P(2) explained, she felt that the chatbot was not capable of processing what she was saying, and therefore, it did not offer her responses that fit her situation:

“It wasn't really interacting with what I was saying so not answering to what I was saying. So if today I felt particularly stressed about a certain thing I felt that the chatbot was not answering to that particular statement.”

In its extreme, the lack of personalisation and repetitiveness led to disengagement:

P(5) *“If the answers were more personalised, I would be more inclined to use the chatbot. The reason why I sometimes did not like using the chatbot was literally because those were the same questions every day. So for me the personalised aspect of it makes a huge difference.”*

Instead of asking the same questions every time, people wanted to have more direct follow ups on the problems that they had previously discussed:

P(10): *“I would suggest to every week have a different questionnaire and feedback, rather than the same questions that chatbot was asking...It should be a follow up. What happened, did you find the root cause, did you try to solve it.”*

7.3.3 Can Apps that Support Chatbot-based Reflection and Problem-solving Lead to Significantly Lower Levels of Perceived Stress?

The mean baseline levels of perceived levels of stress for this sample was 20.2 (SD=5.35). The scores ranged between 9-31 (PSS scores can range between 0-40). By the end of the 3-week period, the participants of this study reduced their levels of

perceived stress by an average of 3.2 points (15.84%). A Wilcoxon signed-rank test was used to assess whether there was a difference between the PSS scores measured at the beginning and the end of the study. There was a statistically significant difference between the PSS scores taken at the beginning ($M=20.2$, $SD=5.35$) and end ($M=17$, $SD=5.27$) of the 3-week self-tracking period; $Z= -2.9$, $p=.003$ (see Figure 49). The effect size was $d=0.6$; $CI = [0.14 \text{ to } 1.46]$.

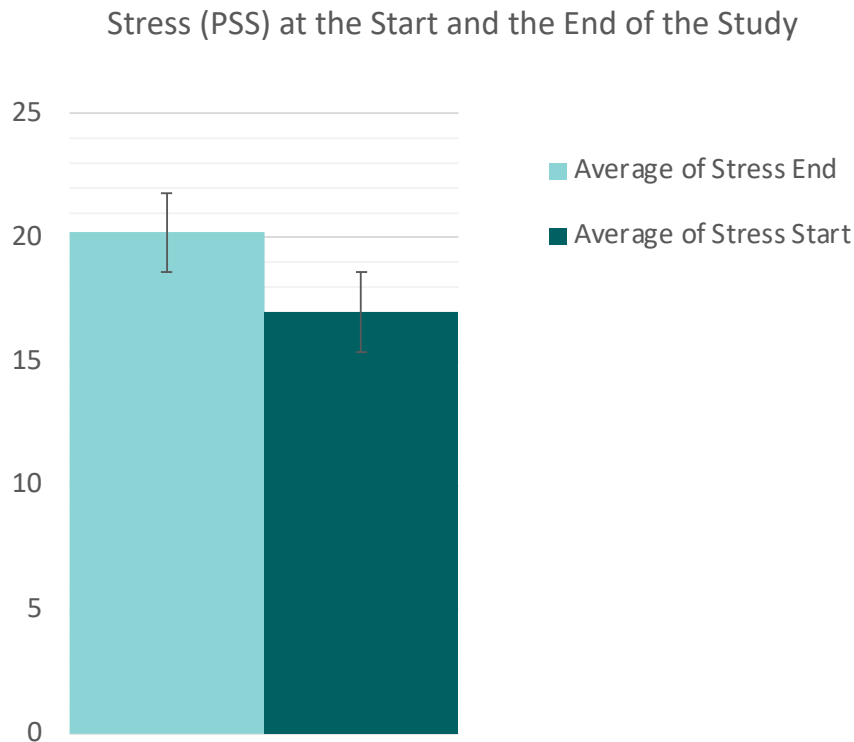


Figure 49. Change in stress (PSS scores) between the beginning and the end of the study (bars represent standard error).

7.4 Discussion

Although existing stress management apps do a commendable job of providing access to a variety of stress coping techniques, they still lack features that support their users' development of problem-focused coping skills (Coulon et al., 2016; Ptakauskaite et al., 2018). Problem-focused coping refers to people's ability to self-manage their stress by better understanding and resolving its sources (Skinner and Zimmer-Gembeck, 2016). Findings from our third study (Chapter 4) demonstrate how the way in which existing apps incorporate BCTs aimed at supporting people with self-regulation (e.g.,

goal setting) undermines peoples' basic psychological needs for autonomy and competence, particularly as applied within a stress management setting. Additionally, in our third study (Chapter 4) we find that this lack of support for problem-focused coping can limit a stress management app's potential efficacy.

The primary aims of the research presented in this chapter were to identify 1) whether reflective questioning delivered via a chatbot interface helps users gain insights into their stress, and 2) whether the use of dialogue-based short-term planning and problem-solving supports stress self-management. In our findings section, we focused on describing people's experiences using the Reffy chatbot together with the Welltory app, and their applications of the strategies supported by these apps in their day-to-day lives. We present below a more detailed interpretation of our findings. We begin by looking more closely at how people come to understand and manage their stress by positioning our work within the context of existing theories and research found in stress coping, behaviour change, and HCI literature. We end the chapter by discussing the limitations of our study.

7.4.1 Gaining Insights into Stress via Reflective Questioning

In this chapter, we confirm our findings from Study 4 (Chapter 5), which show that reflective questioning helps people generate insights into their stress, even in early stages of self-tracking. In doing so, we additionally demonstrate that reflective questioning leads to qualitatively similar insights across different interfaces (e.g., digital journal and chatbot). Similar to Kocielnik et al. (2018), we find that using chatbot-enabled reflective questioning alongside visualisations of sensor-generated data helps people engage in mindful self-tracking. Somewhat surprisingly, our participants also reported that insights elicited through reflective questioning originated from their own observations as opposed to coming from any reflecting on their data visualisations using Welltory.

Based on their findings from a study investigating how a chatbot designed to support people with gaining insights, Kocielnik et al. (2018) argue that people's ability to see their data visually was crucial for raising awareness and revealing progress relating to the target behaviour. During the study, the authors had presented visualisations of their participants' step-count data together with dialogues guiding people through a

series of reflective questions relating to those visualisations. Notably, the authors presented both the data visualisations and the dialogues in the same modality, which means that it was unlikely that users were able to disentangle the two. This may explain why their participants reported perceiving data visualisation as a necessity for reflection.

Our study, in contrast, used the Welltory app and the chatbot as two separate entities; yet like in the Kocielnik et al. (2018) study, our participants also reported improvements in awareness and gaining insights. With its origins in teaching and therapy practice, reflective questioning is not founded on the concept of data visualisation (Baumer et al. 2014; Fleck and Fitzpatrick 2010; Mols et al. 2016). It is therefore unlikely that data visualisation is a prerequisite for reflection or gains in awareness. Rather, it complements reflection, particularly in those instances where the data being used refers to *sensed data* that requires some form of initial pre-processing before it can be used to communicate insights via data visualisation. Once this data becomes visualised, its properties (e.g., trends, patterns) become amplified, this way revealing and emphasizing knowledge that was otherwise unavailable to the user. In our own research, we find that reflective questioning operates via a similar mechanism, whereby it complements reflective practices by enabling people to further develop, and even augment, their self-knowledge. This can then lead to the users' gaining insights that they could not have gained otherwise (i.e., without going through the process of answering reflective questions posed by the chatbot). Yet, unlike the process of reflecting on visualisations of sensed data, reflective questioning can be performed without prior access to self-tracking data. In short, our findings highlight that, reflective practices that draw on peoples own-self-knowledge, rather than quantitative measures and their visualisations alone, hold more value in helping people to gain insights.

Placing this into a broader context, the finding that data visualisation is not necessary for self-reflection to occur needs to be made explicit, as most existing stress and mood monitoring apps rely heavily on data visualisations alone to support reflection (see Chapter 3) (Caldeira et al. 2017). This is not to say that our study undermines the value that reflecting on data visualisations can bring. On the contrary, reflective questioning delivered via a conversational interface is unlikely to outperform, for

example, time series visualisations, conveying information on trends and patterns (Choe et al. 2017; Cuttone et al. 2014). Therefore, a potential avenue for future research would be to explore how to leverage the different channels for eliciting reflection throughout the different stages of self-tracking or even when tracking different facets of life (Choe et al. 2017; Kim et al. 2017b; Ptakauskaite et al. 2018).

7.4.2 Understanding Stress and the Factors Affecting it via Objective Self-monitoring and Reflective Questioning

Our findings highlight the value of enabling people to reflect on both subjective and objective stress reports together, a process that enhances reflection by combining subjective stress inferences with chatbot-enabled reflective questioning. We confirm our findings from Study 3 (Chapter 4) in which our participants expressed their frustration with not being able to exert more control over how the Welltory app quantified and communicated their stress results (high, medium, low, etc.) to them. This was especially apparent in instances where Welltory's inferences did not match the users' subjective evaluations. We also present initial findings on how this need for autonomy when self-tracking via sensor-generated inputs can be addressed through interacting with a chatbot. The chatbot interface provided people with an opportunity to use their own words to express how stressed they were feeling. This enabled them to dissociate and compare their subjective perceptions of stress together with Welltory's objective stress inferences, as defined by physiological markers, which, in turn, benefited them by stimulating deeper levels of reflective thinking. Importantly, introducing the slow and mindful reflective practices facilitated by the chatbot ultimately helped alter and enrich the way in which people reflected on and interpreted Welltory's objective stress measurement results.

Our findings also highlight the value that self-monitoring and reflective questioning can add in helping to create the conditions for people to reflect on their existing self-knowledge about the factors affecting their stress and, by reinforcing such knowledge, encourage behaviour change. To illustrate this, a consistent theme across the findings presented in this thesis is that our participants did not identify new stressors, but rather reaffirmed their prior beliefs about factors causing them stress. Specifically, although they could anticipate their stressors, our participants' objective stress levels, as

indicated by Welltory, were consistently higher than what they had expected. Besides the contrast between subjective versus objective observations about stress, most people did not report learning any additional novel information by using Welltory. The remainder of their observations simply confirmed and reinforced their existing knowledge about stress and the factors affecting it. This finding – that not all users gain novel insights from reflecting on self-tracking data – was anticipated and is not considered to be problematic. Indeed, such an outcome has been observed in other research (Dijk et al. 2017a; Pantzar and Ruckenstein 2017). For example, Bentley et al. (2013) found that visualising obvious and intuitive observations (e.g., stress correlating with a person’s sleep) can be more promising for eliciting change than focusing on observations that are novel but possibly less intuitive (e.g., stress correlating with atmospheric pressure). This is likely because these intuitive observations are already consistent with peoples’ prior world views and their impacts on stress (i.e., we tend to expect sleep to impact our stress levels, but we do not usually expect atmospheric pressure to do the same). Our findings are similar to Bentley et al.’s in that, by learning more about their stress levels and confirming their pre-existing knowledge about factors affecting their stress, our participants were motivated by the Welltory and Reffy apps to continue engaging in helpful self-regulatory behaviours.

Despite similarities in *learning* about stress and the gaining of *insight* into it reported across all three field studies (Studies 3-5), participants involved in the fifth field study expressed a greater *awareness* and a deeper *understanding* of the factors affecting their stress and how to manage it than did those in its predecessors (Chapters 4-5). This difference is likely attributable to the problem-solving exercise that was introduced as a new feature in the fifth study’s chatbot. The problem-solving exercise consisted of a series of reflective questions aimed towards encouraging people to reason out for themselves how they can manage their stress (Nezu 2004), adding a layer of self-reflection not available in Studies three and four.

Specifically, we found that reflective questioning can guide users’ to deeper levels of reflection within the context of stress management. This is accomplished through eliciting *transformative reflection*, a process of reorganising and restructuring existing knowledge to enable fundamental changes in one’s thinking or behaviour (Baumer

2015; Fleck and Fitzpatrick 2010). Although this was not something that explicitly guided the design of our study, we found that the problem-solving exercise lent an unexpected but welcomed aspect to the chatbot, as it led participants to engage in transformative reflection, which in turn helped them form action plans for stress self-management (Nezu 2004). Indeed, we found that this process guided participants in our fifth study toward re-evaluating both their understanding of their stress and their approach to regulating it.

The distinction between the fifth study and prior studies can be highlighted by comparing the chatbot questions in Study 5 (the present study) with those used in the Evernote journal in Study 4 (Chapter 5). Unlike the chatbot's problem-solving approach, which encouraged transformative reflection, the Evernote journal did not explicitly guide people towards changing or reframing their existing assumptions. Instead, the questions in Study 4 (Chapter 5) were oriented toward supporting participants' recall of stress-related events and mental states, and their exploration of the relationships between them. As a result, participants in our fourth study (Chapter 5) reported becoming more aware of *how* stressed they felt or the somatic aspects of their stress, but, unlike those in the fifth study, did not report any greater awareness as to *why* they were stressed. These findings demonstrate that the way in which reflective questions are framed has an important influence on both the level of reflection and, as will be explained in the section below, the impact that reflection and the resulting insights have on self-regulatory behaviours.

7.4.3 Managing stress via dialogue-based short-term planning and problem-solving

We find that short-term planning and problem-solving can help motivate engagement in autonomous self-regulation for stress self-management. Specifically, we highlight that there is a need for technology to support people in the *here and now* by reminding them of the activities they can do to cope with their stress. People who are experiencing high levels of stress may forget what helpful coping activities have helped them in the past and that they have the autonomy and skills to engage in those activities. Below, we discuss in more detail the process by which existing stress monitoring tools impact peoples' stress management efforts and how this process can

be improved by adding intervention features designed to support problem-focused coping in a way that meets peoples' needs for autonomy and competence.

7.4.3.1 Managing stress through short-term planning

The short-term planning feature that was implemented as part of the chatbot's daily reflection report offered an alternative approach toward encouraging people to engage in autonomous self-regulation. Most stress management apps support self-regulation and problem-focused coping through features such as planning or goal setting. These are frequently associated with automated reminders to perform various goal-related activities (Coulon et al. 2016; Ptakauskaite et al. 2018; Sniehotta et al. 2006) and generally operate under the principle of controlled self-regulation, whereby a behaviour becomes initiated due to an external perceived locus of causality (Ryan and Deci 2000, 2002), i.e., the automated push notification. In Study 4 (Chapter 4), we found that people often perceived these reminders as annoying and inconvenient, especially when they came at inopportune moments. In such cases, instead of encouraging participants to engage in stress relieving activities, receiving reminder notifications when they could not or did not want to engage in a planned activity had the adverse effect of engendering feelings of pressure and/or guilt. This is in line with (Diefenbach et al., 2016), who, in a survey of 177 users of self-improvement technologies, found that such negative feelings of guilt and "*getting on the users' nerves*" can result in a technology being abandoned before users gain any benefit from it. Ultimately, these types of negative experiences allude to a design that undermines peoples' sense of autonomy and competence (Calvo et al. 2020; Ryan and Deci 2000). With this in mind, and guided by the principles of positive computing (Calvo and Peters 2014; Diefenbach 2018; Wiese et al. 2020) and SDT (Ryan and Deci 2000), we designed and implemented a chatbot-based feature expressly aimed at encouraging autonomous self-regulation. Our feature relied on self-awareness rather than automated reminders to promote people's engagement in positive self-care activities. As demonstrated in the present study, our approach proved effective not only in encouraging people to engage in more positive self-care activities, but in freely choosing and initiating them on their own volition. Consequently, instead of invoking feelings of annoyance and guilt, the self-care activities facilitated through our

chatbot's short-term planning prompts gave people something positive to look forward to the next day.

By highlighting and reminding people about the positive feelings associated with engaging in self-care, and by making them more cognisant of activities they could do to relax the next day, we encouraged our participants to practice self-care more frequently than they otherwise would have. From a motivational perspective, the chatbot's short-term planning feature encouraged participants to create conditions in which they could practice intentional and mindful self-care (Ryan and Deci 2000; Wiese et al. 2020). This was achieved through 1) daily messages reminding them to reflect on the satisfying and uplifting activities they had done the day before, followed by reminders prompting them to set aside time for themselves the following day, and 2) the chatbot's inherent orientation toward supporting autonomy. By not having specific activities prescribed for them, chatbot users were motivated to self-select and engage in activities that fit with their personal interests, values, and lifestyle, as well as their current self-care needs. From a behavioural perspective, such behavioural autonomy is known to contribute towards heightening peoples' perceived behavioural control, which ultimately promotes self-regulation (Hagger and Chatzisarantis 2014; Sheeran et al., 2003). According to research on planning and action control (Orbell and Sheeran 2000; Scholz et al. 2007), planning encourages people to tie a specific behaviour to an environmental or situational cue. This cue can be anything from coming home from work (environmental/time-based cue) to feeling stressed (psychological state). Once people encounter that cue, it acts as a trigger for enacting the planned behaviour. Because the previous day's planning activity had already made people more cognisant of what activities they could undertake, they subsequently reported engaging in more self-regulatory behaviours than they normally would have.

7.4.3.2 Solving Problems and Changing Approaches towards Stress Management

Findings from the present study also demonstrate that integrating features to support self-monitoring and reflection alone is not enough to encourage engagement in problem-focused coping. This is evidenced in our fourth study (Chapter 5), where, because features designed to trigger problem-focused coping were not included, most

of the participants reported that they found themselves trying to avoid their stressors rather than deal with them. Lack of control is known to contribute towards engaging in such maladaptive and avoidant coping behaviours (Aspinwall and Taylor 1997; Carver et al., 1989) as those described by our participants. There is also evidence in behaviour change literature indicating that people who perceive they lack control are generally less likely to engage in self-regulation (i.e., coping) (Sheeran et al. 2003; Sniehotta et al. 2006). Similar to Kocielnik and Sidorova (2015), we also found that, while self-monitoring and reflection helps people gain insights into and raise awareness of their stress, they nevertheless still struggle to translate that newfound knowledge into actions. Relatedly, a study of mental health apps by Bakker et al. (2018) also found that improvements in coping self-efficacy, as opposed to any increases in emotional self-awareness gained from self-monitoring, contributed most to the apps' overall efficacy. This corresponds well with our findings in the present study, where the short-term efficacy of the chatbot intervention was driven not only by reflection and increases in awareness, but also by features designed to directly target peoples' coping abilities and behaviour change.

In detail, we find that more participants in the present study (85% of those asked) than in Study 4 (Chapter 5) (25%) reported engaging in problem-focused coping, including becoming more proactive and competent in managing their stress and thinking more about how they are doing so. They described realising that they could and, in fact, should take steps to control their stress themselves. These accounts of their discovering their own capacity for *ability* and *control* evidences our participants' increased sense of *competence* in self-managing their stress (Ryan and Deci 2000). This finding also indicates that the design of Reffy's dialogue-based problem-solving exercise was successful in providing direct guidance to users for coping with a given stressor. It also gave our participants a framework upon which they could rely to manage their stress themselves. The coping strategies developed through interacting with Reffy consequently led our participants to fundamentally change the way in which they coped with stress, reporting that they had come to be more likely to approach, rather than avoid their stressors. From a stress coping perspective, as detailed in the previous section, lack of control is known to discourage people from approaching their stressors and even lead them to engage in avoidant and maladaptive coping behaviours (Aspinwall and Taylor 1997; Carver et al., 1989). In contrast, engaging in

problem-solving is known to increase people's perceived control (Nezu 2004). According to Ryan and Deci (2000), people need both a sense of competence and a sense of control (autonomy) to be motivated to engage in self-regulatory behaviours. In line with SDT (Deci and Ryan 2012; Ryan and Deci 2000), our findings demonstrate that providing people with guidance in creating their own coping strategies is a key factor in their attaining a sense of competence and control to motivate their engagement in self-regulatory behaviours for stress self-management.

Another noteworthy observation is that our participants were able to perceive that both the short-term and action plans they had created with the chatbot were flexible, and that this encouraged their engagement in autonomous self-regulation. In her work on positive computing, Diefenbach (2018) highlights the potential for action plans to undermine users' sense of autonomy. She attributes this to the notion that action planning leaves little space for "excuses" as people are asked to specify not only what they will do, but also when, in which situation and/or where (Gollwitzer 1999; Sniehotta 2009). Naturally, one might assume that the clear link between a situational cue and a behavioural response does not provide room for flexibility. Diefenbach (2018) therefore argues that technology should balance *demand* and *autonomy* in its design, with demand referring to a clear call to action that is associated with a concrete set of instructions. In the present study, we satisfied the *demand* component by incorporating action planning into the problem-solving exercise. The need for *autonomy* was met by inviting people to continuously update those action plans based on their current self-care needs (as the chatbot asked our participants to create new action-plans every week). In doing so, we were able to overcome the potential barrier of people perceiving their plans as "set in stone". More importantly, this perceived sense of autonomy may also be attributed to the fact that our participants formed their plans with the help of a chatbot instead of a human coach. Not feeling accountable to another human being may very likely have imparted the sense of flexibility associated with plans made during the current study. What the above findings highlight is that the combination of providing users with a framework for planning, implementing such a framework in a way that invites them to continuously update and adapt their plans, and potentially, not having a human-in-the-loop, enabled us to reach an equilibrium between *demand* and *autonomy* that created favourable conditions for behaviour change.

Finally, as coping theory (Aspinwall and Taylor 1997; E. A. Skinner and Zimmer-Gembeck 2016) would suggest, our participants found that the problem-solving exercise was useful only when they had appraised their stressor as both substantial and within their immediate control. Several participants reported not experiencing stress levels high enough to warrant engaging in problem-solving. Others reported experiencing stressors that they said were outwit their control (e.g., financial difficulties and job hunting), rendering the exercise unproductive. In this case, engaging in emotion-focused coping would have been more helpful. Emotion-focused coping techniques such as meditation or yoga can distract people from stressful experience as well as regulate the way in which they react to future stressors (E. A. Skinner and Zimmer-Gembeck 2016). Although the chatbot did include links to emotion-focused activities, such as deep breathing and meditation, our finding nevertheless highlights the need for proactively guiding users to appropriate coping strategies. Research on stress coping strategies suggests that people usually turn to different coping techniques based on factors such as perceived control of a given stressor and the resources at hand (E. A. Skinner and Zimmer-Gembeck 2016; Taylor and Stanton 2007). Because there is currently a lack of apps that can adequately support both emotion and problem-focused coping (Coulon et al. 2016; Ptakauskaite et al. 2018), future research could investigate how to present people with emotion and problem-focused coping based on the types of stress that people are experiencing.

7.5 Limitations

The first limitation of our work relates to the generalisability of our findings. It is unlikely that within real-world settings most people would complete the problem-solving exercise on a weekly basis without being prompted to do so. This is because it is uncommon for stress management apps to include a protocol detailing how frequently a given app function should be used. Most commercial apps have a variety of features and stress management techniques available to their users at any given time. Therefore, people might use a technique like problem-solving only once a month and instead use other techniques available in the app more frequently. As such, the effects on understanding and stress management that problem-solving has could be different when used in real-world settings. Future research could investigate how to best follow up with users and encourage them to revisit their action plans.

The second limitation of our study relates to us not capturing quantitative outcome measures with regards to using the Welltory app's and the Reffy chatbot's interfaces. This was primarily due to the Reffy chatbot being an early prototype, which was not integrated with the Welltory app, making evaluations on the interface level premature. Rather than focusing on evaluating both apps on the interface level, we were interested in capturing how well the BCT-based conversational features incorporated into the Reffy chatbot supported its users' needs for autonomy and competence when trying to understand and manage their stress. That being said, we acknowledge that future research using more mature wellbeing technologies should evaluate their ability to support peoples' needs on an interface level.

Finally, the chatbot implemented for this study had a linear design and lacked personalisation to the users' responses. This resulted in some users being put off by the repetitiveness and a lack of intelligence and understanding associated with the chatbot. Adding more response types and variations based on user inputs would have provided higher and/or more meaningful levels of engagement, which is vital for the future development of such tools and a fruitful avenue to explore for future research.

7.6 Conclusion

The primary aim of this research was to understand how dialogue-based reflective questioning, short-term planning, and problem-solving together support people with better understanding and managing their stress. To achieve this, we ran a 3-week self-tracking study. Findings from this study help confirm that dialogue-based reflective questioning can successfully help people gain insights into their stress during the initial stages of using a stress monitoring app. We also find that, besides supporting users with BCTs, the design of stress management apps needs to additionally account for motivational factors such as autonomy and competence to help their users with implementing BCTs in their daily lives. In the next chapter we discuss the broader implications of our work, provide design considerations, and discuss future research opportunities.

8 General Discussion

Drawing on a mixed-methods approach, this thesis investigated how coping relevant BCTs could be incorporated into mobile apps in a way that supports people in understanding and managing their stress. In this concluding chapter, we take the opportunity to relate our findings to past research and reflect on our contributions to the understanding of how mobile apps can better support their users with stress self-management. We then discuss broader implications for design and finish the chapter by explaining the limitations of our work and provide future research directions.

8.1 Supporting People in their Efforts to Understand and Self-manage their Stress

In this thesis, we investigated how people use, experience, and apply BCTs delivered via a mobile app as part of their efforts to understand and manage their stress. In doing so, we aimed to inform how coping relevant BCTs could be incorporated into mobile stress management apps so that users can leverage their full potential. Our findings reveal that, for people to be successful in implementing coping-relevant BCTs in their day-to-day lives, the app features that incorporate such techniques need to support peoples' sense of agency and control. In our work, we demonstrated one way in which such features can be designed and implemented, namely, through the use of chatbot-based reflective questioning, short-term planning, and problem-solving.

When looking at research assessing stress management apps, it becomes evident that much of the existing work has focused primarily on either a) evaluating their overall efficacy (Harrer et al., 2018; Ly et al., 2014; Moberg et al., 2019) or b) counting the number of evidence-based techniques that they include (Christmann et al. 2017; Coulon et al. 2016; Ewais and Alluhaidan 2015). Because most research was not expressly aimed at investigating what peoples' experiences of applying the app-delivered coping techniques have been like (with the notable exception of Howe et al. (2022)), it provides limited insight into how to design app features that could lead to improvements on existing solutions.

Through our research, we contribute to the above body of work by providing more granular insights into whether and how existing apps support their users with implementing coping-relevant BCTs and where improvements can be made to better meet user needs. We achieve this by first conducting an in-depth functionality review, which we follow up with three field evaluation studies using existing apps.

Evaluating existing solutions: app review and field evaluation. Our app functionality review and field studies identify limitations in how existing stress monitoring apps support peoples' reflective practices. One possible source of this feature gap relates to much of past research within the PI domain focusing on self-monitoring and data visualisation as a primary means of facilitating self-reflection and self-insight (e.g., Choe et al. 2017; Cuttone, Petersen, and Larsen 2014; Epstein et al. 2014; Huang et al. 2015; Li, Dey, and Forlizzi 2011; Marcengo and Rapp 2014; Swan 2012). Guided by a background review of exiting PI literature, we similarly commenced our research efforts by looking at how apps support their users with understanding their stress through self-monitoring and data visualisation. However, after running a field study using an existing app, we identified that, when it comes to stress self-monitoring, users need to collect more than 3-weeks' worth of continuous self-tracking data for reliable trends and patterns to emerge. This is despite the Welltory app supporting sensor-based measurements that should, in theory, provide users with immediate access to additional information (e.g., HRV-based physiological stress levels). Notwithstanding, the barrier here was that even the sensor-based stress measurements could not reliably and consistently reveal what factors were affecting peoples' stress levels without collecting more than 3-weeks' worth of self-tracking data.

We additionally identify challenges with how existing apps incorporate BCTs such as goal setting and planning to help users engage in beneficial health behaviours. Past research (Moberg et al. 2019), including our own findings (see Chapter 4), suggest that goal setting is associated with improvements in mental wellbeing outcomes. Nevertheless, our qualitative investigation (Chapters 4 and 5) revealed that goal setting features incorporated into existing apps, despite being potentially beneficial in some instances, could also lead to unnecessary stress and pressure when users could not meet their goals. The above findings add to existing body of work evaluating the

efficacy of stress management apps by highlighting that the self-monitoring and goal setting features incorporated into such apps need to be adapted to fit within a stress management context. This is primarily so that users can leverage the full potential offered by such techniques.

Improving on existing solutions: reflective questioning, short-term planning and problem-solving incorporated into a chatbot interface. Through our research (Chapters 3-6), we identified that people have express needs related to their use of stress management apps for implementing coping-relevant BCTs:

- 1) being able to gain insights into their stress during initial stages of self-tracking;
- 2) initiate stress management behaviours without undermining their sense of autonomy, and;
- 3) receiving guidance on how to apply their insights about stress to form effective stress management strategies.

To address the first need, we concentrated our research efforts towards identifying a reflective practice that did not exclusively rely on having immediate access to self-tracking data. Building on Bentley et al.'s (2013) finding that people can anticipate 50% correlations in their data before beginning to self-track, we hypothesised that people should similarly have substantial self-knowledge about their stress. Additionally, the participants in our own and related research (Bentley et al. 2013; Choe et al. 2014; Epstein et al. 2014; Li, Dey, and Forlizzi 2012) reported being primarily interested in discovering what factors were associated with their wellbeing. Considering this, we focused on identifying strategies that could help users uncover such correlations. Then, drawing on research investigating the use of conversational interfaces to facilitate user reflection (Kocielnik, Avrahami, et al. 2018; Kocielnik, Xiao, et al. 2018; Kocielnik and Hsieh 2017a; Kocielnik, Hsieh, and Avrahami 2018), we identified reflective questioning as a suitable method and chatbots as a suitable interface for helping users gain insight into what factors are affecting their stress levels. We found our chatbot-based reflective questioning approach to be effective. However, our findings add to the above work on self-monitoring and reflection by highlighting that, when using reflective questioning to help users gain insights into their stress, the users

may not necessarily need data visualisations to support their reflective practices during the initial stages of self-tracking. As mentioned previously, we identified that our participants were primarily interested in uncovering information about their stress correlates. This finding suggests that data visualisations, such as bar and line charts, would be of little use for people trying to understand what factors affect their stress levels in the short-term. These visualisation types are primarily geared towards communicating trends and patterns, and are less intuitive when visualising correlations, especially those based on short-term self-tracking data (Cuttone et al. 2014). In our final study (Chapter 7), we find that a more effective use of our participants' time was to help them a) reflect on their own self-knowledge to gain insights into what factors are affecting their stress levels and b) apply those insights to inform stress coping strategies.

To address the second and third needs, we aimed to inform the design of novel app features that could help people translate their insights into stress coping strategies whilst promoting their sense of autonomy and competence. We achieved our aim through the design and evaluation of the Reffy stress self-management chatbot, the design of which builds on a body of work presented in the positive computing literature. Through our design contribution, we demonstrate how coping-relevant BCTs and stress self-management strategies can be augmented and incorporated into a chatbot interface to better support people in their efforts to understand and manage their stress.

The Reffy chatbot incorporated a dialogue-based short-term planning feature aimed at encouraging engagement in positive self-care activities and autonomous self-regulation. Our findings add to those discussed in Howe et al. (2022), who compared two chatbot-delivered intervention conditions: one condition based on user-scheduled reminders on when to engage in stress self-management and another condition that used system-identified user stress levels (inferred from computer usage, email and calendar load, as well as facial expressions and breathing rate captured via a laptop's camera) to deliver an automated, just in time (JIT) stress self-management intervention. Similar to Howe et al. (2022), we find that people prefer having the autonomy of deciding when to initiate stress self-management behaviours (see Chapters 4 & 7).

However, our planning approach proposed in Chapter 6 differs to the one described in Howe et al. (2022) in that our system did not send reminders based on the users' stress levels, nor did it ask the users to set reminders to perform the activities at a later time. The benefit of our approach was that we raised the users' awareness of what their stress levels were, which led to them becoming more cognisant of when to engage in coping activities without the need of automated reminders. Relatedly, even though the users in Howe et al. (2022) paper appreciated the system sending contextual prompts to engage in stress management activities, they also reported that sometimes the reminders were not useful and, in some cases, disruptive. This corroborates our own findings on automated reminders presented in Chapter 4, whereby our users found that automated prompts to perform stress management activities sent by Coach.me were perceived as unhelpful.

Looking at Howe et al's (2022) quantitative findings, users who received such reminders also engaged in more stress management activities than those users who were not prompted (the JIT condition). Considering this finding, their design suggestions allude to an approach that personalises the balance between automation and agency based on individual user preferences, ranging from high automation/low control to low automation/high control. Our findings add to those discussed in Howe et al. (2022) in that the short-term planning approach proposed in this thesis acts as an example technique that provides low automation/high control whilst effectively encouraging users to engage in beneficial behaviours for stress self-management.

Notably, what our own and Howe et al's (2022) findings indicate is that there is a need for technology to support people in the *here and now* by reminding them of the activities they can do to cope with their stress. As Howe et al. (2022) remarked, we are still quite a ways away from developing a truly reactive automated system that can accurately sense when users would benefit the most from a stress management intervention as a way of ensuring sustained engagement. Similarly, apps in general are known to be lacking in their ability support lasting habit formation (Stawarz, Cox, and Blandford 2015). In our own research, we demonstrate that using self-monitoring and reflective questioning to raise peoples' awareness and make them more cognisant of what has worked for them in the past can act as a supportive reminder to engage in helpful coping behaviours. We find that these coping behaviours can be simple

activities that can lead to positive experiences (see Chapter 7, Figure 46) (Wiese et al. 2020) and we provide preliminary evidence that such experiences may also contribute to improvements in perceived levels of stress. Considering this, future experimental and comparative studies could explore the benefits of app-based interventions that have their participants engage in positive activities to help them recover and relax in *the here and now* versus interventions aimed towards helping people form habits or other longer-term coping practices.

Finally, the chatbot presented in this thesis also included a problem-solving and action planning exercise explicitly aimed at providing people with a sense of competence in self-managing their stress. The Reffy chatbot was found to be effective in promoting peoples' sense of competence and autonomy with regards to their ability to self-manage stress. This helped them in translating their own self-knowledge into coping strategies that would fit within their daily lives. Instead of creating a sense of guilt and stress associated with existing goal setting app features, we were able to encourage people to engage in beneficial stress management behaviours as and when needed. Findings from our evaluation study demonstrate how, by supporting users' sense of autonomy and competence, we were able to help them apply the app delivered BCTs into their daily lives to help them with better understanding and managing their stress.

8.2 Design Considerations

Past research on health and wellbeing apps has highlighted design considerations aimed at encouraging mindful and meaningful self-tracking practices (Ayobi et al. 2017, 2018; Baumer 2015; Fleck and Fitzpatrick 2010; Shieh et al. 2018), and promoting engagement in positive health behaviours (Calvo and Peters 2014; Isaacs et al. 2013; Kocielnik, Xiao, et al. 2018; Kocielnik and Hsieh 2017b; Wiese et al. 2020). We began this thesis by primarily drawing on the literature discussing stress coping, personal informatics and behaviour change to inform the design of app features aimed towards helping people with understanding and managing their stress. This was driven by the principles of problem-focused coping in that, by identifying how different aspects of peoples' lives were affecting their stress levels, people could apply this knowledge and take concrete steps towards effectively managing their stress. As such, we relied on design guidelines provided by past research to identify best practices related to

data collection and visualisation (Bentley et al. 2013; Choe et al. 2014; Choe et al. 2017; Choe et al. 2017; Cuttone et al. 2014; Kim et al. 2017). We similarly benefited from Baumer's (2015), Fleck and Fitzpatrick's (2010), Kocielnik and Hsieh's (2017) work which provided us with frameworks and guidelines for supporting reflective practices. Over and above, the work reported in the positive computing literature (Calvo and Peters 2014; Diefenbach 2018; Diefenbach et al. 2016; Peters et al. 2018; Wiese et al. 2020) enabled us to intertwine the theory and practice described in the stress coping, PI and behaviour change literature into a cohesive set of design guidelines aimed at addressing peoples' stress self-management needs.

By iterating over our design guidelines, we evaluated different approaches aimed at supporting people with applying coping-relevant BCTs to understand and self-manage their stress. For example, we began our work by first evaluating the use of goal setting to help users adhere to selected stress management behaviours. Then, after identifying limitations with existing approaches, we evaluated the potential of chatbot-based features to support autonomous self-regulation via short-term planning. In the paragraphs below, we merge our insights from the overall thesis to provide more general design considerations on how apps can incorporate coping-relevant BCTs in a way that supports people with their stress self-management needs.

Design for reflection on self-knowledge to gain an understanding about stress and the factors affecting it. To improve the impact and value of stress management apps, features incorporated into such apps should encourage brief moments of reflection and provide users with immediate access to insights into how they can self-regulate their stress. As we found in Chapters 5 and 7, apps can successfully achieve this via reflective questioning – a reflective practice that can reveal insights by having users draw on their self-knowledge about stress. In our research, we find that when the goal of self-monitoring is to gain such an understanding, people benefit the most from engaging in short-term reflection. Across our studies, it became evident that our millennial participants lead busy lifestyles, with little time for self-care, let alone reflection on their current mental and physical states. Yet, despite their busy schedules, our participants actually appreciated the brief moments of reflection facilitated via both the Welltory app and the Reffy chatbot. The apps enabled and encouraged them to set aside a few minutes to reflect on how they were feeling and

what made them feel that way. More specifically, when using Welltory, this process was encouraged by taking a PPG-based stress measurement. In doing so, our participants became aware of their current stress levels, which helped them stay on track towards achieving their goals or intended behavioural outcomes. Using techniques such as reflective questioning added to this process by revealing and making people more cognisant of how different aspects of their lives and behaviours affected their stress levels. Collectively, our findings on enabling people to understand their stress levels and the factors that influence these indicate that app developers should strive to help their users gain such insights right from the beginning of using stress self-management apps.

Design for wellbeing and motivation to help people implement BCTs in their daily lives. Positive computing champions designs that support not only behaviour change, but also motivational factors, such as autonomy, competence, and relatedness (Calvo and Peters 2014; Diefenbach 2018; Wiese et al. 2020). Similarly, we find that when designing technology for stress self-management, or more generally, to promote greater wellbeing, it is helpful to not only include BCTs as app features, but to also ensure that such features are incorporated in a way that supports users' motivational and psychological needs. Accounting for these needs can help users feel better equipped to consistently and successfully implement the BCTs delivered via the app into their daily lives. For instance, by designing app features that meet peoples' needs for autonomy and competence, we were able to minimise the feelings of guilt and annoyance associated with automated reminders (see Chapters 4 and 5) and instead promoted positive experiences arising from engagement in more frequent self-care activities (see Chapter 7). Ultimately, as Diefenbach (2018) argues, technologies designed to support greater wellbeing should strive to implement features that balance *demand* with *autonomy*. In the present thesis, particularly our fifth study, we were able to draw on BCTs and techniques used in therapy settings that *demand*ed users create a stress-self-management action plan. However, the way in which these features were implemented provided our users with a sense of *autonomy* by inviting them to continuously change and adapt their planned activities or coping strategies based on their prevailing self-care needs.

8.3 Using a chatbot interface to facilitate understanding and management of stress

Although this thesis was not exclusively focused on chatbot interfaces, we feel that we have learned valuable lessons from designing and implementing a chatbot interface for stress self-management. Drawing on insights from our fifth study (Chapter 7), we contribute a set of design guidelines expressly aimed at conversational interfaces for stress self-management.

Explicitly guiding people to the right coping strategies based on their current self-care needs. Our participant interviews indicate that people should not only be provided with access to different coping strategies, but to also be explicitly informed on when to use which strategy, based on the type of stress that they are experiencing. Importantly, as was suggested by Howe et al. (2022), people should also have the autonomy to select the type and the duration of the activity to be performed. A unique attribute of chatbots is that they are particularly well suited to eliciting rich contextual information that can help reveal user's current needs (De Nieva et al. 2020; Xiao et al. 2020). This information can then be used to provide users with a set of relevant options to choose from for managing the specific stressful situation that they are facing.

Chatbot response personalisation and relatedness. According to Ta et al. (2020), a chatbot's ability to hold conversations on a variety of different topics facilitates not only engagement, but also feelings of relatedness and social connectedness. Therefore, adding more response types and variations based on user inputs would have provided higher and/or more meaningful levels of engagement with the Reffy chatbot. Our findings further highlight the importance of this type of meaningful personalisation (i.e., responding to a variety of topics and concerns) for the future development of such tools. Notably, when designing for experience of relatedness, in addition to using emphatic language and emojis, we find that, the importance lies in not only *how* the chatbot "talks" to the user, but *what* the chatbot is talking to the user about. In other words, it all boils down to the value that the conversation is adding in helping users to effectively self-manage their stress.

Chatbot response variation. Most of our participants found the daily reflection reports to be repetitive. One way in which this could be resolved is by adding more response variations given by the chatbot and more branching conditions based on user responses (e.g., guiding people to the relevant stress management technique based on the type of stress they are experiencing). Another way of reducing repetitiveness would be to interleave reflective questioning together with prompts to reflect on data visualisations. Notably, Kocielnik, et al. (2018) provide an excellent example of how data visualisations together with reflective questioning can be integrated into a chatbot interface.

Chatbot report frequency. Our participants reported that the daily reflection prompts were too frequent and that they would rather preferred reporting every other day. This was primarily attributed to not having new insights to report daily. One potential advantage of spacing out the reports is that this should also help avoid the conversations being perceived as too repetitive. On a similar note, in their chatbot study Howe et al. (2022) sent five notifications per day to prompt mood reports and suggest stress management activities to their participants. Unsurprisingly, and in line with our own findings presented in Chapter 7, participants in (Howe et al. 2022) study found that being notified five times per day was too frequent and did not bring measurable benefits in terms of intervention efficacy. Based on these findings, (Howe et al. 2022) suggest that notification frequency should be personalised to fit individual user needs and that to achieve this aim the designers of the system will need to leverage user input together with complex ambient sensing capabilities. As mentioned previously, implementing such a system will be a non-trivial challenge to both the HCI and the wider computing communities. This effort will require identifying and optimising various sensing capabilities that will be informative enough to infer the times when people will be most receptive to an intervention. Yet, until the time of when such a system is developed, chatbot designers could overcome challenges associated with repetitiveness by including more response variations, changing-up the types of intervention-related content presented during those conversations and asking their users to adjust their desired report frequency.

8.4 Limitations and Future Work

In the following section, we address the broader limitations of the work presented in this thesis, including our methodological approach and research scope, and provide directions for future work.

8.4.1 Methodology

The aim of this thesis was to inform how mobile apps can incorporate coping-relevant BCTs in a way that supports people in understanding and managing their stress. To achieve this aim, we adopted a mixed methods approach, using quantitative analysis to test whether a technology is behaving as expected (i.e., is effective) during the initial stages of its use and qualitative analysis to inform what users' experiences of interacting with stress self-management apps have been like (Klasnja et al. 2011). It could be argued that a series of controlled experiments or even randomised controlled trials could have provided more reliable findings with regards to the efficacy of the apps and the features they include. However, through our use of field studies and a mixed methods approach, we contributed to our understanding of whether and how existing stress monitoring and management apps support peoples' needs in implementing coping-relevant BCTs. Firstly, our initial field study revealed that people did not have enough data to gain insights into what factors were affecting their stress levels. We also discovered that goal setting features incorporated into existing wellbeing apps do not lend themselves well to supporting peoples' stress self-management needs. This is despite a past RCT indicating that, from a quantitative perspective, goal setting is linked to beneficial mental health outcomes (Moberg et al., 2019).

Drawing on qualitative accounts of how our participants used and experienced existing apps enabled us to identify areas for improvements. This, in turn, has helped to directly inform the design of novel app features aimed at addressing limitations of existing solutions. These app features, including dialogue-based reflective questioning, short-term planning and problem-solving were designed to support peoples' sense of agency and competence when using apps to understand and self-manage their stress. Drawing on our initial findings, future work could involve running comparative studies

to investigate the value that chatbot-based features aimed at supporting reflection and stress self-management add to the efficacy of existing apps.

8.4.2 Research Scope

Other types of coping-relevant BCTs, such as stress management (engaging in emotion-focused activities to reduce stress symptoms) and time management (help prevent stress in the future by effectively managing one's time), could help users self-manage their stress (Christmann et al. 2017). The BCTs investigated by our research were self-monitoring, goal setting, and planning, all of which are known to support people with problem-focused coping (Christmann et al., 2017; Richardson & Rothstein, 2008). We selected these specific app features following the findings from previous research suggesting that the currently available stress self-management apps rarely included coping relevant BCTs. Relatedly, considering our finding that existing literature within the PI domain has primarily overlooked the intention-behaviour gap, we were additionally interested in investigating whether existing apps provided adequate support for both self-monitoring as well as features such as goal setting and planning. Considering that problem-focused coping involves people taking direct action to manage their stress, self-monitoring, goal setting and planning were considered as an appropriate starting point to study how BCTs could be incorporated into stress self-management apps. However, investigating how apps might incorporate other types of coping-relevant BCTs, such as the technique time management, could have a potentially significant impact on helping people to manage the sources of their stress more effectively.

Another crucial area to explore is how to help users in selecting the appropriate stress management techniques based on their current self-care needs. As mentioned earlier in this chapter, chatbots can act as a suitable modality for guiding users towards appropriate coping strategies. This is because chatbots can elicit timely and highly contextual information representing the user's current self-care needs. In our own research (Study 5), we found that people reported on various stressors they were facing, including work, studying, relationships, among others. The chatbot can use this information to subsequently guide people towards content that will be relevant for addressing the challenges they are facing.

8.4.3 Participants

The research presented in this thesis used a sample that primarily consisted of higher education students – individuals who are likely more educated and wealthier than the average UK resident. For instance, only 22% of students entering a higher education institution in 2021 came from disadvantaged backgrounds (UniversitiesUK, 2021). Relatedly, in 2020, only 39.3% of the UK's population aged 15 to 64 had a higher education degree (or its equivalent) (Clark, 2021). Highlighting this limitation is important for several reasons. Firstly, there is a clear link between socio-economic disadvantages and poor mental health outcomes, as well as other, stigma and finance-related barriers to benefiting from mental health treatment (Knifton and Inglis, 2020). A study by Knifton and Inglis (2020) investigated the relationship between poverty and mental health within the most deprived areas of Glasgow. The implications stemming from their research indicate that, before addressing mental health challenges directly, peoples' basic needs must be met, including access to affordable housing and social care. Only once those needs are met, people from lower socioeconomic groups will be able to fully benefit from a stress or any other type of mental health intervention (Knifton and Inglis, 2020). Secondly, because the population used in the studies presented in this thesis did not require delivering intervention components aimed at reducing the stigma associated with seeking out support or addressing the previously mentioned barriers to benefiting from mental health care, further research is required to determine whether the findings stemming from the app-based interventions generalise to other UK's population segments.

9 General Conclusion

Currently available stress management apps do not incorporate features that adequately support their users with both understanding and regulating stress – key processes that underline problem-focused coping. Drawing on a mixed-methods approach, this thesis investigated how to design digital stress management tools that can help people understand and manage their stress in ways that align with their needs. An app feature review and evaluation and a follow up 3-week intervention study revealed two feature gaps limiting the efficacy of existing stress self-management apps: a lack of data during early stages of use on which to reflect, and a lack of guidance on how to better self-regulate stress. To address these limitations, we designed a stress self-management chatbot prototype called Reffy, which we evaluated in a 3-week intervention study. The aim of the evaluation study was to examine whether the addition of chatbot-based planning and problem-solving improves upon Welltory's short-term effectiveness. We found that dialogue-based reflective questioning helps people gain insights into their stress, and that adding features that promote users' sense of autonomy and competence improves Welltory's ability to support coping strategies.

Findings from this thesis improve our understanding of how behaviour change and stress coping techniques can be augmented and incorporated into mobile apps to effectively support people with stress self-management and experiences of competence and agency. These findings are particularly relevant to informing the design of mobile health and wellbeing apps aiming to incorporate behaviour change techniques in a way that aligns with peoples' self-care needs. Potential avenues for future work include exploring how to leverage reflective questioning at different stages of self-tracking, how to help users in selecting the appropriate stress management techniques based on their current self-care needs, and how to incorporate chatbot-based features supporting behaviour change within other areas of wellbeing self-tracking.

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Appendix 1 Chapter 4

Participant Information Sheet for Adult Participants

UCL Research Ethics Committee Approval ID Number: UCLIC/1718/005/Staff Cox/Ptakauskaite
YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

Title of Study: Investigating the use of mobile apps for stress management

Department: Computer Science

Name and Contact Details of the Researcher(s): Nora Ptakauskaite, UCL Gower Street, London WC1E 6BT, United Kingdom, [REDACTED]

Name and Contact Details of the Principal Researcher: Principal investigator: Anna Cox, UCL Gower Street, London WC1E 6BT, United Kingdom, [REDACTED].

1. Invitation Paragraph

You are being invited to take part in a PhD research project investigating how apps could be used to encourage stress management. Before you decided, it is important for you to understand why this research is being done and what participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

2. What is the project's purpose?

Stress is commonly referred to as the health epidemic of the 21st century. Smartphone devices lend themselves well to health and wellbeing interventions: they are widely accessible and can support the delivery of various intervention materials.

The goal of the present research is to explore how people may use mobile wellbeing apps to understand how different factors affect their stress and how they can use this information to change their behaviours.

3. Why have I been chosen?

You were chosen because you meet the inclusion criteria for this study. You are:

- interested in how mobile apps could help people reduce their stress;
- happy to share your own knowledge and experience of using mobile self-tracking apps, e.g., for fitness, stress/mood monitoring;

There will be around 100 participants recruited for this research project, consisting of several studies investigating different aspects (e.g., usability, data visualisation) of mobile apps for fitness and stress management.

4. Do I have to take part?

Your participation in this study is entirely voluntary. It is up to you to decide whether or not to take part.

On-line survey participants: as you will be participating in an anonymous survey, the submission of a questionnaire will imply that you have given us consent. We will not be able to withdraw your data after you have submitted it.

App Evaluation Interview Study Participants: If you do decide to take part in the interview and app evaluation study, you will be given this information sheet to keep and be asked to sign a consent form. You can withdraw at any time without giving a reason and without it affecting any benefits that you are entitled to. If you decide to withdraw you will be asked what you wish to happen to the data you have provided up to that point.

5. What will happen to me if I take part?

You will be asked to share your experiences with self-tracking, e.g., what types of data do you track, what tools do you use etc. The interview will be approximately 30-minutes long and will be conducted either on UCL campus or online. Any travel expenses related to this study will be reimbursed.

6. Will I be recorded and how will the recorded media be used?

The interviews will be audio recorded. The transcripts of the audio recordings made during this research will be used only for analysis and for illustration in conference presentations and lectures. No other use will be made of them without your written permission, and no one outside the project will be allowed access to the original recordings. The recordings will be securely stored on a password protected laptop. All data will be collected and stored in accordance with the Data Protection Act 1998. You may withdraw your data from the project at any time up until it is transcribed for use in the final report (01/01/2021).

7. What are the possible benefits and risks of taking part?

Whilst there are no immediate benefits for those people participating in the project, it is hoped that this work will contribute to the development of new technology for stress management. There are no risks involved in participating in this research.

8. What if something goes wrong?

Should you wish to raise a complaint please contact the Principal Researcher Anna Cox – anna.cox@ucl.ac.uk
If you feel that your complaint has not been handled to your satisfaction by the principle researcher, you can contact the Chair of the UCL Research Ethics Committee – ethics@ucl.ac.uk

9. Will my taking part in this project be kept confidential?

All the information that we collect about you during the course of the research will be kept strictly confidential and anonymised. You will not be able to be identified in any ensuing reports or publications.

10. Limits to confidentiality

Confidentiality will be maintained as far as it is possible and will be strictly adhered to. However, please note that confidentiality may not be completely guaranteed in cases where the size of the participant sample is small (e.g., an interview study).

11. What will happen to the results of the research project?

Results of this research will be disseminated in standard academic outlets and will be a part of a PhD thesis. Results may also be disseminated via general interest magazines / newspapers / journals. You will not be identified in any report or publication.

Should you wish to obtain a copy of the publication related to this study, please contact Nora Ptakauskaite nora.ptakauskaite.16@ucl.ac.uk at least 6 months after taking part in the study.

12. Data Protection Privacy Notice

The data controller for this project will be University College London (UCL). The UCL Data Protection Office provides oversight of UCL activities involving the processing of personal data, and can be contacted at data-protection@ucl.ac.uk. UCL's Data Protection Officer is Lee Shailer and he can also be contacted at data-protection@ucl.ac.uk. ***Your personal data will be processed until the end of this research project (01/01/2022).***

If you are concerned about how your personal data is being processed, please contact UCL in the first instance at data-protection@ucl.ac.uk. If you remain unsatisfied, you may wish to contact the Information Commissioner's Office (ICO). Contact details, and details of data subject rights, are available on the ICO website at: <https://ico.org.uk/for-organisations/data-protection-reform/overview-of-the-gdpr/individuals-rights/>

13. Who is organising and funding the research?

This research is organised by University College London.

14. Contact for further information

Please contact Prof Anna Cox – anna.cox@ucl.ac.uk for any further information.

Thank you for reading this information sheet and for considering to take part in this research study.

CONSENT FORM FOR ADULTS IN RESEARCH STUDIES

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Study: Investigating the use of mobile apps for stress management

Department: Computer Science

Name and Contact Details of the Researcher(s): Nora Ptakauskaite, UCL Gower Street, London WC1E 6BT, United Kingdom, nora.ptakauskaite.16@ucl.ac.uk, [REDACTED].

Name and Contact Details of the Principal Researcher: Anna Cox, UCL Gower Street, London WC1E 6BT, United Kingdom, anna.cox@ucl.ac.uk, [REDACTED].

Name and Contact Details of the UCL Data Protection Officer: Louise Gaynor, UCL Gower Street, London WC1E 6BT, United Kingdom, l.gaynor@ucl.ac.uk, [REDACTED].

This study has been approved by the UCL Research Ethics Committee: Project ID number: _____

Thank you for considering taking part in this research. The person organising the research must explain the project to you before you agree to take part. If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

I confirm that I understand that by ticking/initialling each box below I am consenting to this element of the study. I understand that it will be assumed that unticked/initialled boxes mean that I DO NOT consent to that part of the study. I understand that by not giving consent for any one element that I may be deemed ineligible for the study.

		Tick Box
1.	*I confirm that I have read and understood the Information Sheet for the above study. I have had an opportunity to consider the information and what will be expected of me. I have also had the opportunity to ask questions which have been answered to my satisfaction and would like to take part in the interview study.	
2.	*I understand that I will be able to withdraw my data up to 01/01/2021.	
3.	*I understand that no personal information about me will be collected.	
4.	*I understand that my data gathered in this study will be stored anonymously and securely. It will not be possible to identify me in any publications.	
5.	*I understand that my information may be subject to review by responsible individuals from the University for monitoring and audit purposes.	
6.	*I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason and will be fully compensated if I choose to withdraw.	
7.	I understand that the data will not be made available to any commercial organisations but is solely the responsibility of the researcher(s) undertaking this study.	
8.	I agree that my anonymised research data may be used by others for future research. [No one will be able to identify you when this data is shared.]	
9.	I understand that the information I have submitted will be published as a report and I wish to receive a copy of it. Yes/No	
10.	I hereby confirm that I understand the inclusion criteria as detailed in the Information Sheet and explained to me by the researcher.	
11.	I hereby confirm that: (a) I understand the exclusion criteria as detailed in the Information Sheet and explained to me by the researcher; and (b) I do not fall under the exclusion criteria.	

12.	I consent to my interview being audio/video recorded and understand that the recordings will be destroyed within 3 years after the data has been collected or following transcription.	
13.	I understand that the interview study will be audio recorded and that the transcripts of the audio recordings made during this research will be used only for analysis and for illustration in conference presentations and lectures. No one outside the project will be allowed access to the original recordings. All of the data will be fully anonymised.	

If you would like your contact details to be retained so that you can be contacted in the future by UCL researchers who would like to invite you to participate in follow up studies to this project, or in future studies of a similar nature, please tick the appropriate box below.

	Yes, I would be happy to be contacted in this way	
	No, I would not like to be contacted	

Name of participant Date Signature

Researcher Date Signature

INSTRUCTIONS FOR WELLTORY

QUICK SUMMARY OF INFORMATION PROVIDED BELOW:

- Activate Welltory PRO (instructions provided after completing the initial survey);
- Set morning and evening reminders;
- Take 2 stress measurements a day to see trends and patterns in your stress levels;

MEASURING STRESS WITH WELLTORY THROUGH YOUR PHONE'S CAMERA



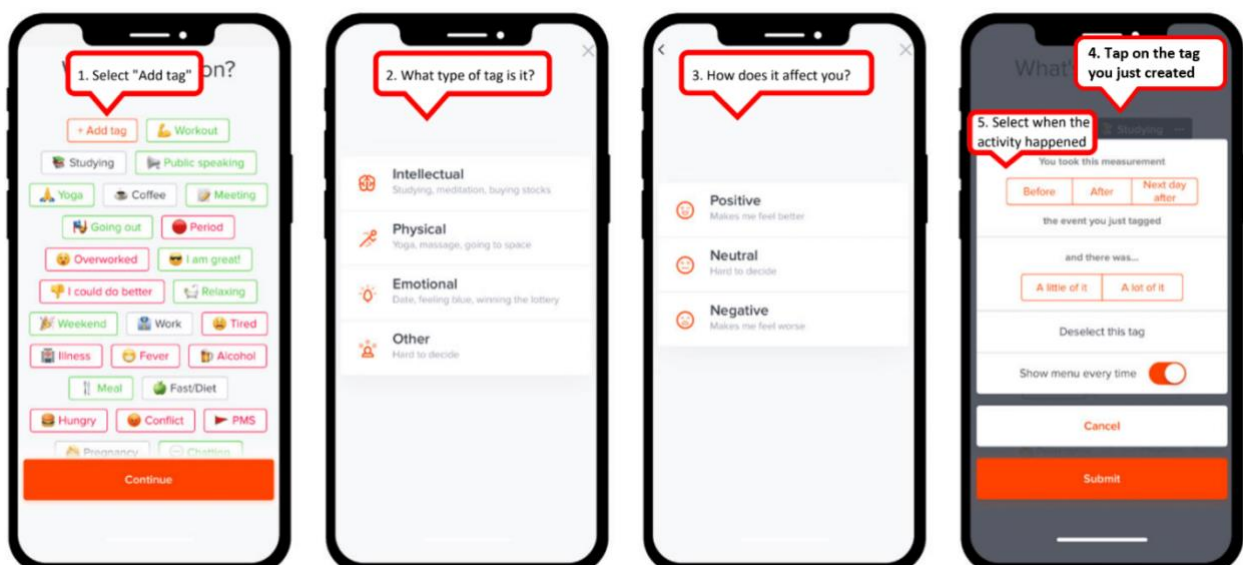
Welltory measures your stress by using your phones camera and flash so it's important that you hold your finger tip over both when taking a measurement. If the flash is too hot you can hold your finger a few millimetres away. You can find more info on how this works here:

<https://support.welltory.com/article/show/26100-how-the-measurement-process-works>.

During the 3-week period you must **take at least 2 stress measurements a day, one in the morning and one in the evening** and there is no limit as to how many measurements you can take.

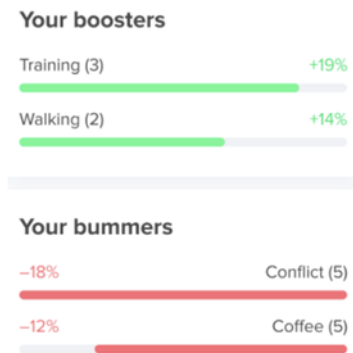
TAGS

You can use tags to understand how specific behaviour and activities affect your stress and energy levels. Be sure to **include tags with each measurement** – this will help



you understand what affected your stress levels. You can also create custom tags, see image below.

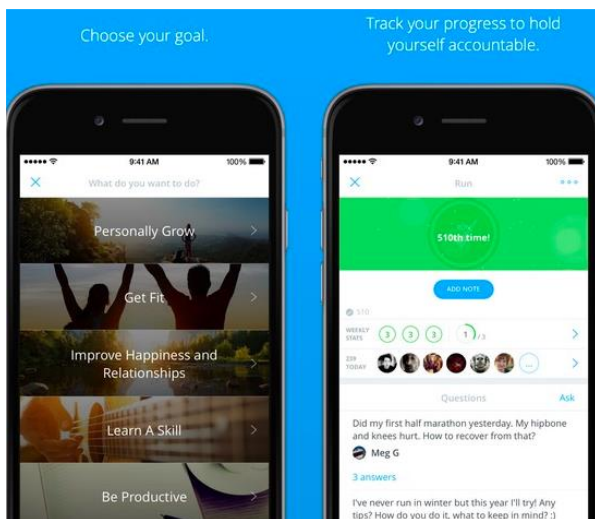
More info on using tags: <https://support.welltory.com/article/show/48983-how-to-use-tags>



YOUR BOOSTER AND YOUR BUMMERS – LOCATED ON THE APP'S CHARTS TAB

To know how certain activities (tags) affect you, you need to take at least 3 measures that include the same tag. The tags will then appear as either a booster or a bumper on your Welltory mobile app → History → Charts → Scroll down the page.

INSTRUCTIONS FOR COACH.ME



Create a list of goals that you think will help you feel less stressed over time. You should try to create goals and habits that address more than one aspect of your wellbeing such as doing relaxation and meditation activities, exercise, or getting enough more sleep.

More on how to use Coach.me:

[https://support.coach.me/category/4-](https://support.coach.me/category/4-basic-functions-and-features)

[basic-functions-and-features](https://support.coach.me/category/4-basic-functions-and-features)

COACH.ME GOALS – MAKING YOU ACCOUNTABLE FOR DOING THE ACTIVITIES YOU CHOSE

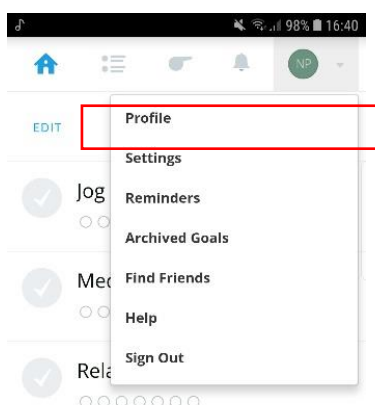
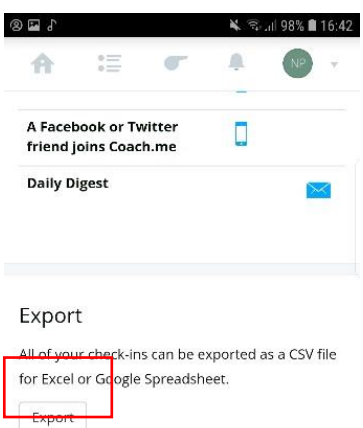
Coach me contains a selection of pre-set goals and plans. Choose these existing goals and monitor them. Alternatively, if your goal doesn't exist yet, create a new goal and add it. Try to log your activity completion every day, either in the mornings (e.g., sleep for 8 hours, eat breakfast) or in the evening (e.g., jogging, meditate, eat healthy). If

you do forget to log your activities for that day, you can always go back the next day and fill in the missing information. You can only go back 7 days.

END OF WEEK INSTRUCTIONS – SHARE WITH THE RESEARCHER WHAT YOU’VE DISCOVERED

At the end of weeks 2-3, you will need to export and email your Coach.me data to the researcher. This can be done either through the app or on the www.Coach.me website. When you select to export your data, the resulting .csv file will be emailed to you and you can simply forward this email to the researcher. You do not need to export data from Welltory, simply share your dashboard with the researcher in the survey.

EXPORTING DATA THROUGH THE APP (SAME CAN BE DONE THROUGH THE WEBSITE):

<p>Step 1</p> <p>Open up your coach me app, click on your profile icon and select Settings from the menu.</p>		<p>Step 2</p> <p>Once in Settings, scroll down to the bottom of the page and click on Export. This will email the data to your account.</p>	
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Appendix 2 Chapters 5 & 7

3. CONSENT FORM FOR ADULTS IN RESEARCH STUDIES

Please complete this form after you have read the Information Sheet.

I confirm that I understand that by ticking/initialling each box below I am consenting to this element of the study. I understand that it will be assumed that unticked/initialled boxes mean that I DO NOT consent to that part of the study. I understand that by not giving consent for any one element that I may be deemed ineligible for the study.

I confirm that I have read and understood the Information Sheet for the above study. I have had an opportunity to consider the information and what will be expected of me. I have also had the opportunity to ask questions which have been answered to my satisfaction and would like to take part in the interview study.

I understand that I will be able to withdraw my data up to 01/02/2022.

I understand that no sensitive personal information about me will be collected.

I understand that my data gathered in this study will be stored anonymously and securely. It will not be possible to identify me in any publications.

I understand that my information may be subject to review by responsible individuals from the University for monitoring and audit purposes.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason.

I understand that the data will not be made available to any commercial organizations but is solely the responsibility of the researcher(s) undertaking this study.

I agree that my anonymized research data may be used by others for future research. [No one will be able to identify you when this data is shared.]

I understand that the information I have submitted will be published as a report.

I do not suffer from any cardiovascular, major muscle or joint conditions that may limit me or be aggravated by physical activity.

I consent to my interview being audio recorded and understand that the recordings will be destroyed within 3 years after the data has been collected or following transcription.

I understand that the interview study will be audio recorded and that the transcripts of the audio recordings made during this research will be used only for analysis and for illustration in publications, conference presentations and lectures. No one outside the project will be allowed access to the original recordings. All of the data will be fully anonymized.

PARTICIPANT INSTRUCTIONS

Please take time to read this form carefully as it contains vital information on how to participate in this study. The duration of this study is 3 weeks + an interview. If you have any questions, email me at nora.ptakauskaite.16@ucl.ac.uk.

To participate in this study, you will need to download and install **Welltory** stress management and Evernote diary apps on your mobile device. Place both apps on your home screen next to each other so you remember to use them both:

 **Welltory Download:** <https://app.welltory.com>

 **Evernote Download:**

Apple: <https://apps.apple.com/app/evernote/id281796108>

Android: <https://play.google.com/store/apps/details?id=com.evernote>

Welltory uses your phone's camera to monitor stress and energy levels based on your heart rate variability and provides feedback on how other aspects of your life (such as physical activity and sleep) affect your stress and energy levels. Evernote will be used to keep a diary of the insights (i.e., understanding/information about yourself) that you gained during the study.

INSTRUCTIONS FOR WELLTORY – SAME AS IN APPENDIX 1

PARTICIPANT INSTRUCTIONS

Please take time to read this form carefully as it contains vital information on how to participate in this study. The duration of this study is 3 weeks + an interview. If you have any questions, email me at nora.ptakauskaite.16@ucl.ac.uk.

To participate in this study, you will need to download and install **Welltory** stress management app and use the Reflection bot chatbot. Place Welltory on your home screen so you remember to use it:

 **Welltory Download:** <https://app.welltory.com>



Reffy bot: <https://www.facebook.com/Reflection-bot-422857371654409/>

Welltory uses your phone's camera to monitor stress and energy levels based on your heart rate variability and provides feedback on how other aspects of your life, such as physical activity and sleep, affect your stress and energy levels. The reflection bot will be used to help you understand what causes you stress and how to manage it. It will also act as a diary for the insights (i.e., understanding/information about yourself) that you gained during this study and will help you plan in daily relaxation activities.

INSTRUCTIONS FOR THE CHATBOT

The link to the chatbot is <https://www.facebook.com/Reflection-bot-422857371654409/>. You can also communicate with the chatbot via the facebook messenger app. Optional: If you don't already have facebook messenger installed on your phone, you can download it here: <https://www.messenger.com/>

Step 1. Initiate a conversation by sending a message that says "Start" to the chatbot. This will begin the onboarding process.

Step 2. After completing the onboarding activity, every evening at 9pm the chatbot will ask you to complete a daily report on your stress. You can also initiate this conversation by sending any type of message to the bot whenever you like.

INSTRUCTIONS FOR WELLTORY – SAME AS IN APPENDIX 1