

Towards Maintainable Physical Activity Behavior Change: Designing for Reflection in a Technological Intervention

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Towards Maintainable Physical Activity Behavior Change: Designing for Reflection in a Technological Intervention

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To you who have supported me, both dead and alive.



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Abstract

In 2018, non-communicable diseases (NCDs) such as heart disease or diabetes were the leading causes of deaths worldwide, and physical activity (PA) is proven to help prevent and treat NCDs, as well as having broad social and economic benefits [1] [2]. Traditional health and clinical interventions cannot fully address this problem because of resource constraints and other factors [3]. With the ubiquitousness of computers and smartphones, computer-based interventions present a vast potential to improve health behavior [4] [5] [6]. Computer-based interventions are capable of supporting short-term increases in PA, but these effects tend to diminish as the follow-up time increases [3] [7]. A lack of focus on theory as put forth by Hekler et al. and too little regard for the social world and environment of individuals, as noted by Consolvo et al., might be contributors to that problem [8] [9].

In our work towards creating a computer-based intervention, we identified a combination of self-determination theory (SDT) and motivational interviewing (MI) as a promising theoretical basis to elicit long-term PA behavior change. Reflection could play a critical role in that combination as it could both further autonomy of the behavior as well as offering significant potential to be supported by technology. Lastly, there is a need for detailed documentation of design decisions in this field for comparing and judging approaches.

We created a computer-based intervention called “Josef” and have given detailed accounts on the decisions involved from multiple perspectives. To generate data for analysis, we used a mixed-method research approach. We conducted qualitative interviews with 6 participants using a prototype and collected quantitative data in the form of two questionnaires and measurements taken during the use of a second prototype by 94 participants from 20 countries.

Analysis with paired t-tests showed no statistically significant difference for SDT & MI related questions after a one week intervention period. Nevertheless, we observed statistically significant correlations between multiple factors of this category, which may provide insights on how supporting one aspect of SDT & MI might have positive effects on another. Participants did reflect both in terms of dimensions as well as on high levels of reflection. These results provide knowledge on how to support reflection with technology. Lastly, our target group preferred talking with Josef rather than another human being and found Josef likable as well as very easy to use. This persuasiveness did have a surprising correlation with our other results, leading us to consider if past interventions might have encountered false negatives because of a lack of consideration of persuasive design. Overall, these indicative findings from our one week intervention period could, together with our in-depth account of all decisions, provide a solid starting point for future work towards a long-term approach.



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Kurzfassung

Im Jahr 2018 waren nicht übertragbare Krankheiten (NCDs) wie Herzerkrankungen oder Diabetes die häufigsten Todesursachen weltweit [1]. Körperliche Aktivität (KA) trägt nachweislich zur Prävention und Behandlung von NCDs bei und hat einen breiten sozialen und wirtschaftlichen Nutzen [2]. Traditionelle gesundheitliche und klinische Interventionen können dieses Problem aufgrund von Ressourcenengpässen und anderen Faktoren nicht vollständig lösen [3]. Mit der Allgegenwart von Computern und Smartphones bieten computerbasierte Interventionen ein enormes Potenzial, dieses Gesundheitsverhalten zu verbessern [4] [5] [6]. Computergestützte Interventionen sind in der Lage, kurzfristige Erhöhungen der KA zu unterstützen, aber diese Effekte neigen dazu, nach der Zeit abzunehmen [3] [7]. Ein Mangel an Fokus auf Theorie, wie von Hekler et al. dargelegt, und zu wenig Rücksicht auf die soziale Welt und das Umfeld des Einzelnen, wie von Consolvo et al. festgestellt, könnten zu diesem Problem beitragen [8] [9].

In unserer Arbeit zur Schaffung einer computerbasierten Intervention haben wir eine Kombination aus Selbstbestimmungstheorie (SDT) und Motivierender Gesprächsführung (MI) als vielversprechende theoretische Grundlage identifiziert, um langfristige Veränderungen des KA-Verhaltens hervorzurufen. Reflexion könnte in dieser Kombination eine entscheidende Rolle spielen, da sie sowohl eine höhere Autonomie des Verhaltens verspricht, als auch ein erhebliches Potenzial zur Unterstützung durch Technologie bietet. Schließlich ist eine detaillierte Dokumentation der Designentscheidungen in diesem Bereich erforderlich, um Ansätze zu vergleichen und zu beurteilen.

Wir haben eine computergestützte Intervention namens “Josef” entwickelt und die damit verbundenen Entscheidungen aus verschiedenen Perspektiven detailliert beschrieben. Um Daten für die Analyse zu generieren, verwendeten wir einen gemischten Forschungsansatz. Wir führten qualitative Interviews mit 6 Teilnehmern mit einem Prototyp durch und sammelten quantitative Daten in Form von zwei Fragebögen, sowie Messungen, die während der Nutzung eines zweiten Prototypen mit 94 Teilnehmern aus 20 Ländern gemacht wurden.

Die Analyse mit gepaarten t-Tests ergab keinen statistisch signifikanten Unterschied für SDT & MI-bezogene Fragen nach einer einwöchigen Interventionszeit. Dennoch beobachteten wir statistisch signifikante Korrelationen zwischen mehreren Faktoren dieser Kategorie, die Aufschluss darüber geben können, wie die Unterstützung eines Aspekts von SDT & MI positive Auswirkungen auf einen anderen haben könnte. Die Teilnehmer haben sowohl auf mehreren Ebenen, als auch auf mehreren Dimensionen reflektiert. Diese Ergebnisse liefern Erkenntnisse darüber, wie man Reflexion mit Technologie unterstützen kann. Weiters bevorzugte unsere Zielgruppe es, mit Josef statt mit einem anderen Menschen zu sprechen, und fand Josef sympathisch und sehr einfach zu bedienen. Die Überzeugungskraft von Josef hatte eine überraschende

Korrelation mit unseren anderen Ergebnissen, was uns dazu veranlasste, darüber nachzudenken, ob frühere Interventionen aufgrund mangelnder Berücksichtigung von überzeugendem Design fälschlicherweise auf negative Ergebnisse gestoßen sein könnten. Insgesamt könnten diese indikativen Ergebnisse aus unserem einwöchigen Interventionszeitraum zusammen mit unserer detaillierten Darstellung aller Entscheidungen einen soliden Ausgangspunkt für die künftige Arbeit an einem langfristigen Ansatz bilden.

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Introduction

In its 2018 report, the World Health Organization (WHO) mentions non-communicable diseases (NCDs) as the leading causes of deaths worldwide [1]. A key behavioral risk factor stated is physical inactivity, since regular physical activity (PA) is proven to help prevent and treat NCDs such as heart disease, stroke, diabetes, and breast and colon cancer [2]. Furthermore, physical activity has multiple health benefits ranging from an increased mood, sense of confidence, self-esteem, and cognitive functioning as well as social and economic benefits. It is consequently interconnected with 13 of WHO's sustainable development goals for 2030 [2] [10]. Nevertheless, the WHO reports over 28% of adults aged 18 years and over were not meeting the WHO recommendations for physical activity in 2016, with a prevalence in high-income countries [1]. Worldwide, levels of physical activity have not increased in the past 15 years, and the world is not on track to meet the global 2025 target for reducing physical inactivity.

To be able to contribute towards a solution to this problem, we need to be aware of the definition of *physical activity* (PA). Biddle et al. clarify the definition, and its distinction with exercise and sports, by the following three elements [10]:

1. movement of the body produced by the skeletal muscles
2. resulting energy expenditure which varies from low to high
3. a positive correlation with physical fitness

Exercise distinguishes itself from PA by a *very* positive correlation with physical fitness, a planned, structured, and repetitive bodily movement and the objective to maintain or increase PA. *Sport* is described as a sub-component of exercise that has rules, is structured and competitive, and involves “gross motor movement characterized by physical strategy, prowess, and chance”. The WHO recognizes *moderate*-intensity PA, such as brisk walking, gardening, or dancing and *vigorous*-intensity PA, such as running, swimming, or fast cycling [11]. In our work, we consider PA every activity that contributes towards the WHO recommendation for adults aged 18–64 of 150 minutes of moderate-intensity PA per week or 75 minutes of vigorous-intensity PA per week or an equivalent combination of them [12].

There is a clear need to promote PA that traditional health and clinical interventions cannot fully address because of resource constraints, limited access to hard-to-reach populations, and other factors [3]. Computers, smartphones, and other related information technologies offer an innovative resource for health promotion. In 2017, there was an estimated 3.9 billion internet users worldwide [4]. In 2018, around 3 billion people worldwide were smartphone users [5]. Additionally, approximately one in five smartphone users used an app to support their health-related goals, and 38% of health app users have downloaded an app for PA [6].

With these numbers, the potential to use these devices to deliver interventions to improve health behavior as computer-based interventions is clear. This endeavor has shown success already, with intervention recipients improving health behaviors in regards to nutrition, tobacco use, substance use, safer sexual behavior, binge/purge behaviors, and general health maintenance [3]. For PA, there is modest evidence that computer-based interventions are capable of producing short-term increases in PA [13] [14].

Nevertheless, these short-term effects tend to diminish as the follow-up time increases [15] [14]. For fitness trackers, in particular, research seems to show that they are utilized only for short periods [16] [17]. Some results even suggest that more than half of the fitness trackers get abandoned within the first month of usage [7]. The same issues seem to be present in health and fitness apps, which fail to engage and motivate over a sustained period [18], and which experience adherence rates dropping significantly before three months [19]. Part of the problem might be that standalone health and fitness apps are designed and developed without the necessary foundation of expert knowledge or experience [20] [21] [22].

It seems that there is another approach needed to achieve the wanted long-term behavior change in PA, but it is not well understood which technique, or combination of techniques, is sufficient to do so [7]. Considering health, behavior change theory could play an important role. Hekler et al. advise that theory should be used to inform the design of technical systems, and that testing the assumptions behind design guidelines could enable researchers to build knowledge about ways in which theories can be translated into better designs [8]. Consolvo et al. proposed theory-driven design approaches for technologies that support behavior change, and highlight an additional challenge that traditional behavioral theories often ignore how technological support for behavior change can impact the individual's social world [9].

In our work, we, therefore, focused on the theoretical background of maintainable, long-term PA behavior change, and considered the social world and environment of our target group. We identified a combination of self-determination theory (SDT), motivational interviewing (MI), and reflection as a promising theoretical basis in that effort. Reflection could play a critical role in that combination as it could both further autonomy of the behavior as well as offering significant potential to be supported by technology. However, we identified a lack of detailed accounts of design decisions in the field.

Our main research question, therefore, considered the effects of components designed to further reflection in a computer-based intervention that aims to elicit long-term PA behavior change in people who are physically able to increase their PA behavior and have a general interest in doing so. Our key contributions were the empirical test of the combination of SDT & MI in a computer-based intervention, the investigation of how technology could be used to support reflection, and a detailed documentation of all related decisions from multiple perspectives to

help with closing an identified gap of a lack of documented examples for components aimed at supporting reflection in a computer-based behavior change intervention.

We designed, implemented, and evaluated a computer-based intervention and in the process, respected perspectives of health behavior change, persuasive design, and software engineering. In chapter 2, we documented our research in regards to the current state of the art and looking closer at problems and opportunities in the field to find a theoretical background that lends itself to long-term PA behavior change. We found a combination of self-determination theory (SDT) and motivational interviewing (MI) promising for this approach, with the former providing guidelines on how to support users with internalizing a behavior, a key factor to go towards the maintainability of that behavior and the latter contributing with concrete strategies on how to support the three innate psychological needs—competence, autonomy, and relatedness given by SDT [23] [24] [25]. Technology played a part in this combination by offering opportunities to support reflection, a potentially important component in supporting autonomy [26] [23].

Our methodological approach, where we used the intervention mapping (IM) protocol as guidance to create a computer-based intervention [27], is described in detail in chapter 3. We conducted mixed-method research with two experiments, collecting qualitative data from 6 participants as well as quantitative data from 94 participants.

Chapter 4 will give a detailed account of how we constructed a computer-based intervention and the design decisions that were involved from the perspectives of health behavior change, persuasive design, and software engineering.

In chapter 5, we found that, while we did see indicators that our intervention could support SDT, they did not yield statistical significance. Nevertheless, we discovered correlations between results for this topic, which could provide additional insights for the field of SDT interventions, where operational characteristics require further research [25]. The chapter will further show that our intervention did successfully support reflection in more ways than expected and that results regarding persuasiveness correlated significantly with the other fields of this research.

Our discussion in chapter 6 will interpret our findings and consider in which ways our intervention worked as a therapist, could express empathy, simulate reflective listening, and touched on the topic of repercussions of reflection, positive reinforcement and gridlocked thoughts about PA. The chapter will further present a critical look at the scope of our work and a lack of impact tracking along with our way of handling misinterpretation of participants and negativity.

Lastly, our key contributions in regards to our empirical test of the combination of SDT & MI in a computer-based intervention, the investigation of how technology could be used to support reflection, and our detailed account of design decisions is synthesized in chapter 7.



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State of the Art

Apps apply behavior change techniques to help users change their behavior. Michie et al. define a behavior change technique (BCT) as an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behavior [28]. It is the “active ingredient” to bring about behavior change.

In their article about “Apps to improve diet, PA and sedentary behavior in children and adolescents,” Schoeppe et al. found that from 25 apps, 24 incorporated some BCTs, with an average of 6 BCTs per-app [29]. BCTs such as goal setting, feedback, rewards, and social factors are just some of the topics of relevance there [7]. In the following sections, we will consider different approaches by looking at existing research on the topic, consider the effectiveness of BCTs and the role theory plays in that context before examining the problems and opportunities of existing approaches in more detail.

2.1 Related Work

A significant difficulty with measuring changes in PA is getting appropriate data. To that purpose, pedometers, measuring steps taken in a time frame, were used in previous studies such as by Tudor-Locke [30] and Chan [31].

Houston, a prototype mobile phone application for encouraging activity by sharing step count with friends created by Consolvo et al., is of relevance here [32]. The three weeks in situ pilot study was conducted with women who wanted to increase their PA. The focus was on encouraging opportunistic physical activities, where a person incorporates activities into her everyday life to increase her overall level of PA.

Consolvo et al. showed that pedometers do not necessarily provide a proper measurement of overall PA, as common activities such as cycling, weight lifting, or vigorous house-cleaning are not adequately detected. They then derived four design requirements for technologies that encourage PA: 1) Give users proper credit for activities, 2) Provide personal awareness of activity level, 3) Support social influence, and 4) Consider the practical constraints of users’ lifestyles. [32]



Figure 2.1: The Omron HJ-112 pedometer in use [32]

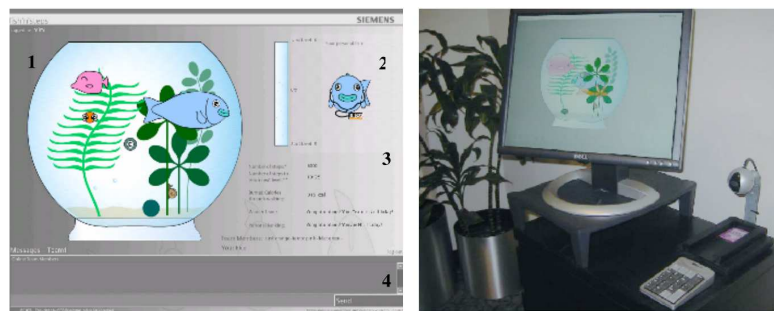


Figure 2.2: A participants display of Fish'n'Steps and a Fish'n'Steps kiosk [33]

Another intervention relying on a day's footstep count is Fish'n'Steps, a social computer game that links a player's activity to the growth and activity of an animated virtual character, a fish in a fish tank. During the fourteen-week study, Lin et al. found that although most player's enthusiasm in the game decreased after the game's first two weeks, they had established new routines that led to healthier PA patterns. 14 out of 19 participants had a positive change during the study, with 4 participants increasing their daily step count, 3 participants changing their attitude towards PA, and 7 experiencing a combination of the two. [33]

Specific issues that elicited the design requirements Consolvo et al. presented after their observations with Houston were also noticeable in Fish'n'Steps. Multiple factors challenged the continuous sustainability of the new, healthier behavior. One such factor was the inconvenience of having to wear the pedometer on the belt, forgetting to put it on, or forgetting to log in. Issues that can be mapped to Consolvo et al.'s design requirement to consider the practical constraints of users' lifestyles.



Figure 2.3: UbiFit Garden's display [33]

It was exciting at the beginning, but then it turned into a nuisance; you would forget to put it on, or you would forget to log it in and stuff like that... I have to remember a lot of things during the day, and that is on top of that... [33]

Another lesson learned from the study was that games such as Fish'n'Steps should provide positive reinforcement to foster long-term behavior change, rather than negative reinforcement. The virtual pet character was designed to negatively reinforce the lack of desired behavior by showing a crying fish that did not grow. While many participants felt responsible for their fish and tried to prevent it from crying, some reduced their interactions with the game to avoid seeing them crying. [33]

Drawing on several previous projects, including Houston and Fish'n'Steps, Consolvo et al. went on to develop UbiFit Garden, a healthy lifestyle technology. It consists of a fitness device, an interactive application, and a glanceable display. The fitness device automatically captures a user's PA, like walking, running, and biking. The interactive application includes information about physical activities and provides a journal where activities can be added, edited, and deleted. Lastly, the performed PA is linked to the growth of a virtual garden on the device's glanceable display. Overall, UbiFit Garden was well-received—most participants found all components essential, and some participants were surprised at how motivating the garden was. [34]

Consolvo et al. further discussed the results from UbiFit Garden in regards to the effectiveness of displays as a means for improving awareness of daily life and the general implications for the use of everyday mobile devices to promote awareness [35]. This awareness of one's behavior is particularly useful if one is trying to change behavior or habits. UbiFit exclusively used positive reinforcement. Doing PA added butterflies to the garden on the glanceable display,

but inactivity did not result in any punishment. If the individual did not meet a goal, the garden simply did not gain a butterfly.

Theory and prior work were used to extend a set of existing design goals to design UbiFit Garden. Concepts from behavioral and social psychological theories were used to gain knowledge about how to support behavior change. Consolvo et al. pointedly remarked on the importance of considering how technological support for behavior change impacts the individual's social world. [9]

UbiFit Garden and Fish'n'Steps are examples of early approaches in this field. In 2015, there were 59400 mobile health apps available on the market for the category "fitness" [36]. However, Sullivan et al. have found in 2017 that it is still not clear which parts of fitness technology, including trackers and smartphone applications, are most impactful and being used by consumers [7].

Effectiveness of Design Components for Behavior Change

With so many options available to design fitness technology, the question remains which elements are most effective. Even more so, what does effectiveness mean in this regard? Is it a sharp short-term rise in PA behavior? Is it building a sustainable, albeit lower, increase in PA? Or is it finding a component that works well with specific at-risk population groups?

We have seen different behavior change techniques used in the previous examples. However, which one is most useful for driving PA behavior change? Sullivan et al. have looked into this question and have found that many successful interventions include a combination of behavior change techniques, suggesting that this approach is likely the most suitable [7].

Nevertheless, designing an intervention is not just a mixing of BCTs together. The Behavior Change Technique Taxonomy developed an extensive list of 93 techniques clustered into 16 hierarchic groups in order to allow for characterization of the active content of interventions with precision and specificity [28]. Examples of BCTs include self-monitoring, goal-setting, rewards, feedback, personalization, and social support. Which BCTs to use as an intervention's building blocks needs to be a conscious and informed decision. Not only that, knowledge from other fields might be necessary as well. One such field is persuasive technology, defined by Fogg as any interactive computing system designed to change people's attitudes or behaviors [37].

Some of the previous examples, such as Houston, Fish'n'Steps, and UbiFit Garden were designed to be persuasive. They combined advantages of persuasive technology with the use of multiple behavior change techniques to the goal of changing the PA of their users. What does this combination imply for the design of a health behavior change intervention?

Thomson et al. argue that there is an overlap of design-related issues commonly encountered with the implementation of BCTs and the application of persuasive design principles in PA behavior change. They further argue that both perspectives, of health sciences and persuasive technology, are relevant and necessary for designing successful PA behavior change apps. BCTs are the components of health behavior change interventions, whereas the principles of persuasive design inform the design of software features applied and implemented in persuasive behavior change systems. Applying both field's perspectives together, considering the relevant persuasive design principles (as software design features), as well as the relevant behavior change techniques (as intervention components), can enrich the user's immersive interactions and en-

gements with apps. It will further enhance the overall persuasive potential the intervention can have on facilitating, motivating, and supporting individuals through the behavior change process. [20]

The Role of Theory in Driving Behavior Change

We have highlighted that a combination of behavior change techniques and a combination of those with persuasive design principles is advantageous to change PA behavior in the previous section. For designers of a health intervention, this implies a multitude of complex design choices. What combination of behavior change techniques should be adopted in the intervention? Which persuasive design principles need to be upheld?

Balaam et al. argue that “theoretically-driven approaches and their interpretation and/or adaptation for design, are critically important for human computer interaction, especially when we want to design applications that can be widely used” [38]. They suggest that there is still a design gap between a conceptual theory and theoretically-principled guidelines for designing for the everyday lived reality of individuals. Consolvo et al. proposed theory-driven design approaches for technologies that support behavior change [9], noticing that traditional behavioral theories often ignore the critical design component of how technological support for behavior change impacts the individual’s social world. Hekler et al. also notice that instantiating theory is a difficult task, as theoretical constructs lack specificity for concrete design situations [8]. They argue that “Behind each guideline is a set of assumptions about how a technology that embodies the guideline should affect users’ behavior. Testing these assumptions explicitly in user studies, along with exploring the design space for guidelines, can enable HCI researchers to build generalizable knowledge about ways in which behavioral theories can be translated into better designs.” A theoretical background should inform the design of technical systems, guide evaluation strategies, and define target users. In the last section, we have discussed how a random mix of BCTs in an intervention is unlikely to be successful in significantly changing behavior in a focused way towards a goal. Theory can improve interventions by helping to identify which theoretical constructs should be targeted and by guiding the choice of BCTs [39].

The current state of research suggests a closer look at the target behavior an intervention aims to establish. Analyzing theories for a match to that behavior change, and respecting design guidelines is a necessity for informed design decisions during the implementation of an intervention.

2.2 Problems of Given Approaches

The previous sections did not clearly distinguish between behavior change in general, and behavior change specific to PA. To look at the problems associated with interventions targeted at that particular behavior, we first need a solid understanding of it.

Allender et al. have examined qualitative research studies of UK children’s and adults’ reasons for participation and non-participation in sport and PA, and have given motivations and barriers in table 2.1 [40]. Common reasons for participation in physical activities were weight management, social interaction, social support, and enjoyment. Most people recognized the health

benefits associated with PA, but it was not their main reason for participation. Self-perception was found to be an essential motivator for people to participate in all types of PA. Individuals with a self-perception as a physically active person tended to be active more frequently and in more types of activity than those who perceived themselves as not physically active. High costs, poor access to facilities, unsafe environments, and issues related to identity, and shifting social networks were barriers to participating in physical activities. These motivators and barriers differ with the age group. For example, adults were motivated by a sense of achievement, skill development, and to spend “luxury time” on themselves away from daily responsibilities, while older adults cared more about social support, health benefits, and enjoyment.

Age Group	Motivations	Barriers
Young children	Experimentation Unusual activities Parental support Safe environment	Competitive sports Highly structured activities
Teenagers and young women	Body shape Weight management New social networks Family support Peer support	Negative experiences at school Peer pressure Identity conflict PE uniforms Boys’ dominance in class Competitive classes Lack of teacher support
Adults	Sense of achievement Skill development Medical sanction Support networks Enjoyment	Negative school experiences Anxiety in unfamiliar surrounds Lack of social network Identity conflict Lack of role models
Older Adults	Social support Health benefits Enjoyment	Unclear guidance Lack of role models

Table 2.1: Motivations and barriers for physical activity [40]

Wearable activity trackers have entered the consumer market in the past years with the promise to help with a healthier lifestyle in areas such as PA, diet, and sleep. Companies such as Apple, Fitbit, Garmin, and Jawbone have created wrist-worn trackers that often come with a smartphone app or online platform. Apple’s iOS “Health” app and Google’s Android “GoogleFit” support the ecosystem around tracking health metrics. They both collect health metrics from multiple apps installed on the phone, combine them with the phone’s sensor data, and allow other apps to import that data. For example, they can provide an overview of weight, daily steps, and water intake by combining metrics measured on a digital scale, wrist-worn tracker, or manual entries in another phone-app.

These trackers work well to provide an initial boost to PA behavior. A cross-sectional study by Maher et al. showed that 68.3% of current users and 70.2% of former users reported an

initial increase in their PA [17]. The trackers often provide a multitude of features. Nevertheless, only 35% using social features, and only 23% shared their activity data on social media platforms. When looking at the maintainability of the increase in PA, 9.5% of current users and 27.0% of former users reported that this increase was fleeting and that their activity levels had subsequently declined to baseline levels. [17]

These findings go in line with earlier studies that reported a plateau in participants' daily step count after the first four weeks of pedometer use [30] [31]. The long-term effect of trackers on behavior change is furthermore questioned by reports that suggest that activity trackers are used only for short periods [41] [42]. Some even report that more than 50% of the participants stopped using their device after two weeks, and 75% within the first four weeks [42]. The most common issues were issues with remembering, such as to wear the device or the whereabouts of it, and issues with physical design and aesthetics, reporting the device to be uncomfortable to wear or interfering with their PA.

While fitness trackers alone may be sufficient in facilitating behavior change, some interventions are more effective in fostering lasting behavior change by incorporating extra motivational techniques [7] [43]. Wearables often use prompts or cues to introduce changes or improvements in behavior. Fritz et al. point out that although these aspects have proven to be valuable, persuasive technology tools should offer explicit motivation for the maintenance of the new behavior, as it is critical for durable behavior change [44]. They believe that in addition to offering initial motivation for change, long-term wearers have different needs and practices after the initial weeks of use. In the context of weight loss through PA, some authors even suggest that fitness trackers may not be more beneficial than a purely theory-based strategy at all [45].

While standalone health and fitness apps are promising, and constitute a substantial category within the consumer native app market, they are often designed and developed without the necessary foundation of expert knowledge or experience [20] [21] [22]. Indeed, Sullivan et al. argue that the most relevant behavior strategies for inactive populations may be absent from fitness technology [7]. This issue is exemplified by a trend of visualizing health data in a "show 'em a graph and hope" approach that, without proper scaffolding, leads to bewilderment or spurious conclusions exemplifies that issue [46]. These apps experience issues with long-term behavior change similar to their wearable counterparts, with adherence rates dropping significantly before three months [19].

Beyond a lack of theoretical background, this may be due to a disregard of the individual's social world in context to the targeted behavior change. For PA, consider the prevalence of injuries as an example [47] [48]. A behavior change intervention must take into account that users might not physically be able to continue the wanted behavior due to injury to build towards sustainable behavior change. Receiving supposedly motivating messages during that time, or statistics of unachievable goals will fail to achieve their intended effect, and might even cause adverse reactions from users.

Consider health interventions based on habits. Lally and Gardener have given one definition of habit as a behavioral pattern enacted automatically in response to a situation in which the behavior has been performed repeatedly and consistently in the past [49]. Health-related behavior such as diet, sleep, substance use, and PA is more determined by habit than a conscious decision, and efforts to motivate the creation of healthy habits with an intervention have been



Figure 2.4: Likelihood of engaging in a behavior over time [53]

a topic of research [50] [51]. Habits are, by definition, enacted in a consistent situation, and are easily disrupted [52]. With PA, there are numerous sources such as injuries, sickness, or the change of the seasons that could disrupt a habit. An intervention based on habits should, therefore, consider the social world of a physically active individual by preparing for moments when those disruptions occur and support individuals in these situations. Due to this relation between disruption, habits, and the environment of PA, it is questionable to us if habits are the right choice as the central mechanism to create maintainable long-term PA behavior change.

It is still not well understood which behavior change techniques in fitness technology are sufficient to achieve the wanted long-term effects [7]. The supposed lack of using a theory-backed approach that we have highlighted in the previous section 2.1 and the insufficient consideration of the environment/social world of PA may be a contributor to that problem.

2.3 Opportunities

So how could an intervention look like, that would, based on theory and with consideration of the target groups environment/social world, be designed to create a more maintainable PA behavior change?

Figure 2.4 by Kawsnicka et al. show how a new behavior can become a maintained, leading behavior [53]. One observation from the previous sections is that activity trackers and PA behavior change apps seem to be prone to be abandoned. These interventions often trigger a sharp initial increase in PA as visualized with the first area A in figure 2.4, but instead of leading towards maintained behavior, drop down to baseline levels.

Some of the previous examples of computer-based interventions employ motivational mechanisms that visualize progress. The mechanisms for that can be quite creative, ranging from diagrams to fish and flowers, such as we have seen in section 2.1. As PA decreases, so is the progress in those interventions. Users seem to like that—but do they just like what the interven-

tion is rewarding them with, or do they enjoy having a healthier PA behavior, too? Users might keep up their PA behavior mainly to progress in the intervention, rather than for themselves. We have looked at possible barriers to PA behavior in section 2.2. What happens if users fail to keep up their new behavior because of a disruption such as sickness, injury, or a momentary relapse? It might lead to stopping their behavior change efforts in their tracks, even despite being motivated. If progress in the intervention was the primary motivator for the initial PA behavior change, instead of joy in the new behavior, it might cause users to drop out. Indeed, Deci et al. confirmed that rewards related to engagement, completion, and performance undermined intrinsic motivation in a meta-analysis of 128 studies [54]. Current research on increasing and maintaining PA, however, shows the importance of the concept of autonomous forms of motivation [55] [56] [57]. In a meta-study in a health care and health promotion context Ng et al. found that behavior change is more effective and lasting when patients are autonomously motivated [58]. We will take a closer look at supporting intrinsic motivation and autonomy in the next section.

Self Determination Theory and the Types of Motivation

The self-determination theory (SDT) is a general theory of human motivation that emphasizes the extent to which behaviors are relatively autonomous versus relatively controlled [23] [59].

Motivation in the context of SDT concerns energy, direction, persistence, and equifinality—all aspects of activation and intention—and is not a singular construct. People can be motivated very differently. They could value an activity itself, and do it primarily for themselves, or be urged into action by a reason external to the self like a monetary bribe, for example. The functional and experiential differences between self-motivation and external regulation is a focus of SDT. The meta-theory suggests that if people's motivations are self-authored, in contrast to externally controlled, they show a multitude of advantages like more behavioral effectiveness, greater volitional persistence, and enhanced subjective well-being [23]. To the goal of trying to elicit more maintainable PA behavior, these advantages of self-authored motivation are promising. How could a behavior change intervention be designed, that helps participants build this type of motivation?

The organismic integration theory (OIT), a sub-theory within the self-determination theory, details the different forms of motivation and the contextual factors that either promote or hinder them. Figure 2.5 shows the OIT taxonomy of motivational types. They are arranged from left to right according to how self-determined they are. At the far left is amotivation, the state of lacking any intention to act. Amotivation can result from perceiving the activity to provide no value, it providing no desired outcome or a lack the competence to do it. On the other end of the spectrum is intrinsic motivation, the doing of an activity for its inherent satisfaction. This type of motivation is highly autonomous and represents self-determination in a pure form. Different styles of regulation are used to uphold this type of motivation. [23]

As a technological intervention is an external motivator, it will elicit motivational regulation between these two extremes on the spectrum, in the area of extrinsic motivation. The behavior change intervention should aim to help users build motivation regulation that is as close to intrinsic motivation on the spectrum as possible to support long-term change. Even if regulation for a behavior starts further on the left of the spectrum, the intervention should support users in

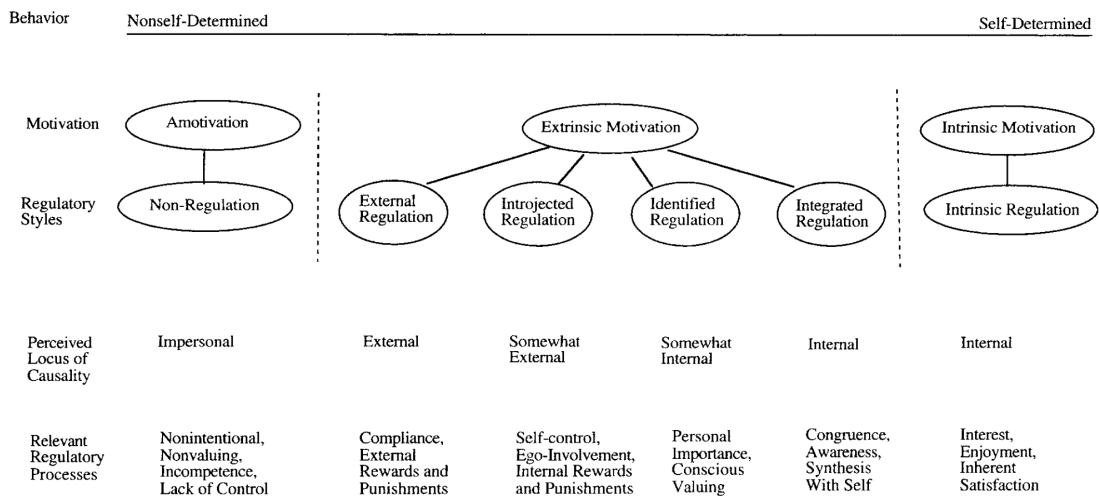


Figure 2.5: Self-determination continuum showing types of motivation [23]

continuing to internalize it. Consider a scenario where an intervention elicits motivation through external regulation in the beginning and supports a transition to more and more internalized types of motivational regulation. At one point, the user no longer needs the intervention and has fully internalized the new behavior, needing no further external motivator. People do not necessarily have to go through each of the stages of internalization sequentially. Instead, they can internalize behavior regulation at any point on this continuum. [23]

Externally regulated behaviors are performed to satisfy an external demand or reward and are typically experienced as controlled. *Introjected regulation* represents behavior that is not full-heartedly perceived to be part of the self, but allows regulation to avoid guilt or anxiety, or to maintain or enhance one's ego. If behavior is owned or accepted as personally meaningful, it is *regulated through identification*, a more autonomous, or self-determined, form of motivation that reflects a conscious valuing of a behavior. The most autonomous form of extrinsic motivation is *integrated regulation*. It occurs when regulations are perceived as part of the self and are in line with one's other values and needs. This type of motivation differs from intrinsic motivation because the actions are not purely done out of inherent enjoyment, but shares many qualities with it. [23]

With the significance of internalization shown, the question for the design of an intervention is how to promote it. The intervention should help users build autonomous regulation for their behavior through external motivation.

Especially with PA, it is common to have a friend, colleague, or loved one prompt one to partake. One might join in, even though the activity itself might not be interesting in itself. OIT identifies *relatedness*, the need to feel belongingness and connectedness with others, as a facilitator for internalization.

Being good at an activity that relevant social groups value, such as finishing a particularly hard bouldering route while colleagues are watching, is motivating, and people are more likely to adopt such activities. OIT suggests that the perceived *competence* in such activities facilitates

internalization.

A pleasant evening run to relax is an example of doing an activity purely out of one's motivation, out of autonomous regulation. For integrating a regulation, this *autonomy* is a critical element.

An intervention should, therefore, aim to motivate in a way that allows a person to feel *related, competent, and autonomous* to yield integrated regulation of the target behavior.

This high internalization is essential in helping to facilitate long-term maintainable PA behavior. SDT provides us with a solid basis for our intervention's general approach—it should support relatedness, competence, and autonomy. In the next chapter, we will look at how this approach could look like when empirically applied.

Motivational Interviewing

Motivational interviewing (MI) was developed in the context of alcohol counseling. Poor motivation, denial, and resistance were viewed as qualities of the clients themselves at the time. MI emerged from the hypothesis that the way clients were spoken to could improve or hinder motivation to change. The guiding notion was that motivation to change should not be imposed from without, as from counselor arguments for change, but should be *elicited from within the client*. The three central concepts of readiness, ambivalence, and resistance were turned into the three core counselor skill areas of empathic listening, eliciting self-motivating statements, and responding to resistance. [24]

When we looked into the self-determination theory (SDT) in the last section, advantages of high internalization was made clear. In terms of MI, “eliciting motivation from within the client” seems like a very similar notion. This match has been investigated before [60] [61] [59] [25]. SDT offers a theoretical background where MI gives specific directions for particular clinical techniques.

In MI, avoiding confrontation and coercion, letting clients present arguments for change themselves, and setting a mutual agenda that reflects the client's goals and concerns in an agreement between client and therapist is part of the practice. These concepts fit with SDT's concept of supporting autonomy [62]. A therapist's genuine interest and demonstrated warmth, the expression of empathy and support, and the avoidance of criticism or blame support the need for relatedness. Finally, by helping the client to pick goals that can realistically be achieved, providing positive, nonjudgemental feedback and presenting neutral information, the need for competence is supported by MI. [60]

Therefore, MI provides concrete guidelines and strategies on how to support the three innate psychological needs—competence, autonomy, and relatedness—which, according to SDT, yield enhanced self-motivation and mental health when satisfied.

Supporting these needs leads to higher internalization of the target behavior, making the combination of SDT and MI a solid theoretical backing to guide design decisions for a behavior change intervention.

Resnicow et al. used that formula to create a print-based intervention of three tailored newsletters. The participants who received more autonomy-supportive communication in these newsletters increased their fruit and vegetable intake compared to those who received tailored newsletters not focused on autonomous motivation [63].

I Move combined SDT and MI in a web-based computer-tailored PA intervention [64]. It was developed using the intervention mapping (IM) protocol and translated MI skills and processes into web-based computer tailoring. I Move simulated conversations with an interactive question and answer approach. The project investigated both virtual and video coaches. I Move aimed at increasing and maintaining PA among adults and was successful at increasing weekly minutes of moderate to vigorous PA at 12 months from baseline [65]. However, the difference to Active Plus, a traditional web-based computer-tailored PA intervention based on traditional health behavioral theories, was not as significant as hoped. The study concluded with the argument that the focus of the theoretical foundations should depend on the intended outcome and that more research on the effects of SDT and MI in web-based PA promotion is needed [65]. When taking a look at the use of behavior change techniques in commercial apps, we can draw a similar conclusion. Not a single app employed MI in a review of 25 apps (included out of initially 42,595 identified ones) to improve health behaviors [29].

The Role of Reflection in SDT & MI Interventions

Reflection has been of interest in different fields of research, including healthcare, education, and design, which consequently drew on different definitions of it. Boud's understanding of reflection is "a generic term for those intellectual and affective activities in which individuals engage to explore their experiences in order to lead to new understandings and appreciations" [66]. For Schön, reflection involved a type of thinking which enables problem-solving through the construction of an understanding and reframing of the situation [67]. Drawing on Moon, reflection is "a form of mental processing with a purpose and/or an anticipated outcome that is applied to relatively complicated or unstructured ideas for which there is not an obvious solution" [68]. Baumer et al. consider Dewey [69], Schön, Moon, and others, to define reflection as "reviewing a series of previous experiences, events, stories, etc., and putting them together in such a way as to come to a better understanding or to gain some sort of insight" [70].

This work does not attempt to distill one definition of reflection, but will instead build on previous definitions, and their creator's understanding of it, to inform design decisions. In particular, Fleck and Fitzpatrick, as well as Baumer, have provided guiding work for consideration of reflection in design [26] [71].

When combining SDT and MI, we have looked at the importance of supporting autonomy, "an important psychological need for optimal functioning of the natural propensities for growth and integration, as well as for constructive social development personal well-being" [23]. Ryan and Deci mention deep, holistic processing we would consider akin to reflection as a facilitator for gaining insights about oneself, which could be a key component in supporting autonomy:

To integrate a behavioral self-regulation, people must grasp its meaning and synthesize that meaning with respect to their other goals and values. Such deep, holistic processing is facilitated by a sense of choice, volition, and freedom from excessive external pressure toward behaving or thinking a certain way. In this sense, support for autonomy allows individuals to actively transform values into their own. [23]

Again, there are parallels to MI, where reflective listening is an important technique that is likely to be related to autonomy support. Reflections in this context involve the clinician repeating part or most of the person's words back to the person, either verbatim or with various emphases. They allow the patient to gain more access to their true feelings and thoughts so that they can be better recognized. Consequently, they help to increase a person's self-awareness and puts him/her in a position to make autonomous choices. [62]

We believe that a connection of these arguments show that reflection could be vital in supporting autonomy in a technological intervention.

The next section will look at the advantages of a technological intervention over more traditional interventions, and what role supporting autonomy through reflection has in that context.

Persuasiveness & Reflection in a Technological Intervention

In the last sections, we have looked at the advantages of combining self-determination theory (SDT) and motivational interviewing (MI) to elicit more maintainable PA behavior change in an intervention. We have furthermore looked into the importance of reflection to support autonomy, a vital need to support the facilitation of internalized motivation. None of that implies that the intervention necessarily has to be a technological one.

When comparing a technological intervention to a print-based intervention, or a session with a clinician, Fogg's six distinct advantages computers have over human persuaders come to mind [37]:

1. **Higher Persistence:** They can be more persistent than human beings, do not need to sleep or eat, and do not get bored or frustrated. They can work around the clock to wait for the right moment to intervene.
2. **Greater Anonymity:** They allow for higher anonymity, which is important for sensitive areas such as psychological problems or experimenting with new attitudes or behaviors. It is often easier to get help or information anonymously than to face another human being.
3. **Utilize Huge Data Stores:** Computers can store, access, process, and manipulate vast amounts of data. For example, they could store all therapy sessions ever happened with the patient, load all recorded behavior data, and decide on the perfect next step for the patient.
4. **Multiple Modalities:** The presentation of information-the modality-influences its persuasiveness. People are not only influenced by information, but also by how it is presented. Computers can leverage graphics, audio, video, animation, simulation, or hyperlinked content and combinations thereof, and further match those modes to the preferences of the user to produce the optimum persuasive impact.
5. **Scalability:** It is difficult to scale the experience a human persuader offers, especially when thinking about expensive and hard to scale traditional interventions such as face-to-face sessions with a clinician. By contrast, computer software can be easily deployed to be available to millions of people around the world.

6. Ubiquitousness: Technology can be almost everywhere; it is ubiquitous. With the growth of embedded computers and the pervasiveness of smartphones, computers can intervene at precisely the right time and place and in situations where a human persuader might be unwelcome.

Even in the scope of purely digital health interventions, such as interventions delivered via means such as smartphones or text messaging, this potential to provide effective, safe, and scalable interventions has been used to improve health [72]. Digital interventions have been created in the context of smoking cessation, safer sex, healthy eating, alcohol consumption or diabetes [73] [74] [75] [76] [77].

Beyond the advantages of persuasion we have just detailed, Thomson et al. point out that there is a disconnect between persuasive design and behavior change techniques [20]. If leveraging both fields' perspectives, they argue that the enhanced overall persuasive potential of the intervention can help with facilitating, motivating, and supporting the PA behavior change process.

Although reflection is another field where technology offers vast potential, it is not a well understood use-case [26]. Baumer analyzed 76 papers, with the median publication year of 2011, and found that few of them defined the concept of reflection, explicitly focused on reflection itself and that the techniques used in them to encourage reflection were working with implicit assumptions, especially that feedback constitutes reflection [70].

To close the gap on how to design for reflection, and guide design decisions for technological interventions, Fleck and Fitzpatrick advise on the aspects and levels of reflection [26]. Baumer, presenting another perspective, introduces the dimensions of reflection [71]. Both will be crucial for the construction of a technological behavior change intervention in this work.

Research Outline

At the beginning of this chapter, we have presented that building maintainable PA behavior through the use of a technological intervention is still a problem. We have found that, for an intervention to be successful in this area, it needs to be based on theory and consider the target group's environment.

The self-determination theory (SDT) was found to be promising as a basis for our intervention since it provides guidelines to support users with internalizing the target behavior, a key factor to go towards the maintainability of a behavior. This approach matches the environment of PA since it offers resistance to disruptions in behavior, which are common there because of seasonal changes, health issues, or injuries. Next, we found that motivational interviewing (MI) combined well with SDT to provide us with guidelines and techniques on how to support the three innate psychological needs—competence, autonomy, and relatedness—presented by SDT.

Reflection plays a crucial part in this approach since it could be a key component in supporting autonomy. Although technology offers excellent opportunities to support reflection, there is still much to be learned in that area. Especially the lack of examples for concrete design decisions in an intervention that aims to support reflection, and their impact, presents a gap. On the same notion, we have observed that the reasoning for design decisions in the computer-based

intervention field is seldom done in a holistic way that considers perspectives of health behavior change, persuasive design, and software engineering. This lack of detail in regards to these different perspectives and decisions in an interconnected way makes it harder to reason about observed results or to take another approach that focuses on a specific aspect of previous work. A researcher's lack of proficiency in any of these three fields could pose a risk. The omittance of one perspective could decrease the comparability of the work or increase the chance to arrive at the wrong conclusions.

I Move, which we have previously discussed, describes itself as one of the first attempts to integrate SDT and MI in web-based computer tailoring [64]. Patrick et al. notice on the topic that “the use of theory to inform and test interventions is important both for expanding basic science and for developing interventions that have real-world practical utility. From the perspective of basic science, theories must be tested in multiple domains and through multiple methods to refine and expand them appropriately.” [59] and Teixeira et al. remark that the operational characteristics of an SDT intervention still require further research [25].

Therefore, we aim to contribute in three ways. First, there is still a need to empirically test the combination of SDT and MI in a technological intervention. Second, we will focus on how technology could be used to support reflection, which could further autonomy in that context. Third, we document our related decisions in detail. The presentation of the concrete design decisions necessary for the construction of our PA behavior change intervention should help to reason about our results and increase comparability with other work or findings. We will document the reasoning that brought about these decisions from the perspectives of health behavior change, persuasive design, and software engineering.



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Methodology

When looking for guidance on how to create a behavior change intervention, we encountered the Intervention Mapping (IM) protocol. It was used by I Move [64] to reduce the risks of picking the wrong behavior change objectives, picking inappropriate behavior change methods, or creating an inadequate implementation of the intervention [78]. We used the IM protocol to aid us in translating our behavior change approach to a technological behavior change intervention. It assisted us in gaining a clearer picture of the behavior we want to change, and the approach we wanted to take to do so, as well as documenting our reasoning. We refrained from using a randomized controlled trial since they are best undertaken when the intervention and its delivery are stable, can be delivered with high fidelity, and with a reasonable likelihood that it yields clinically meaningful benefits [72].

The steps of the IM protocol are summarized as follows [27]:

1. Conduct a needs assessment or problem analysis, identifying what, if anything, needs to be changed and for whom.
2. Create matrices of change objectives by combining (sub-)behaviors (performance objectives) with behavioral determinants, identifying which beliefs should be targeted by the intervention.
3. Select theory-based intervention methods that match the determinants into which the identified beliefs aggregate, and translate these into practical applications that satisfy the parameters for the effectiveness of the selected methods.
4. Integrate methods and practical applications into an organized program.
5. Plan for adoption, implementation, and sustainability of the program in real-life contexts.
6. Generate an evaluation plan to conduct effect and process evaluations.

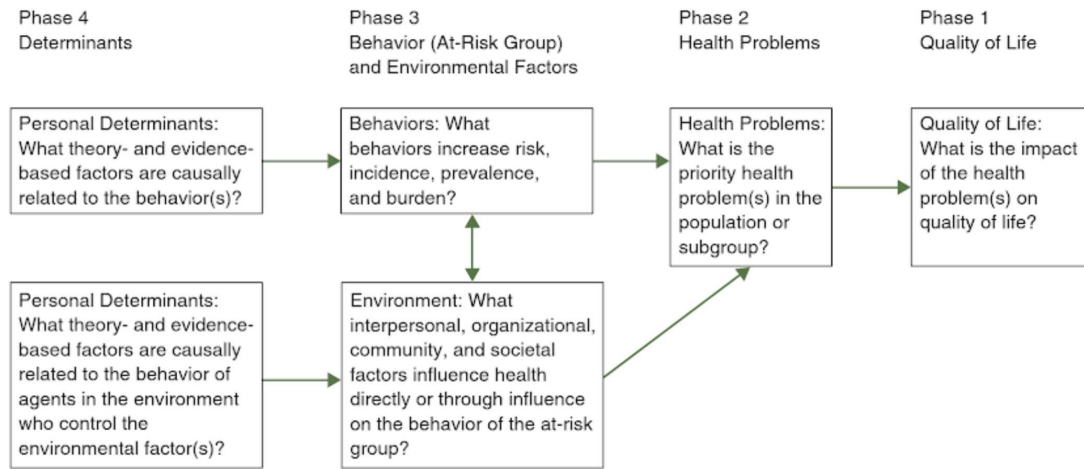


Figure 3.1: Logic model of the problem [79]

We took great care to base our technological prototype on theoretical work and conducted the accordingly extensive literature review. With this background, we built a prototype of the intervention, documenting the design decisions in the process. We then conducted qualitative interviews with participants to gain first insights and check in which ways the construction was feasible. Based on the results, we refined the prototype and ran another experiment round, this time, following a quantitative approach. The quantitative part of this mixed-method research allowed us to do a statistical analysis with relation to the persuasiveness of our prototype, provide descriptive statistics of possible effects of our design decisions on reflection and allowed for statistical analysis with relation to our hypothesis.

3.1 Logic Model of the Problem

For the *first step* of the IM protocol, to conduct a needs assessment or problem analysis [79], we built a logic model of the factors that cause or influence a lack of maintained PA. It helped us to gain a better understanding of the environment in which our intervention aims to solve a problem.

The logic model of the problem, which is displayed in figure 3.1, is usually developed from right to left, and read from left to right as a causal model after completion.

PA improves *Quality of Life* on multiple layers. In its global strategy on diet, PA, and health, the WHO notes a reduced risk of hypertension, coronary heart disease, stroke, diabetes, breast and colon cancer, and depression, as well as improved bone function, functional health, and weight control [80].

PA is further associated with improved mental health, delay in the onset of dementia, and improved the perceived quality of life and well-being. Psychological benefits range from an increased mood, sense of confidence, self-esteem, social opportunities, and cognitive function-

ing [10].

Although a lack of PA is a global issue as we've shown in chapter 1, we identified our target group as people who are physically able to increase their PA behavior and have a general interest in doing so. We selected this group because it was assumed to be the easiest to convince to change their behavior. If our intervention does not work for them, it is unlikely to work for harder-to-convince target groups such as people suffering from serious injuries or depression.

Among the *Environmental Factors* for the current levels of physical inactivity is an increase in sedentary behavior during occupational and recreational activities. Furthermore, the increase in the use of motor vehicles and a change in the design of cities lead to a decline in walking and cycling. Increased urbanization and the connected factors of violence, high-density traffic, low air quality, pollution, lack of parks, sidewalks, and sports/recreation facilities may discourage participation in PA. [81]

Biddle et al. highlight the importance of *Behavioral Factors* of PA behavior with the following example:

For example, even when a workplace is well served with dedicated cycle routes and safe walking routes, creating an incentive system for people to cycle or walk to work still requires the development of beliefs and attitudes, as well as decision-making, choice, motivation and, ultimately, behavior on the part of the individual [10].

Concrete behavioral factors hindering regular PA are shown in figure 3.2.

In section 2.2, we have presented a focus on the issues of eliciting *maintainable* PA behavior.

Personal Determinants are factors that individuals at risk or agents in the environment can directly control or influence. They usually include cognitive factors—such as knowledge, attitudes, beliefs, self-efficacy, and values—as well as capabilities such as skills. These are factors that interventions can change or influence. [79]

Since our approach focuses on changing the behavior of individuals at risk, we will focus our consideration on these factors only. To provide a better picture of the overall situation, we nevertheless provide the WHO's global action plan on PA 2018 – 2030 in the following. We consider it an excellent source to derive personal determinants for agents in the environment [2]:

1. *Create Active Societies*: Create a paradigm shift in all of society by enhancing knowledge and understanding of, and appreciation for, the multiple benefits of regular PA, according to ability and at all ages.
2. *Create Active Environments*: Create and maintain environments that promote and safeguard the rights of all people, of all ages, to have equitable access to safe places and spaces, in their cities and communities, in which to engage in regular PA, according to ability.
3. *Create Active People*: Create and promote access to opportunities across multiple settings to help people of all ages and abilities to engage in regular PA as individuals, families, and communities.

Table 2.1 Factors given as barriers by people aged 16–69 years in the Allied Dunbar National Fitness Survey for England (Sports Council and Health Education Authority 1992)

Barrier label	Barriers
Physical	I have an injury or disability that stops me I'm too fat My health is not good enough I'm too old
Emotional	I'm not the sporty type I'm too shy or embarrassed I might get injured or damage my health
Motivational	I need to rest and relax in my spare time I haven't got the energy I'd never keep it up I don't enjoy physical activity
Time	I haven't got the time I don't have time because of my work I've got young children to look after
Availability	There is no one to do it with I can't afford it There are no suitable facilities nearby I haven't got the right clothes or equipment

Figure 3.2: Factors given as barriers by people aged 16–69 years in the Allied Dunbar National Fitness Survey for England [82]

4. *Create Active Systems:* Create and strengthen leadership, governance, multi-sectoral partnerships, workforce capabilities, advocacy, and information systems across sectors to achieve excellence in resource mobilization and implementation of coordinated international, national and subnational action to increase PA and reduce sedentary behavior.

Personal Determinants for behavioral factors are factors that individuals control or influence to avoid *Health Problems* and improve *Quality of Life* in regards to PA. We have chosen the following:

1. *Knowledge:* Considering the knowledge individuals have about PA.
2. *Attitude:* The attitude individuals show towards PA.
3. *Skills:* Necessary skills individuals have or need to develop to engage in healthy PA.
4. *Self-Efficacy:* The individual's belief in their innate ability to engage in maintained healthy PA.
5. *Perceived Barriers/Benefits:* Individuals can shift their perception of benefits/barriers in regards to their PA behavior.

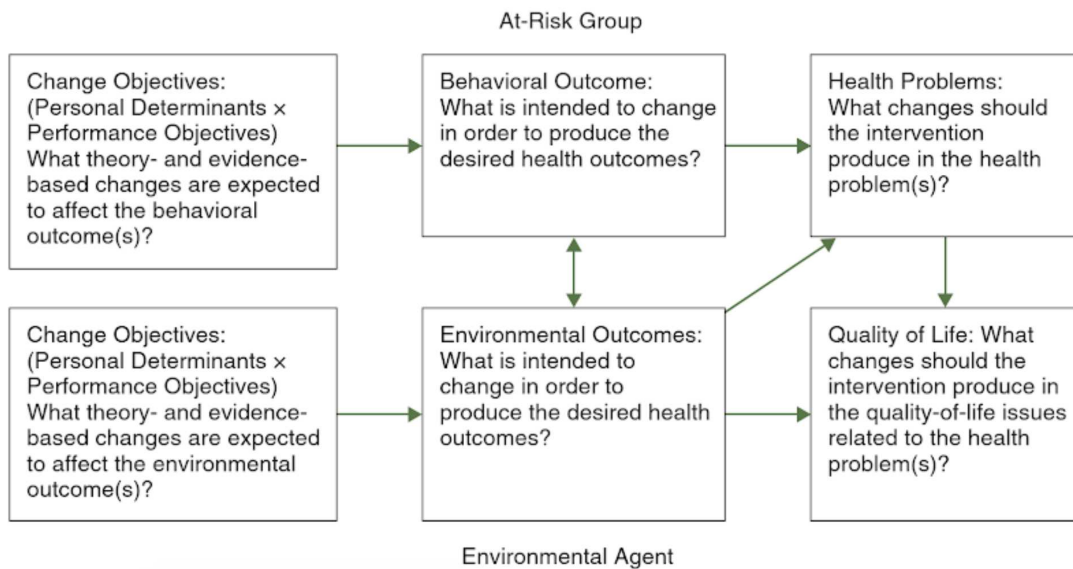


Figure 3.3: Logic model of change [79]

These determinants will be guiding us with finding change objectives in the next step of the intervention mapping protocol.

As the last step in our logic model of the problem, we derive *goals for the intervention*. We want to make the benefits of maintained health levels of PA accessible for people that are physically able to increase their PA and have an interest in doing so. We will create an intervention that helps individuals to fosters maintainable PA over a fast increase in PA from their base level to do so.

3.2 Logic Model of Change

Following our logic model of the problem, in *step two* of the IM protocol, we go into detail on who and what will change as a result of the intervention to build our logic model of change.

We start by considering what needs to change in the behavior of our target group, the *behavioral outcomes* for individuals. As with the determinants in the logic model of the problem, we disregard the environmental outcome due to this work's focus.

1. *Show healthy levels of PA:* Individuals have a baseline PA fitting the WHO recommendation [12].
2. *Maintain healthy levels of PA over multiple months:* Individuals maintain healthy levels of PA in the long-term with smaller setbacks and breaks.
3. *Re-engage in PA Behavior after Disruption:* Even if the PA behavior of an individual is disrupted for a time, such as because of injury or sickness, the individual will pick it up again after the disruption.

From the behavioral outcomes, we can derive our *performance objectives*, defining what participants need to do to perform the behavioral outcomes.

1. *PO1 Question their Views about their PA Behavior*: Individuals question their current views of their PA behavior and re-evaluate if they want to change them.
2. *PO2 Increase Baseline PA Behavior if below the recommended levels*: Individuals slowly increase PA behavior from baseline if below healthy levels. For our stated goal, it is not necessary to rapidly increase PA behavior from the baseline.
3. *PO3 Regularly Check their PA Behavior*: Individuals think about their levels of PA behavior regularly and consider if it needs adjusting.
4. *PO4 Motivate Themselves to Start their PA Behavior*: Individuals start doing PA out of their own volition.
5. *PO5 Discuss their PA Behavior with Someone*: Individuals have a conversation partner to discuss their PA behavior.
6. *PO6 Feel Competent in their PA Behavior*: Individuals feel competent in their chosen type of PA.
7. *PO7 Re-engage in PA Behavior after Disruption*: Even if the PA behavior of an individual is disrupted for a time, the individual will pick it up again afterward.

Next, we will create a matrix of change objectives to detail the change we want to support. It crosses our performance objectives (what we want participants to *do*) with the determinants of that behavior (factors that explain *why* participants would or wouldn't change their behavior) to arrive at our change objectives (what participants have *to learn* to achieve the performance objectives).

With our behavioral outcomes defined, we have derived our performance objectives and brought them together with the determinants to draw a clearer picture of the change objectives of our intervention. In the next step, we will use that knowledge to build a behavior change intervention.

3.3 Translating Theory into a Computer-Based Intervention

Step three of the intervention mapping protocol is the program design, where we build a coherent and deliverable intervention [79].

The main work in this step revolves around finding a theoretical background to our behavioral outcome. We believe that in order to foster a maintainable PA behavior change, instead of a sharp short-time increase that falls to baseline rapidly, we have to focus on an approach that aims to motivate in ways that support users in internalizing the target behavior, instead of providing external motivation.

Performance/ed of Knowledge (K) the Attitude (A) in print at Skills (SK) thek.	Objective (PO)	Self-Efficacy (SE)	Perceived Benefits/Barriers (BE, BA)
PO1 Question their Views about PA	K1.a. Know that PA is good for their physical health. K1.b. Know that PA is good for their mental health.	SK1.a. Express the ability to process information about PA. SK1.b. Express ability in thinking about past PA. SK1.c. Express the ability to envision alternatives to current behavior. SK1.d. Express the ability to look at PA behavior from different perspectives.	BE1.a. Recognize that PA is good for them. BA1.a. Understand that, given the huge variety of options, a healthy level of PA has low barriers of entry.
PO2 Increase Baseline PA	K2.a. Know an engageable type of PA.	A1.a. Believe that PA is a worthwhile activity for them. A2.a. If below healthy levels, believe that they should increase their PA. A2.b. If above healthy levels, believe that they should uphold healthy levels of PA.	BA2.a. Recognize their physical and mental capability to perform PA. BA2.b. Understand that they can find the time to do PA.
PO3 Regularly Check their PA	K3.a. Recognize that some benefits of PA only apply in the long-term if the behavior is maintained.	SK3.a. Express to have a way of reminding themselves to do PA.	BA3.a. Recognize that the time effort for regulation can be negligible. BE3.a. Understand that regularly checking their behavior is necessary to keep it at healthy levels.
PO4 Start Doing PA Themselves	K4.a. Recognize that there are multiple ways of reminding oneself to do PA.	SK4.a. Express the ability to think about PA on their own.	BE4.a Understand that getting started on their own helps to ensure the benefits over the long-term. BA5.b. Recognize that relying on external cues could lead to avoidable disruption.

Table 3.1: Matrix of change objectives for maintaining PA behavior; performance objectives 1-4

Performance Objective (PO)	Knowledge (K)	Attitude (A)	Skills (SK)	Self-Efficacy (SE)	Perceived Benefits/Barriers (BE, BA)
PO5 Discuss PA with Someone	K5.a. Recognize that talking to someone about PA helps with regulating it.	A5.a. Believe that someone cares about their PA behavior.	SK5.a. Express that they have someone to talk to about their PA behavior.	SE5.a. Demonstrate confidence in discussing their PA behavior.	BA5.a. Understand that discussing PA with someone should not be embarrassing.
PO6 Feel Competent Doing PA	K6.a. Know what it takes to perform a type of PA competently.	A6.a. Believe that their competence in a type of PA is adequate or better.	SK6.a. Express that they can judge how good they are in a type of PA.	SE6.a. Demonstrate confidence in performing a type of PA.	BE6.a. Understand that practice will influence their ability to perform PA. BA6.a. Recognize that they do not need to master a type of PA to gain benefits from it.
PO7 Re-engage in PA after Disruption	K7.a. Know of alternative PA behavior for different types of disruption. K7.c. Know how to adjust their breaks in behavior according to different types of disruption.	A7.a. Believe that disruption is not the end of their PA behavior.	SK7.a. Express the ability to apply the necessary treatment for different types of disruption.	SE7.a. Demonstrate confidence in their ability to start their behavior after a disruption.	BE7.a. Recognize that the key behavior is to restart after disruption. BA7.a. Understand that there are healthy ways to keep up with PA behavior for a multitude of disruptions.

Table 3.2: Matrix of change objectives for maintaining pa behavior; performance objectives 4-7

Our methods, the general processes for influencing changes in the determinants of behavior and environmental conditions, will be based on the theoretical foundation of the combination of SDT, MI, and reflection. We have detailed this choice in section 2.3.

We have highlighted the opportunities of using technology to support reflection and how technology was used in the context of SDT and MI in section 2.3. Furthermore, we have looked at Fogg's distinct advantages computers have over human persuaders in section 2.3. Especially in the context of sensitive areas such as psychological therapy, the greater anonymity and higher ubiquitousness a technological intervention offers is promising. We will, therefore, create a technological intervention.

The necessary effort in transitioning from idea to an actual behavior change intervention cannot be overstated since one of the basic premises of this work is to consider the theoretical background for the targeted behavior change. However, there is little guidance on how to do that in current research. MI provides advice on how to transfer SDT into practical application. Nonetheless, there is a lack of research to draw from concerning concrete decisions in a technological implementation of this concept. Focusing on reflection, we perceive this gap in regards to correctly making such a translation even more vividly.

Since MI is an interviewing technique conventionally used in therapy sessions, our primary method will be a dialogue with our users. This dialogue offers the possibility to tackle multiple change objectives and allows us to tackle these change objectives from multiple angles. We will need to make a design decision on how to implement a dialogue in our intervention in detail.

Next, we need to consider the topic of application. Application is a practical technique for the operationalizing methods in ways that fit with the intervention group and the context in which the intervention will be conducted [79].

To increase the ubiquitousness and persuasiveness of the intervention, we will build our intervention as a responsive web-app. As a responsive web-app, it will be usable as a regular website on a computer as well as on a smartphone.

In line with the findings of related work, where negative reinforcement leads to reduced interaction over time, see 2.2, the theme of the intervention will be a positive and supportive one.

We have already mentioned that we will create a dialogue derived from MI techniques. Persuasive artificial agents come to mind, which may function as a useful tool to induce changes in human behavior [83]. Therefore, we will have to select an avatar that matches our chosen theme.

We named this avatar "Josef". To make sure the dialogue between the user and the avatar matches our theoretical background, we will derive the approach and questions from MI learning material to the best of our knowledge. Although MI is usually conducted over multiple sessions, we will limit our intervention to two sessions, with one week between sessions, in order to stay within the scope of this master programme.

With the theoretical background, theme, and scope of our behavior change intervention defined, and most importantly, the delivery method as a responsive web-app, we can look into the program production of the intervention in the next section.

3.4 Program Production

In *step four* of the IM protocol, we create an organized program for our intervention. We define and refine the program structure and prepare, test, and produce the needed materials [79].

Our intervention’s foremost “material” is the technological intervention we create to conduct our experiments. We will document this creation and design process in detail as part of our research. We will conduct qualitative interviews with participants using it as soon as the initial prototype for our intervention is completed. For conducting interviews, we will create an interview guide.

A qualitative approach was chosen mainly because qualitative research lends itself to the analysis of the effects of our many design decision, which were expected to be manifold. With interviews, we had a higher possibility of finding out early about issues in mapping from the theoretical background to our implementation than a quantitative approach would offer. This approach further offered an opportunity for adjustments according to the first findings. We may choose to simulate the intervention sessions of this experiment round in a quick manner to gain insights faster in this phase. Klasnja et al. support this approach of tailoring the evaluation approach to the intervention strategy for HCI researchers, since it enables them to show that the systems are doing what they are supposed to be doing, without requiring a full-blown demonstration of behavior change [84]. They further mention better comparability between implementations of the same intervention strategy, and a contribution in understanding how the design of a technology for behavior change affects the technology’s use by its target audience—both being essential advantages for our efforts in this research.

The next step will be to create a second, refined prototype; this time made accessible to a larger group of people. For this, we will try to adhere more closely to the split nature of the therapy sessions the prototype simulates.

The mixed-method research approach with a qualitative and quantitative part should provide the wanted insights into our behavior change approach.

For the experiments with the prototypes, we will create the following documents:

1. Consent documents for participants allowing the use of collected data for research purposes.
2. Consent texts for allowing us to contact participants by e-mail to notify them about further intervention sessions.
3. Selection of channels to find experiment participants for the second prototype.
4. Wording to advertise to take part in the experiment.

3.5 Program Implementation Plan

In *step five* of the IM protocol, the research team plans for the adoption, implementation, and sustainability of the program. The performance objectives defined in this step state who has to do what for the program to be adopted, implemented, and continued.

For this research, we are mainly gathering research data and knowledge about the feasibility of a behavior change intervention approach. We do not plan for target group adoption and maintenance of the intervention beyond that.

Nevertheless, since we are building a technological intervention that is delivered over the internet, our approach has notable scalability advantages. If the approach is determined to be feasible, adoption and maintenance can be supported very effectively with technological and automated ways.

3.6 Evaluation Plan

Generating an evaluation plan is the *sixth step* of the IM protocol [79]. We want to evaluate the effectiveness of our intervention in regards to the change objectives in our logic model of change. In consideration of the theoretical background of our intervention, we should further structure our evaluation questions to help work to answer a possible connection to our approach of combining SDT, MI, and reflection. In particular, we want to gain further knowledge of this combination in a technological intervention.

Before we can look into indicators and measurements for an assessment, we need to take a closer look at how reflection can be evaluated.

Evaluating Reflection

As we will show in this section, reflection is notoriously hard to evaluate. In section 2.3, we have shown previous approaches to defining reflection. The lack of a general agreement on what constitutes reflection provides a rough starting ground for evaluation. Since there are no widely accepted means of identifying or assessing reflection, Sumsion and Fleet go as far as to state that reflection appears unsuited to quantitative measurement and should be assessed from a broader perspective than typically apparent in academic assessment [85]. They argue that coding reflection requires a high degree of interpretation and would, therefore, advise for a single coder, yielding higher consistency but more bias.

Furthermore, they state that, since rating scales that are usually utilized depend on ease and reliability of use for their effectiveness, they provide a rather simplistic view of reflection. Consequently, such scales may fail to provide insights into the complex nature of reflection and how to promote it effectively. Lastly, reflection does not necessarily conclude in the necessary behavior change immediately but can occur on its own.

Baumer has taken a more recent look at evaluating reflection and found that relatively few papers clearly defined the concept of reflection, offering an opportunity to engage with the diverse theoretical literature on the topic to develop further techniques to support reflection [70]. The lack of a specific focus on reflection in the reviewed papers was another notable finding. Baumer concludes with a suggestion to engage with the theoretical literature to gain grounding and inspiration for more sophisticated designs for reflection. To evaluate reflection, Baumer suggests that, instead of trying to determine when an individual is “more reflective,” an unfitting reduction of an incredibly complex phenomenon, reflection should be evaluated with other approaches [71]. First, instead of asking *how much* a person is reflecting, we should ask *in*

what ways the person reflected. Second, one could instead ask what role reflection plays in the broader contexts in which it occurs to determine what benefits reflection provides. Lastly, instead of asking, “Did it work?” during the evaluation, working towards a means of deepening our understanding of reflection itself to gain knowledge about both the nature of reflection as well as the potential impacts of our interventions.

Towards evaluating reflection in this work, we have given our understanding of the definition of reflection in section 2.3. In further investigating how technology could be used to support reflection, we give it a specific focus. Lastly, we have considered existing literature on the topic to provide solid grounding.

To go towards measurable performance objectives as part of the intervention mapping protocol, we have taken into consideration research perspectives from Fleck and Fitzpatrick and Baumer. Fleck and Fitzpatrick have outlined aspects of reflection that they have organized into levels of reflection [26], and Baumer defines three dimensions of reflection, which serve as the basis for reflective informatics [71].

Drawing from Moon [68], Fleck and Fitzpatrick state that reflection can have many purposes, including learning and the material for further reflection, action or other representation of learning, critical review, the building of theory, self-development, decisions or resolutions of uncertainty, empowerment or emancipation and other outcomes, ideas or images that might be solutions [26].

Fleck and Fitzpatrick continue with an analysis of the conditions for reflection [26]. Since reflection takes time, it is essential to create or allow for time to reflect [68]. Reflection is often discussed as a development process, and people can learn to be more reflective over time with support [86] [68] [87]. For more formal purposes of reflection, structured support or guidance of reflection is of value. Finally, reflecting does not come naturally to all people and is time-consuming. Therefore, they usually need a reason or encouragement to do so [86] [68].

For the purpose of design, it is useful to think of different *levels of reflection*, where higher levels are considered to be more reflective [26], and where it is suggested that lower levels are prerequisites for higher levels of reflection [88]. Fleck and Fitzpatrick defined five different “levels of reflection”, from R0, the lowest, to R4, the highest [26].

1. *R0 Description: Revisiting* is a description or statement about events without further elaboration or explanation, and as such, not reflective.
2. *R1 Reflective Description: Revisiting with Explanation* occurs when explanations, reasons, or justifications accompany descriptions, but in a reporting or descriptive way, missing alternate explanations or changes of perspective.
3. *R2 Dialogic Reflection: Exploring Relationships* probes for relationships between descriptions and primarily involves seeing things from a different perspective, which is an aspect of an ideal conversation with another person. This reflection involves cycles of interpreting and questioning, generalizing from the relationships between ideas and descriptions, and consideration of alternatives to reach a different level of understanding.
4. *R3 Transformative Reflection: Fundamental Change* is about altering or transforming the reflector’s point of view to take into account new perspectives. It is necessary to rec-

ognize that many of our actions are governed by a set of beliefs that have been almost unconsciously assimilated from our environment to achieve this transformation. Reflectors should ask fundamental questions and challenge personal assumptions to lead to a change in practice or understanding.

5. *R4 Critical Reflection: Wider Implications* involves taking into consideration the much wider picture, such as social or ethical issues and is reportedly very rare.

Fleck and Fitzpatrick have provided us with guidelines to design for reflection by thinking about the purpose and conditions for reflection, as well as ways to identify the types of behaviors we want to encourage and how to encourage them. To simplify the concept of levels of reflection, we could describe them as answering the question of *how deep* the reflection was.

Looking at reflection from another angle, Baumer has analyzed the theoretical background of reflection, and identified three independent *dimensions of reflection* – breakdown, inquiry, and transformation – which serve as the foundation for reflective informatics to help articulate how design may support reflection [71].

1. *Breakdown*: Baumer presents breakdowns as doubtful or puzzling situations, situations of surprise or uncertainty, or disturbing anomalies that do not fit with an individual's current meaning perspectives. They provide opportunities for reflection by leading to a conscious and explicit consideration of previously unconscious or implicit behavior. Useful strategies to provide technological support for breakdowns are drawing attention to them, inducing them, or creating moments of perplexity.
2. *Inquiry* is a conscious and intentional process. It involves generating, testing, revising, and further testing hypotheses, or a re-examination of existing knowledge. Supporting and creating opportunities for inquiry could take many forms, such as providing for iterative hypothesis testing and refinement, making clear to the user what he/she already knows to encourage a re-examination of that knowledge, or may even occur along the way of interacting with the system. Baumer suggests three design strategies to support inquiry: a design that incorporates reviews of past experiences, a design that designates a particular space for inquiry, separate from the primary activities that should be inquired upon, and group discussions.
3. *Transformations*: Reflection is not only examining the current state of the world or one's self but also about envisioning alternatives. It ultimately involves change – transformations. This reflection could involve transforming understanding of learned material, of existing conceptual schemata or situations. In an example of cognitive approaches, reflective decision making stands in contrast to more automatic thought processes. While heuristic decisions are often based on loss-aversion, the preference for avoiding losses over seeking gains, reflective decision making enables decisions that are free from such biases.

To simplify the approach of the concept of dimensions, we could describe it by answering the question of *in which ways* reflection occurred.

To guide the evaluation of reflection in our work, we will use both the perspective of levels of reflection, as well as the dimensions of reflection, to try to get an idea of *how deep* and *in which ways* our intervention participants reflected.

Indicators and Measures

Now that we have found an appropriate approach to evaluate reflection, we can define the indicators and measures we want to evaluate to help to answer our research questions.

For the prototype, we programmatically implement the automatic taking of technical measurements during intervention usage, as shown in table 3.3, and conduct qualitative interviews according to an interview guide. The interview guide is designed to help us get a basic understanding of the current situation of the participants in regards to PA. It includes questions regarding their current attitude towards PA, inquires about their previous efforts to increase PA, and if they think about their PA behavior. The questions are designed to help us build connections with the prototype usage and the environment of the participants in order to understand possible issues with our design.

Measurement	Background
Total usage time	conditions for reflection
Average time to text answer	contemplation
Average length of response	deliberate responses

Table 3.3: Technical measurements from intervention usage for prototype 1

After the prototype usage, we continue the interview with questions about how app usage was connected to the respondent’s thoughts about PA behavior. We furthermore go through each dialogue option one by one, so participants get another chance to speak their minds or point out particular consequential, confusing, or otherwise puzzling situations they encountered during usage. After that, we thank them for their time, indicate that we are about to reach the end of the interview, and give them a few more moments to be able to speak about their experience freely.

For the quantitative part of our research, we will present participants with a short up-front questionnaire, and a longer questionnaire after they have completed the intervention. Some questions from the up-front questionnaire will repeat in the questionnaire at the end of the intervention.

We chose the questions themselves in a way that they can be used to indicate changes in participants that we are interested in from the perspective of our chosen theoretical background. Our measures regarding SDT and MI will focus on providing us with data regarding changes in the three innate psychological needs—competence, autonomy, and relatedness. For reflection, we will choose questions considering the levels of reflection and dimensions of reflection.

We used Typeform to conduct the questionnaire [89]. Each section started with a short description, and each new type of answering option was presented with a short introduction. For example, the first Likert scale is paired with the accompanying introduction of “To which extent do you agree with this statement?”.

For scale types, we used Likert Scales from 1 to 5 (Strongly Disagree, Disagree, Undecided, Agree, Strongly Agree) for questions regarding agreement. Multiple-Choice questions had an “Other” option where reasonable to avoid a forced-choice bias, and the answer choice order was randomized for each participant. We further mixed the answer types and used both negative and positive statements (“I liked Josef’s appearance” was reframed as “I disliked Josef’s appearance.”) to reduce the biases of No-saying and Yes-saying.

Table 3.4 shows the questions for the up-front questionnaire from a research perspective. The classifications and background were not visible to participants of the questionnaire.

Question	Background
General Questions & Demography	
What is your country of origin?	Demography
What’s your e-mail address?	Experiment Structure
In what year were you born?	Demography
What’s your gender?	Demography
Do you currently use an app or wearable (Fitbit, Apple Watch,...) to help motivate you to do physical activity?	Demography
Would you say that you are physically more active, less active or about as active as other persons your age?	Demography
Questions concerning SDT & MI	
I get as much exercise as I need.	SDT autonomy
Doing physical activity is worth my time.	SDT autonomy
I think I’m good at my preferred physical activity.	SDT competence
In daily life, what triggers you to do physical activity?	SDT autonomy
Doing physical activity helps me to reach a personal goal.	SDT autonomy
I feel pressured into doing physical activity.	SDT autonomy

Table 3.4: Up-front questionnaire (also see Appendix)

The questionnaire presented to participants after the intervention repeats questions from the up-front questionnaire to measure changes. Furthermore, it aims to deepen our understanding of the effects our intervention had on participants during usage from the perspective of our theory-backed approach.

In addition to the questionnaires, we will implement measurements that are taken automatically during the usage of the intervention, or can be constructed from the saved responses participants have given.

When looking back at our logic model of change as part of the IM protocol, it is noticeable that our questions and measurements are focused on answering questions for the determinants of attitude, perceived barriers, and -benefits and self-efficacy. In the environment of PA behavior change, interventions to increase knowledge about PA, and providing individuals with the necessary basic skills to do PA, are abundant. For example, physical education is a mandatory subject throughout full-time compulsory general education in the EU [90]. We designed our intervention to work in concert with this environment and improve support for the other determinants.

Question	Background
Questions concerning SDT & MI, Repeated from first Questionnaire	
I get as much exercise as I need. Doing physical activity is worth my time. I think I'm good at my preferred physical activity. Doing physical activity helps me to reach a personal goal. I feel pressured into doing physical activity.	SDT autonomy SDT autonomy SDT competence SDT autonomy SDT autonomy
Questions concerning Persuasiveness	
How easy/hard was Josef (the robot) to use? I disliked Josef's appearance. Josef was supportive towards me. I would have preferred discussing my physical activity with a human rather than Josef.	Persuasiveness Persuasiveness SDT relatedness SDT relatedness
Questions concerning Conditions for Reflection	
Josef helped me structure my thoughts about my physical activity behavior. Josef discouraged me from thinking about my physical activity behavior.	structure encouragement
Questions concerning levels of reflection	
Josef helped me find new reasons to do physical activity. I have looked at my physical activity behavior from a new perspective. My attitude towards physical activity is still the same as it was before talking to Josef.	reflection level R3 reflection level R2 reflection level R3
Questions concerning the dimensions of reflection	
Josef made me stop and think about my physical activity behavior. I have considered new alternatives to my previous physical activity choices. I can envision myself doing one or some of these new alternatives.	breakdown transformation transformation

Table 3.5: Post-experiment questionnaire (also see Appendix)

Measurement	Background
Total usage time	conditions for reflection
Average time to answer	contemplation
Average length of text responses	deliberate responses
Word cloud of responses	better understanding of responses

Table 3.6: Technical measurements from intervention usage for prototype 2

Furthermore, it may be noticeable that we do not attempt to directly measure for the maintenance of actual PA behavior, such as through step counts. We believe that if our technological intervention fails to support even the aspects of the theoretical background, it is unlikely that the goal of eliciting a more maintainable PA behavior can be met. If, on the other hand, the intervention successfully implements support for behavior according to the theoretical background, future work can then continue with investigating the resulting long-term PA behavior.

3.7 Study Details & Experiment Expectations

Table 3.7 shows an overview of the study details we consider in detail in this section. The construction of the initial prototype of Josef served as the basis for experiment *EX1*. *EX1* was done with six participants in our target group we recruited with a convenience sampling approach of “friends of friends” [96]. We have presented an overview of the experiment’s structure in figure 3.4. We met each person separately, and, after the introduction and some small talk, started with a short interview to learn about the participant and their behavior in regards to PA. For the interview, we used the interview guide given in the Appendix. Then, we opened the prototype on their phone and left the room while they completed the first session of the intervention. When they made it known that they finished the first session, we did a quick check if any technical problems occurred and initialized the second session of the intervention on their phone. Then, we told them to imagine that a few days had passed and left the room again until they were done. After this step, we did another interview with a focus on finding out about any issues and asked questions to help us determine in which ways our intervention had an impact on the participants. While our intervention’s sessions were designed to have a week between them, we decided to take this overall approach to have a quicker way to check our assumptions and to get feedback in case of issues with our intervention mapping or the technical implementation. We transcribed the interviews using *f4transkript* and did a thematic analysis using the transcripts we coded using *f4analyse* [92] by looking for patterns related to our research question. We programmed Josef to automatically created the measurements shown in table 3.3. After *EX1*, we manually checked that the values were reasonable in that users had usage patterns that indicated that they did indeed contemplate their responses instead of rushing through the app.

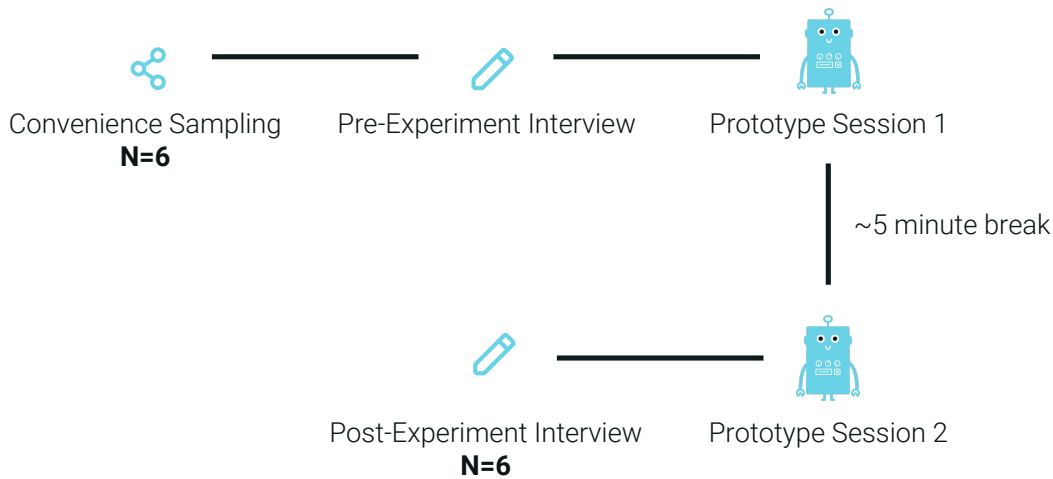


Figure 3.4: Structure of the experiment *EX1*

Research Question	Contributions	Sampling & Instruments	Analysis
What are the effects of components designed to further reflection in a computer-based intervention that aims to elicit long-term PA behavior change in people who are physically able to increase their PA behavior and have a general interest in doing so.	Empirically test the combination of SDT & MI in a technological intervention.	Mixed-method research with qualitative- and quantitative data collection. <i>Experiment 1 (EX1):</i> Qualitative interviews with 6 participants found through convenience sampling using prototype 1 of Josef according to the structure shown in figure 3.4. Software implementation of automatic technical measurements shown in table 3.3. Persisting of all dialogue responses in a database.	<i>EX1:</i> Interviews conducted using an interview guide (see Appendix), transcribed using <i>f4transkript</i> [91] and coded with thematic analysis using <i>f4analyse</i> [92]. Technical measurements checked manually. <i>EX2:</i> Statistical analysis using <i>Minitab</i> [93]. Descriptive statistics and Spearman rank-order correlation for questionnaire responses. Descriptive statistics for technical measurements. Paired t-test analysis for SDT & MI questionnaire responses. Word cloud and sentiment analysis of participant's dialogue responses using <i>Word Cloud Generator</i> [94] and <i>sentiment</i> [95]. Self-written tool to show a text overview of answers to contribute to thematic analysis.
	Investigate how technology could be used to support reflection, which could further autonomy.	<i>Experiment 2 (EX2):</i> Quantitative data collection according to the structure shown in figure 3.5 with prototype 2 of Josef published on the internet with 94 participants invited through social media (Reddit, Instagram,...). Questionnaires according to tables 3.4 and 3.5. Software implementation of automatic technical measurements shown in table 3.6. Persisting of all dialogue responses in a database.	
	Document all design decisions in detail from the perspectives of health behavior change, persuasive design, and software engineering.	Documentation in chapter 4.	Consideration of decisions in chapter 5 and 6.

Table 3.7: Study details

We were fully expecting to change our implementation approach quite extensively after *EX1*. After looking at the first results, we determined that we would not need to deviate as much as expected, but could work with minor changes. These influences from the first experiment resulted in changes that included:

- removing a date selector choice for the date of the second session in favor of a fixed one week break
- simplify wordings of specific dialogues
- building support for questionnaires
- replacing the registration/login approach with using the e-mail entered during the up-front questionnaire

For *EX2*, we used quantitative data collection. *EX2*'s structure is visualized in figure 3.5 and listed in the following:

1. Invite participants to the study
2. Up-front questionnaire 1
3. Automatic forward to prototype session 1
4. Prototype session 1
5. One week break
6. Manually sent e-mails to all participants that have completed session 1
7. If no reaction to previous e-mail, send a “drop-out” e-mail
8. Prototype session 2
9. Automatic forward to final questionnaire 2

Participants filled out the up-front questionnaire we have given in table 3.4. During the whole intervention, we took automatic measurements as given in table 3.6. After participants had completed both sessions, we presented the questionnaire we defined in table 3.5. Our goal was to have at least 20 participants completing all parts of the experiment and used social media (Instagram, Reddit,...) to find people in the target group. We expected that a large part of our users would not complete both sessions. We reasoned that, while the novelty effect should be in our favor, the focus on fostering internal motivation instead of external ones might be a hindrance in this regard because it relies mostly on the user's own motivation, promising no external reward. Nevertheless, our approach resulted in 94 participants filling out the first questionnaire, and 39 completing the whole experiment *EX2*. We adhered to the separation of two sessions, with a break of one week after the first session. We implemented this one week break by keeping Josef in the state of the dialogue ending the first session until we use a script

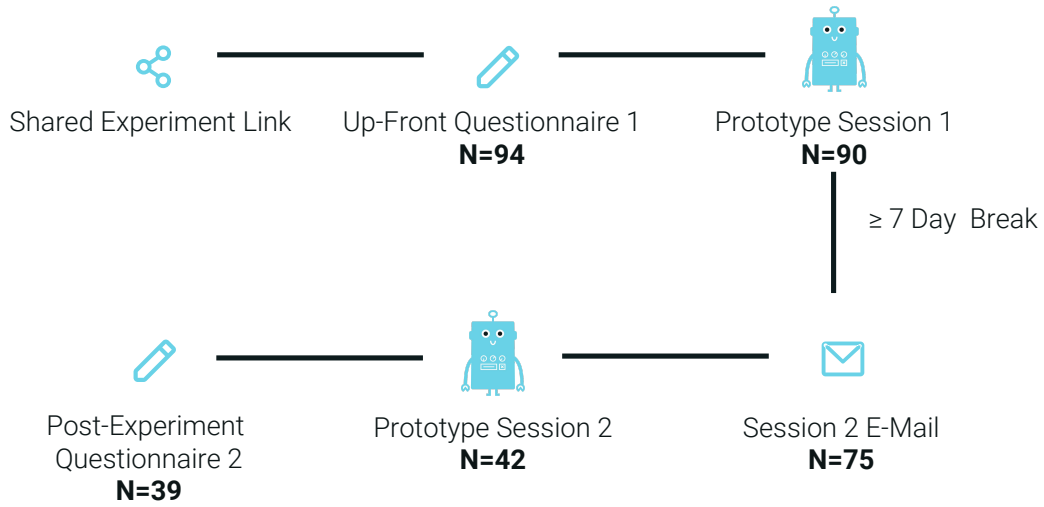


Figure 3.5: Structure of the experiment *EX2*

to switch to the dialogues of the second session. Once the dialogues were ready for the second session for a particular user, we informed him or her by e-mail:

Subject: Josef the Robot [robot emoji]: Ready for your next meeting

Hi,

you've talked to Josef the Robot about your physical activity behavior a week ago. Josef is now ready for your next meeting!


To continue, click [here].

Best Regards,
Josef's Research Team

We analyzed the questionnaire results of *EX2* to see in which ways our intervention had affected participants with regards to the logic model of change we have given in chapter 3.2. We expected to see results indicating that our intervention supported the change processes defined by our theoretical grounding of SDT, MI, and reflection. The statistical analysis was conducted using *Minitab* [93]. We used descriptive statistics for all questionnaire responses and Spearman rank-order correlation to analyze the relationship between them. For correlation, we chose the Spearman correlation coefficient over the Pearson correlation coefficient because we heavily used Likert scales for the questionnaires, which use ordinal values rather than continuous

variables, and expected monotonous, but not necessarily linear, relationships between variables. For the questions related to SDT & MI, which we asked both in the up-front as well as the post-experiment questionnaire, we used a paired t-test analysis. Paired t-tests are useful for analyzing the same items measured under two different conditions, such as in our case, on the same participant before and after intervention usage.

During the intervention use, we automatically tracked metrics given in table 3.6, which we analyzed using descriptive statistics to see if users did contemplate their responses as intended. For the readiness to change ruler, we expected to see a slight increase in reported motivation. For our approach, this is not a primary indicator, though, since our focus on internal motivation is not meant to result in high immediate motivation increase, but maintainability of the new behavior. For the measurements, such as total time in the app, the average time to answer, and the average length of response, we expected to see values indicating that the answers were not rushed.

 [REDACTED EMAIL]:
Session se1: Initialized , Completed: , Completed At: 7/11/2019, 7:13:45 PM
Session se2: Initialized , Completed: , Completed At: 8/9/2019, 10:19:06 PM

I am moderately physically active and prefer to try and incorporate activity into my daily routine, rather than follow a set exercise regimen. I don't usually enjoy working out, but I feel guilty about not doing it.

To develop better exercise habits in order to maintain my health as I age. My parents have health problems related to weight and I don't want to have similar problems.

So I can maintain a healthy lifestyle better through adulthood. I'm still young and able to get away with more minimal effort right now, but I know that won't last forever.

Weight loss, better physique, better endurance, bonding with others over interest in physical activities, decreased risk of weight-related health problems when I'm older.

Seeing results, finding a routine that I genuinely enjoy.

[S] Overall, I know that my physical activity levels are likely too low, and that continuing at this pace will likely not be enough to keep me healthy and physically fit through adulthood. I want to develop a better relationship with exercise and physical fitness in order to receive the physical and mental benefits of exercise throughout adulthood.

Fairly good. I was on holidays so I took a break from my normal routine, but when I got back I made a point of trying out some more intensive exercises that I haven't done before. Hopefully I can stick with them and incorporate these other levels of activity into my routine.

Struggling to stay healthy and fit as I age. I want to develop good habits now before it turns into a problem.

Commit to working out 3x/week (up from my current 2x/week).

If I enjoyed the new activities I was trying better

[S] I'm mentally ready to make progress, but still struggle with not actually enjoying the activities I'm doing all that much, so sticking with them is difficult.

Figure 3.6: Example output of tool to show respondent text answer overview, experiment *EX2*

All answers given to Josef in *EX2* were automatically saved in a database, yielding 420 text answers to open questions. We implemented a software tool to show a text overview of these answers (see figure 3.6) and collected more example answers for the topics that emerged in the thematic analysis from *EX1*. For further analysis of the participant answers we created a word cloud with *Word Cloud Generator* [94] and did a semantic analysis using *sentiment* [95]. In *EX1*, we observed that people had mixed feelings about their current PA, and therefore expected both “positive” and “negative” words in the word clouds and a mixed sentiment of the answers.

The results for questions concerning our performance objectives were expected to show changes in regards to attitude towards PA. Since we made several decisions to implement an

SDT and MI approach, we hoped to see a slight increase in the related questions but were skeptical if our intervention period would suffice.

We built mechanisms specifically targeted at supporting reflection, and therefore expected agreement in the related questions. The conditions for reflection were expected to see the highest agreement, with the nature of the dialogue structure being designed with that background in mind. The levels of reflection were expected to drop in agreement with the increasing complexity of the involved processes. That is, the higher the level of reflection, the more improbable we considered related thinking to have occurred. For the dimensions of reflection, we expected to see agreement in all three dimensions.

Implementation

In chapter 2 we have identified a need to test the combination of SDT and MI in a technological intervention, how technology can be used to support reflection and to document the design decisions involved in such an endeavor. In the last chapter, we have detailed how we proceeded in developing our approach from an identified opportunity to a behavior change intervention in a structured way following the intervention mapping protocol. Now, we will give a thorough account of the many design decisions involved with designing and implementing the behavior change intervention as a technological solution. We will refer to this part of our work as the “mapping,” i.e., the transformation of the requirements for our behavior change intervention to a software program.

While undergoing this mapping, we had to take great care to have a solid understanding of each decision, since each one could potentially impact the behavior change our intervention invokes in our users. Essentially, this required us to bridge psychological theory, persuasive design, and practical software decisions. Although we were aware that we could not judge every decision to its full extent, we made sure to look at each one from the perspective of the intervention’s positive and supportive theme and our theoretical background. Furthermore, for decisions that we expected to be more impactful, we conducted a further literature review to help make our choice. This way, we tried to ensure that we create a technological adaptation that is true to the behavior change approach we have designed. Even if, after further study, we conclude that a particular decision had unintended effects, us documenting each decision should help with critiquing it, reasoning about potential other decisions, and further research.

4.1 Persuasive Artificial Agents – Designing the Avatar “Josef”

We have previously discussed our use of MI in this intervention. However, human therapists conduct conventional MI sessions. Therefore, the mapping’s first step required consideration about the translation of a therapy session, and the dialogues in those sessions, to a technological behavior change intervention.

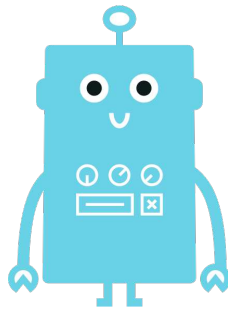


Figure 4.1: “Josef”, our persuasive artificial agent, kindly provided by Daniel Bader, tinygraphy e.U.

Since dialogue implies at least two actors, we felt that it was natural to design a persuasive artificial agent for communication with our users. Since people respond socially to computer technology [97] [98], having an agent that matches our theme of being supportive and positive was in line with trying to support the need for *relatedness* as given by SDT. If the agent worked according to our design, people would build a supportive relationship with it.

Especially in this decision, we had to be aware of the issues and advantages of technological intervention in our setting and environment we have discussed in section 2.3. We need to carefully support relatedness since computer-based systems cannot compete with a human-to-human therapy session in that aspect. We have to make sure we have a sophisticated dialogue system since we lack a semantic understanding of the answers. At the same time, we can play our strengths of higher persistence, greater anonymity, and ubiquitousness in this area. Once we have decided we would need to create a persuasive artificial agent, we needed to decide on its looks.

While this might seem superficial at first, in the context of promoting motivation, the appearance of the agent was shown to be a key factor for its success in promoting motivation [99]. While providing users with a choice of agents might seem intuitive in that situation, it is generally unwise as users tend to choose agents who are not the most beneficial for them [100] [101]. When looking at other technological health interventions, human avatars are widely used. They can provide a form of social interaction that, according to social cognitive learning theories, may contribute to learning [99].

However, the creation of a fitting anthropomorphic avatar is challenging, since the imitation of a human being requires modeling of bodily movements, emotions, and intelligence [51]. Nevertheless, when researching the topic more closely, we found that people may respond to computers as if they are people. People are “attributing personalities, motivations and attitudes to inanimate devices, even if the interfaces are not specifically designed to be anthropomorphic” [102]. This finding is in line with research that suggests that simple non-anthropomorphic support avatars can be beneficial for health interventions [51].

With this newfound knowledge, we decided to use a picture of a robot (see figure 4.1 as an avatar for our intervention. We named our avatar “Josef”.

We picked this particular picture of a robot because it matched the positive and supportive

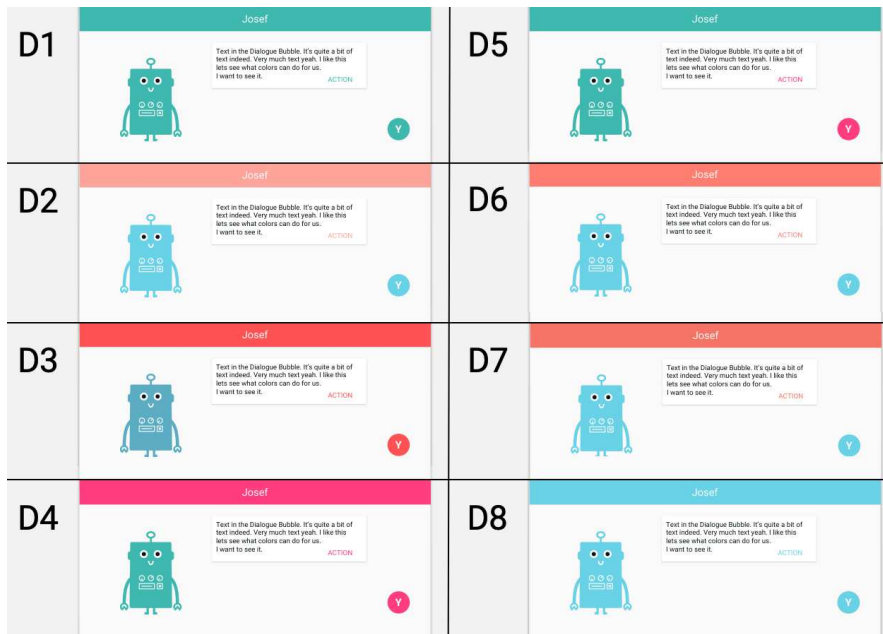


Figure 4.2: Color variations for Josef

theme of our intervention. It looks friendly and simplistic for a robot. This distinct lack of sophistication in the robot was an essential choice because, for our intervention to be persuasive, we did not want to stress the fact to users that they are doing therapy sessions. Josef makes it clear in one of the first dialogues we designed that it is a simple and friendly robot that aims to help users in its limited capacity.

A choice of a human avatar, on the other hand, might have highlighted the relation to a therapy session more prominently and might have conveyed a false sense of complexity, understanding, and professionalism. This wrong expectation, which our intervention cannot reasonably fulfill, would hinder persuasiveness.

Our goal for Josef was to make the avatar persuasive and relatable, which, as mentioned, is one of the innate psychological needs defined by SDT.

Color Selection

We created eight color variations for our primary UI elements. Next, we gathered feedback from seven students matching the target group. We explained our intervention's theme to them, showed the design to them one after the other, and asked them to make a first and second choice for the color theme.

Table 4.2 shows the ranking of the choices. Since design number 8, a bright blue color choice, got picked most often, with three students making it their first choice and two students voting it as their second choice, we decided to use it for Josef. Participant choice of color coincided with our intervention theme also from the perspective of the effects of color on emo-

Student	# 1st Design Choice	# 2nd Design Choice
S1	D3	D8
S2	D3	D6
S3	D5	D8
S4	D8	D5
S5	D5	D2
S6	D8	D4
S7	D8	D2

Table 4.1: Color design choices

tion, where Blue is associated with emotions such as “secure/comfortable” and “tender/soothing” [103].

Design	Sum of 1st Choices	Sum of 2nd Choices
D1	0	0
D2	0	2
D3	2	0
D4	0	1
D5	2	1
D6	0	1
D7	0	0
D8	3	2

Table 4.2: Ranked color design choices

4.2 Josef’s Motivational Interviewing Dialogue System

The last sections have given insight into our choice of the avatar’s visual representation, a picture of a robot. Now, we will discuss how we designed the primary interaction with our technological intervention—a dialogue. The main challenge in this step was to create a faithful mapping of an MI therapy session to a technological behavior change intervention. Especially with our background in software engineering, we had to take great care to make this transition.

First of all, we revisited the conversation style used in MI, a “collaborative” conversation style for strengthening a person’s own motivation and commitment to change [104]. At its core are principles of partnership, acceptance, compassion, and evocation, which are supported by processes of engaging, focusing, evoking, and planning. These are applied in practice in using communication skills such as asking open questions, affirming, reflective listening, summarizing, and informing/advising [104]. As previously discussed in section 2.3, these strategies are argued to fulfill the basic psychological needs as defined by SDT. That is, the need for competence could be furthered by strategies to explore and build confidence, autonomy by allowing clients to discover their own reasons for change and relatedness by being compassionate [64].

Bringing this concept back to our intervention theme, and to further try to bridge the gap between fields, we have looked at this approach from the perspective of persuasive strategies [105]. We have categorized our intervention as follows:

- **Non-Authoritative:** Persuading the user through a neutral agent such as a friend, who encourage the user to meet their goals, rather than a strict personal trainer or authoritative figure like a therapist.
- **Cooperative:** Persuade the user through cooperating and teamwork, in our case with Josef, rather than by competition.
- **Intrinsic:** Persuade the user through internal motivators such as feeling healthy, rather than external.
- **Positive Reinforcement:** Persuade the user by adding a positive stimulus, rather than by removing an aversive stimulus.

With the general theme set from the perspective of MI and persuasive strategies, we continued to build our actual dialogue. The Motivational Interviewing Treatment Integrity [106] was our main source in this step. It is used to determine how well or poorly a practitioner using motivational interviewing is doing by using scales to score Evocation, Collaboration, Autonomy/Support, Direction, and Empathy [106]:

- **Evocation:** The extent to which the clinician conveys an understanding that motivation for change, and the ability to move toward that change, reside mostly within the client. The clinician focuses efforts to elicit and expand this motivation within the therapeutic interaction.
- **Collaboration:** The extent to which the clinician behaves as if the interview is occurring between two equal partners, both of whom have knowledge that might be useful in the problem under consideration.
- **Autonomy/Support:** The extent to which the clinician supports and actively fosters client perception of choice as opposed to attempting to control the client's behavior or choices.
- **Direction:** The degree to which clinicians maintain appropriate focus on a specific target behavior or concerns directly tied to it. Unlike the other scales, high scores on this scale do not necessarily reflect better use of MI.
- **Empathy:** The extent to which the clinician understands or makes an effort to grasp the client's perspective and feelings. Literally, how much the clinician attempts to "try on" what the client feels or thinks.

We have used this scoring system to judge our decisions, especially in terms of the actual wording of each dialogue. It is worthwhile to look into them more closely from a general perspective on how our intervention can potentially work as an MI practitioner.

With an inherent lack of emotional understanding of answers, we will have to focus our efforts towards *Evocation* on the clients as intended by the scale. This impediment is where using reflection provides ample opportunities. Letting clients reflect on their thoughts, opinions, experiences, or even past sessions could help to evoke motivation to change in our users.

Looking at the theme of our intervention, the persuasive strategy we follow, and the scale of *Collaboration*, our approach of Josef as a cooperative and collaborative agent instead of an authoritative is very fitting.

Especially commercial interventions often actively provide suggestions to users for increasing their PA behavior, such as showing how many steps to take or that they have a 5km run planned for tomorrow. We have already criticized that approach in section 2.2. Proceeding in this way would rate low on the scale of *Autonomy/Support*, where actively fostering the client's perception of choice is the goal. Again, structuring the intervention to offer users the opportunity for reflection seems straightforward here. In section 3.6, we have discussed how structured support or guidance of reflection is of value. With our design of the dialogue, we will help users find out if and how they want to change their behavior, instead of restricting them to pre-defined paths.

This mentioned structure is our primary influence on *Direction*. We will need to design the dialogue loose enough to avoid feeling restricting, while at the same time working with a predefined and programmed flow that users will follow towards changing their PA behavior.

Empathy will be the greatest challenge for us because our technological intervention has none. All empathy our agent will show will be because of how our users interpret and perceive Josef and project understanding onto an artificial agent. Our dialogue design must leave space, or even facilitate, for such moments to take place.

Now that we have looked at how we can judge our intervention as an MI practitioner, we can continue working towards the concrete dialogue structure of Josef. In this endeavor, the various motivational interviewing resources from the “Motivational Interviewing Network of Trainers” [107] were a good source for us to find “good” dialogue options and concrete examples of phrases therapists use. These were especially helpful because our confidence could be high that we are creating a faithful implementation of an MI therapy session dialogue. In particular, the Motivational Enhancement Therapy Manual (METM) [108], a clinical research guide for therapists treating individuals with alcohol abuse and dependence, was of use since it provided us with an example of MI therapy lasting multiple sessions.

Dialogue Wording and Sequence in Detail

This section so far has shown what approach we used to judge our choices when building the dialogue system. We will now present a choice of principles and examples from the METM [108], and our translation of them to a technological intervention with dialogue sequence and wording.

First of all, MET structures therapy into four sessions which are based on the phases of the therapy:

- Phase 1: Building Motivation for Change

- Phase 2: Strengthening Commitment to Change
- Phase 3: Followthrough Strategies

Especially because phase 3 can use strategies from phases 1 and 2 to renew motivation and redo commitment, we decided to focus on the first two. We would implement two sessions for phase 1 and 2, and leave the option to redo the same two sessions for the future if a followthrough is needed.

First Session

The *first session* would be designed to help the clients begin to elicit thoughts, ideas, and plans for what might be done to change their behavior. Depending on how far towards determination to change their behavior our users are, it would be possible and desirable for them to elicit self-motivating statements.

In this session, we want to communicate expectations for the approach and communicate the free choice of the client. Some clients will come with the expectation of being led step by step through a therapist-directed change process. We will want to set clear expectations from the very beginning and give a persuasive explanation of our approach. Luckily, the METM had an example wording, which we have rephrased to our purpose and separated into the following dialogues, which the user confirms to proceed to the next one:

1. Hi, I'm Josef. I'm programmed to work with you on your physical activity behavior.
2. Before we begin, let me just explain a little about how we will be working together.
3. My circuits are very limited. I hope that I can help you think about your present physical activity behavior and consider what, if anything, you might want to do.
4. What we won't do today though is to make an exercise plan. Today is all about helping you think about changing.
5. But if there is any changing, you will be the one who does it. Nobody can tell you what to do; nobody can make you change.
6. I'll be giving you a lot of information about yourself, but what you do with all of that is completely up to you. I couldn't change you if I wanted to.
7. The only person who can decide whether and how to change is you.
8. How does that sound? Shall we get started?

Especially the last utterance was an interesting design choice, because it offers a clear option to quit with a yes/no selection, highlighting the free choice of the client. If clients chose X (no) for the question, Josef would utter, "That's fine. I'll be here whenever you're ready." If clients proceed with the interaction, they get presented another choice of "Do you feel ready to think

about your physical activity behavior?" that allows them to proceed with the session or loop them back to the "... whenever you're ready" dialogue.

When continuing with the session, we followed the principle of eliciting statements about the consequences of action and inaction by asking several questions:

- How do you feel about your current physical activity behavior?
- What would be reasons for you to change?
- Think about what you just described. Why is this important to you?
- What would some of the benefits of changing be?

Next, to determine how far in the process the user is, we presented a scale that users could interact with to rate that aspect themselves, called the "readiness to change ruler" [109].

- On the following scale from 1 to 10, where 1 is definitely not ready to change and 10 is definitely ready to change, what number best reflects how ready you are at the present time to change your physical activity?

At this point, it is not especially important for us if the resulting value is high or low. Instead, it offers users an important opportunity to reflect and to elicit self-determined motivational statements. We programmed three different follow-up questions, depending on the last answer:

- Value 1: What would it take to move a bit higher on the scale?
- Value 2-6: Higher than one, that's good! Any ideas what might raise your confidence?
- Value 7-10: Why not lower?

Especially the choice of "Why not lower?" might be surprising, but is based on the principle that change is less likely to happen when patients express more sustain talk than change talk [110]. We have chosen those responses from active practitioners of MI [111], and "Why not lower?" prompts the patient to express change talk rather than sustain talk in comparison with "Why not higher?". Motivational Interviewing Strategies and Techniques validates this approach as "therapeutic paradox"—an effort to get clients to argue for the importance of changing by presenting them with unexpected contradictions [109].

The METM [108] mentions concepts of summarizing and recapitulating. They are used to repeat and summarize the client's self-motivational statements. Elements of reluctance or resistance may be included in the summary as well to prevent a negating reaction from the client. The goal is to allow clients to hear their own self-motivational statements once more. This concept goes hand in hand with our approach to support reflection.

Reflection is a core principle here because it allows us to convey understanding and empathy in a technological intervention lacking both. We solve this issue with design by intentionally creating mechanisms for reflection that carefully consider the problem space. Without reflection, our intervention would not be much more than a persuasive form to fill out instead of a persuasive

agent designed for the problem space. We use three main mechanisms to support reflection: recording user answers with reflection statements, automatic summaries, and manual written summaries.

As the basis for reflecting on one's answers, Josef records every answer a user provides and a pre-written reflection statement for that dialogue. These are the building blocks from which we can build automatic summaries and interweave past responses in future sessions. For example, our reflection statement for the answer to the question "What would be reasons for you to change?" was "Your reasons to change would be...".

At the end of each session, we show an automatic summary consisting of the user's answers and the connected reflection statements. This summary allows the user to look back on everything that was said during the session. Presenting participants with a concise overview that lets them read their answers in their own words could help them to take a step back and look at their behavior from a higher level.

- Let me play back some of the things you said.

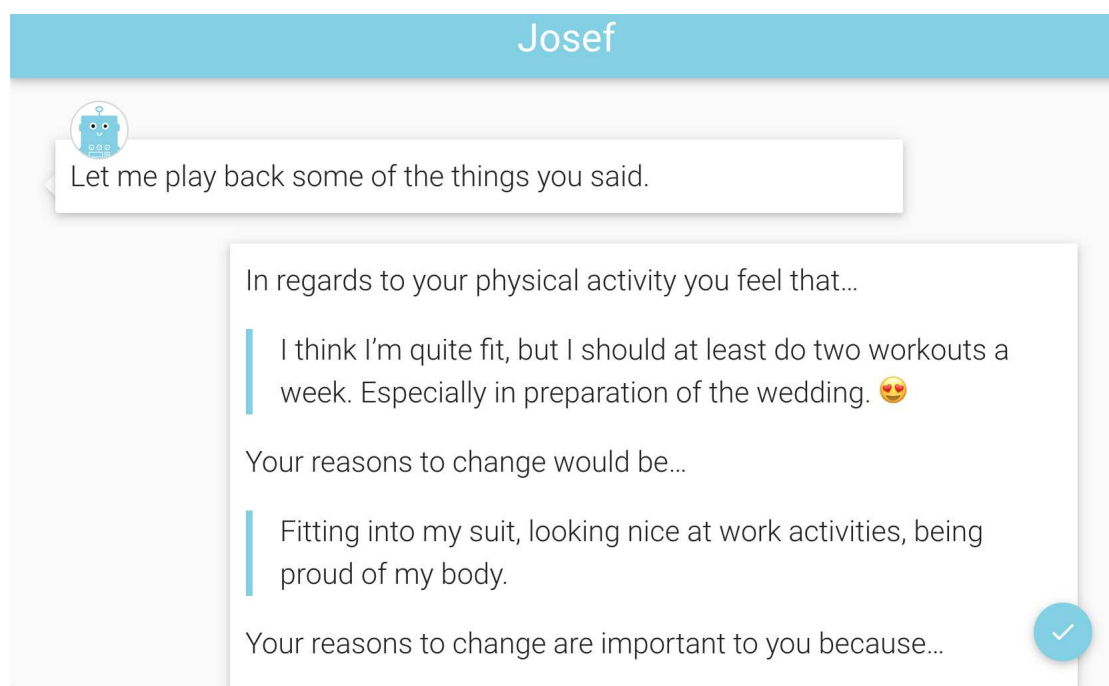


Figure 4.3: PC browser dialogue examples for the automatic summary

Right after the automatic summary, Josef asks participants to write a summary of the session in their own words, giving participants a chance to write down closing revelations and thoughts. Furthermore, this is Josef's way to avoid misinterpretation and is expected to not be too tedious for our users right after the automatic summary.

- How would you summarize what you've said?

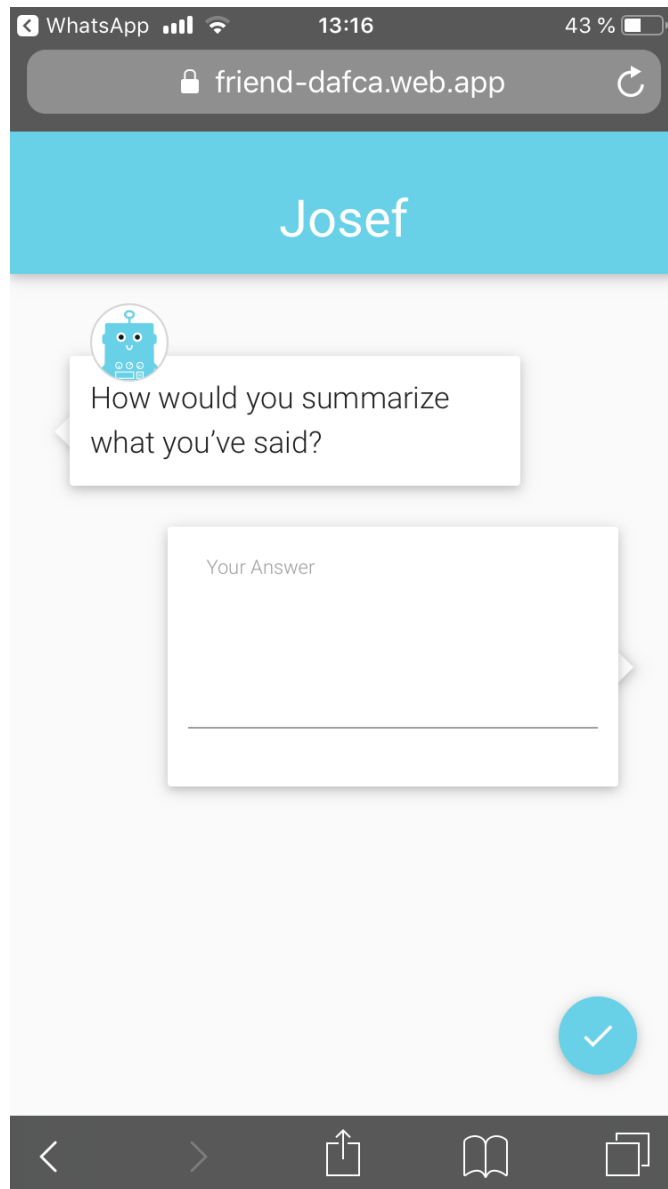


Figure 4.4: Smartphone dialogue example for the manual summary

After the manual summary, Josef asks the user for a good time for the second session, a dialogue we removed with the second prototype in favor of a fixed one-week period, and closes the first session on a positive note.

- Thank you for the effort you have shown today. Would it be useful to check in with me again to review how you are doing? If so, when?

- I appreciate the motivation you have put into this process today, and am happy to see you then!

Second Session

In the *second session* with Josef, we want to focus on phase 2 of MET, strengthening the commitment to change. We start by welcoming the user back and setting the user expectation.

- It's good to see you again! I appreciate the motivation you have put into this process so far.
- Today, I'll help you to think about your physical activity behavior some more, and how the first steps towards changing could look.

Next, we offer the opportunity for reflection by playing back the user's summary. We use it instead of the automatic summary to remind the user in his/her own words of the last session's discussion. This approach reduces the chance for participants to be alienated by Josef's lack of semantic understanding that might have occurred were we to present the automatic one. The manual summary helps to provide a starting point on what may have changed in the participant's thoughts and behavior since the last session.

The dialogue continues by giving the opportunity to reflect on the time since the last session, followed by more questions that follow the principle of eliciting statements about the consequences of action and inaction.

- How did your last days go in regards to your sports behavior?
- What would be possible negative consequences of not changing your physical activity behavior?
- Here's what you told me last time on what the benefits of changing would be for you.

In the last utterance, we play back the user's answer to the benefits question we asked in the first session, offering another opportunity to reflect. We use this interweaving of past answers whenever it furthers the goal of the dialogue structure. In this case, Josef asks for negative consequences of not changing the PA behavior. It then follows up with the benefits the user mentioned last time to get the participant to take a look at the negative aspects of sticking with their current behavior, before highlighting the positive aspects of changing their behavior. We then continue furthering a commitment to change.

- What would be a specific and achievable step for you that you could take to reach those benefits?
- On the following scale from 1 to 10, where 1 is definitely not ready to change and 10 is definitely ready to change, what number best reflects how ready you are at the present time to change your physical activity?

This time, when presenting the readiness to change ruler, we can look back on the response from the first session, and ask a more refined follow-up question depending on the user's answer in the following order of conditionals:

- Last Value 4-6, Current Value 1-3: So, it sounds like you went from being ambivalent about changing your physical activity behavior to no longer thinking you need to change your physical activity behavior. How did you go from a (Last Value) to a (Current Value)?"
- Last Value 1-4, Current Value 6-10: So it sounds like you went from not being ready to change your physical activity behavior to thinking about changing. How did you go from a (Last Value) last time to a (Current Value) now?"
- Last Value 1-8, Current Value < Last Answer: What would it take to move a bit higher on the scale?
- Last Value > (Current Value + 1): What one thing do you think would have to happen to get you back to the (Last Value) from last time?
- Last Value < Current Value: How do you feel about making those changes?
- Current Value 8-10: How do you feel about making those changes?
- All other cases: What would it take to move a bit higher on the scale?

This time, the answer to the scale does provide us with more information. Not only do we know where the user started in terms of readiness to change, but we also know their current situation. Preferably, if they were low on the scale in the first session, they will be higher on the scale in this second session. If they were previously high on the scale, we hope they still are. Regardless, Josef can react accordingly and help users dive deeper into the matter.

We close the session just like the first, by giving the automatic summary, requesting a manual summary from the user, and ending the session on a positive note.

- Let me play back some of the things you said.
- How would you summarize what you've said?
- I'm glad you took your time with me, and hope I could help you reflect and think about your physical activity behavior.

We have chosen to implement Josef with only two sessions mainly because phase 3 of MET uses the same strategies as session one and two. Because of the flexible wording we have chosen, further sessions could be designed with a similar approach with less effort.

Looking back over the dialogue options of the second session, it is apparent that we offer substantially more opportunities for reflection. This circumstance is caused by the need to gather data in the first session that users can reflect on in the second. Wise choices of when to offer a reflection opportunity on which topics and previous answers are what helps with keeping up the illusion of Josef as an agent with understanding, a topic we will take a closer look at in section 4.3. Next, we will take a look at the technological construction of the dialogue system.

Technical Design of the Dialogue System

A significant part of this work is to have a solid theoretical background for our behavior change approach. The actual technical implementation of the intervention as a technological intervention involves a diversity of design decisions and construction intricacies. The connection to this psychological grounding is rather complicated for some of these decisions. This circumstance might be one reason why explanations for them are often omitted. We consider it a crucial contribution to future work to exemplify those choices and will, therefore, give ours in the following.

Dialogue User Interface

Our intervention's dialogues require the capability to pose a statement, question, and a way for our users to respond. Early in this design phase, we were playing with the idea of allowing responses with different media such as voice recordings, photos, or videos, in addition to text (figure 4.5). For the initial prototype, we decided to use text only, both for the utterances of Josef as well as the response options. The main deciding factor was this decision was that for the evaluation of our intervention, text responses would be more favorable. Furthermore, a limitation to text input yields fewer technological requirements for the user's device (e.g., we do not even need a camera or microphone). Another advantage was that typing text would work in more settings and environments of our users than other media input, allowing for more ubiquitous use. That is, for example, one might still type sensitive answers when using the intervention in the subway, while not wanting to make a voice recording in the same situation.

Having decided on the input method, we proceeded with the concepts for various input modes we might need to translate our dialogues from section 4.2 adequately. Figure 4.6 shows us playing with different types of scales as well as a very intuitive agree/disagree input.

For the text itself, we decided to use the font "Roboto". Developed by Google, Roboto was mainly designed with geometric forms, but at the same time having friendly features and open curves [112]. Equipped with the sketches shown in figure 4.5 and 4.6, we created the following types of dialogue elements:

- Registrations: Input for registering for the intervention;
- Statements: Dialogue statements from Josef that do not require an answer.
- Yes/No Questions: Questions that users need to confirm/deny.
- Open Questions: Multi-line text answer possibility.
- Scales: Readiness ruler that can be moved on a scale from 1 to 10.
- Scale Response: A follow-up question depending on the readiness ruler scale answer.
- Automatic Reflections: Summed up responses of the session.
- Manual Reflections: Text answer possibility for the user to summarize the session.
- Single Reflections: Statements showing a past answer of the user.

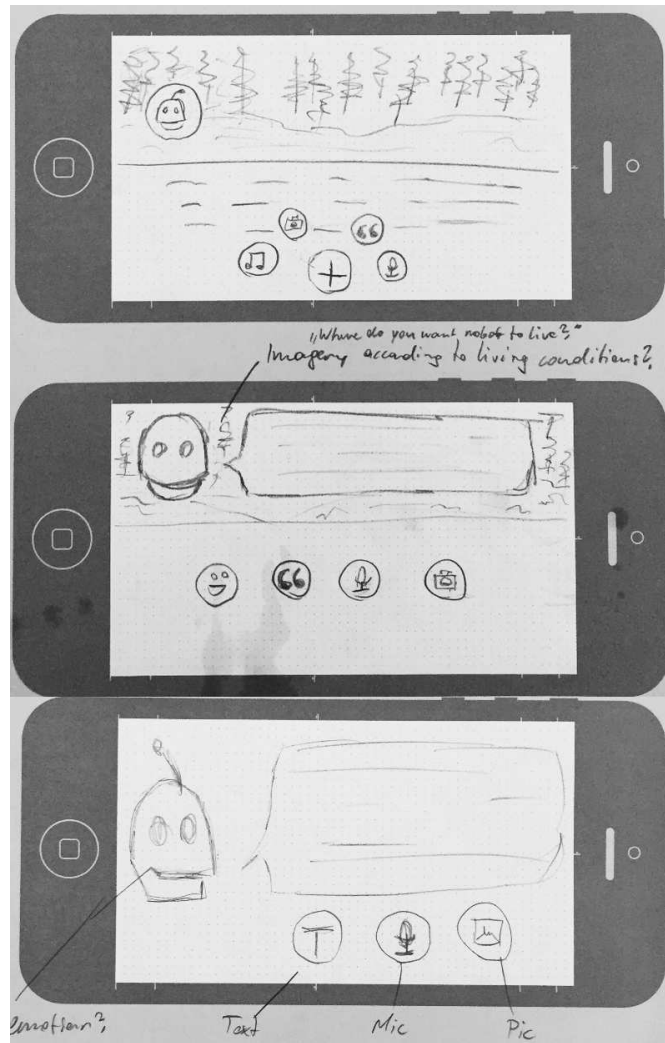


Figure 4.5: Playing with the idea of allowing input of different media types

- Date Questions: Allow for time and date input, e.g., for the date of the next session.
- Endings: Closing statements for a session.

User Response Design

We have shown our dialogue structure 4.2 as well as the dialogue elements 4.2 we designed as the technical realization of it. For multiple element types, we are asking for the user to respond. From an evaluation standpoint, closed questions would be favorable in these cases, since we can limit the response types to pre-defined ones. Furthermore, pre-determined answers would bring closer control of the flow through the intervention, allowing for more fine-grained reactions to

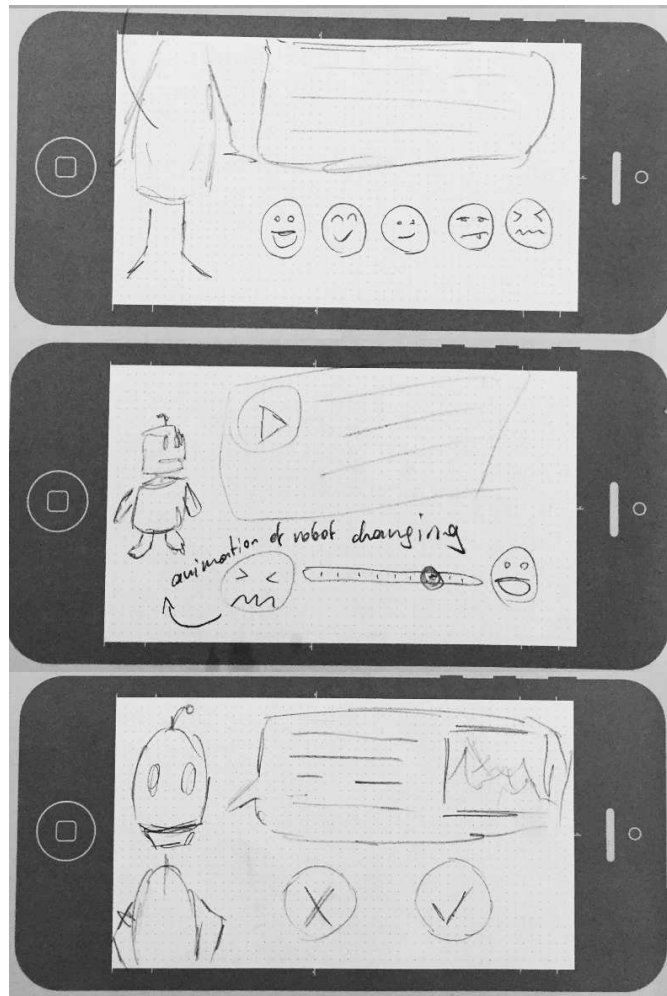


Figure 4.6: Concepts of input modes

the user's answers. I Move implemented this using a structured approach with multiple choice questions, although they underline the importance of asking open questions [64].

An important design decision during this phase was to leave ample space for responses to open questions since this approach is heavily used in MI [62].

MI makes particular use of open questions, those that invite the person to reflect and elaborate. Closed questions, in contrast, ask for specific information that can usually be offered as a short answer. In MI, gathering information is not the most important function of questions. In the engaging and focusing processes, open questions help to understand the person's internal frame of reference, strengthening a collaborative relationship, and finding a clear direction. Open questions also play a key role in evoking motivation and planning a course toward change. ([104])

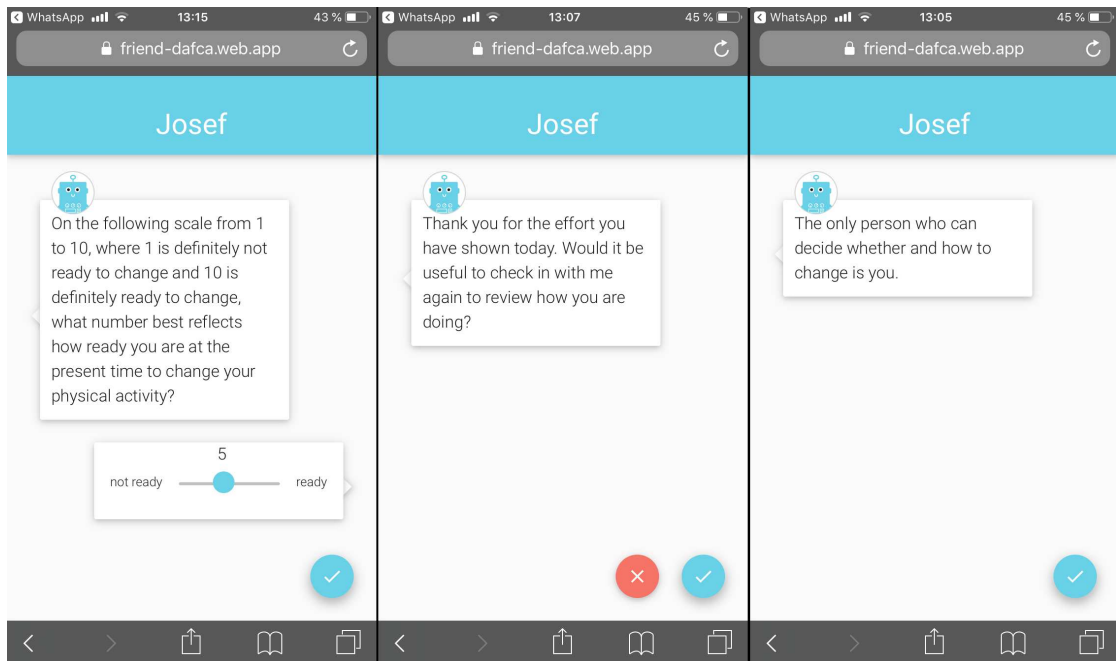


Figure 4.7: Smartphone dialogue examples for scale, yes/no and statement

Relying solely on closed questions might even be perceived as limited by the clients, as observed by Bickmore et al. [113].

I felt that she [relational agent] was programmed to answer. She was programmed to listen to the questions that you put on the screen. She would ask a question and I would have a choice, one, two, three, four. .. But I could never explain. Or she could never follow up, or follow through with another question. (In response to Response from a participant on freedom of expression in a constrained interaction [113])

For Josef, we accepted a lack of full understanding of a response to an open question in favor of inviting users to think about their answers in more detail and unrestricted direction. “The goal is to promote further dialogue that can be reflected back to the client by the therapist. Open-ended questions allow clients to tell their stories.”, as Sobell and Sobell put it [109].

To be able to simulate any understanding of Josef, we decided to record user responses to open questions in a distinct way that we could play back to the user. We pre-defined short sentences we call “reflection text,” which we used to show a past response to an open question to the user. This approach offered opportunities for reflection and provided direction. For example, the dialogue question “How do you feel about your current physical activity behavior?” would get played back in the automatic summary with our reflection text as “In regards to your physical activity, you feel that. . . (the user’s answer)”. We can further play back past answers of the user with our single reflection dialogue element, such as showing “Here’s what you told me last time on what the benefits of changing would be for you.” with the user’s past response.

With our intervention heavily relying on open questions, we were wondering if users would feel the urge to provide short answers to proceed. Such behavior would be adverse to our approach. Therefore, we decided to create a configurable minimum time-to-answer (TTA) in seconds for each open question with a default of 10 seconds. If a user tries to confirm input to an open question faster than the configured TTA for that particular question, Josef displays an additional statement of “Think about your answer. Is there something more that feels relevant to you?”. Users could still choose to continue to the next question after that without changing the initial answer. If users take time for each answer, they would never encounter this mechanism, but if they would try to rush through the answers, it would hopefully lead them to a more thoughtful frame of mind.

Technical Target Platform

In the last sections, we have structured the dialogues and designed their visualization. We have not yet defined the target platform of our technological intervention. The choices span from a pedometer, smartphone app, website, specialized machine in a lab to any combination of the above. We need to make this choice specific to the needs of our intervention. Two goals that match our intervention theme in regards to the platform are being as persuasive as we can and supporting ubiquity.

Smartphones, with their widespread use in people’s daily lives, come to mind when thinking about ubiquity [114] [19]. Apps have the potential for a wide range of uses such as clinical, preventive, public health, and rehabilitation settings [115]. Furthermore, the approach of using behavior change techniques in apps is effective and may serve as a tool to motivate smartphone users who have limited access to healthcare [115]. Offering our intervention as an app could further lead to exciting research results since there is a reported decline in adherence to app-based interventions - an issue we try to tackle with our work [116] [117].

In terms of *persuasiveness*, letting users taking part in the intervention on their phone could be of value. In particular, the mobility and connectedness a smartphone offers could help with influencing attitudes and behaviors by being available at the right time and context [37]. Smartphones are always available and responsive, resulting in high convenience that allows users to take part in our intervention in gaps in their schedules or other moments of downtime—moments where they may be open to interactive experiences that influence them.

Nevertheless, the role of smartphones in encouraging PA in regards to their effectiveness remains inconclusive [118], with many challenges still to be solved [20].

One reason why some interventions need to decide to run exclusively on a smartphone is the need for sensors that track PA. Since our intervention aims to work on a completely different approach, our device requirements are comparably minimalistic. Therefore, for Josef, we decided to create a *responsive web app*, allowing the intervention to be conveniently used both on a smartphone as well as a regular web browser on a PC or laptop. This inclusiveness is a “best of both worlds” approach, increasing the reach of our intervention and allowing our users to choose the platform that is most convenient to them at the time they choose to participate. They might start the first session on their smartphone and do the second on their PC, or any combination of the two.

4.3 Reflection in a Persuasive Artificial Agent lacking Empathy and Understanding

The last sections have shown how we constructed a dialogue system with the theoretical background of our approach in mind. It is now apparent that, while there are some conditionals and utterances that depend on the user's answer, it can be mostly statically programmed. This circumstance highlights the starkest contrast our technological intervention has to a human practitioner—Josef has neither semantic understanding nor empathy.

We cannot completely solve this issue in all its facets. However, we can attempt to help with suspension of disbelief by appearing like our intervention possesses these properties to a limited degree through careful design and knowledge about the environment of the intervention. Our most important choice for the topic at hand was to support reflection deliberately. The illusion of Josef as an agent with understanding is supported by carefully choosing the moments to offer opportunities for reflection on specific topics and previous answers. Our mechanism of offering automatic summaries, presenting reflections of previous answers of the user, and showing user-written summaries at opportune moments was deliberately designed with this goal in mind.

To understand the effect of these choices more closely, we need to look at the understanding of reflective listening, a core skill in MI [104], in a regular therapy setting.

Reflective Listening in a Persuasive Artificial Agent

In Kyle Arnold's look on Carl Roger's work on reflective listening [119], it is made clear that Roger's saw a mechanical repetition of what the client utters as a misconstruction of the technique. Instead, it should be a fully interactional conception of reflection of feelings where every reflection must include an implied invitation to the client to revise the perception of the therapist if it is not accurate. The goal, according to Rogers, is to ascertain whether the therapist's understanding of the subjective experience is correct [120]. Roger's further notes that the client will perceive accurate testing of understanding as reflections of his or her inner world [119].

Arnold concludes with a list of clinical recommendations, distilled from Rogers' work regarding the reflection of feelings. Note that in this context, reflections refer to the utterances of the therapist during reflective listening:

1. Reflections should be directed to the emotional essence of what the client has expressed, and to the client's felt sense of their emerging experiencing, rather than to particular issues.
2. Reflections must congruently implement therapist attitudes of acceptance and empathy.
3. Reflections are part of an empathic dialogue. Accordingly, they must include the implicit invitation for the client to check their accuracy with the client's inner felt experiencing, and to correct them if needed.
4. Reflections may be safest when sculpted out of material drawn from the client's remarks, and when they further develop insights that have already begun to emerge in the client, rather than referring to feelings and attitudes that the client has not yet expressed. However, if the empathic dialogue has advanced to the point that client and therapist are in

a shared, altered state of consciousness (=empathy trance), therapist understandings may emerge naturally as remarks that may appear unrelated to what the client has explicitly said.

5. To be in a position to effectively use reflections, the therapist may cultivate an empathic frame of mind. If this underlying attitude is absent, reflections may be incongruent and, therefore, are unlikely to be effective.
6. Reflections are best couched in provisional form, allowing the client to amend or reject them, rather than a declarative one.
7. Reflections should not interrupt the flow of the client's process.

While we cannot hope for this depth of reflective listening from our artificial persuasive agent, we can look for meaningful ways in which our agent can work. Our chosen theme and persuasive strategy are in line with 2) of the above list. First, showing our manual summary before allowing clients/users to write their own automatic summary allows them to make corrections as suggested by 3) and 6). We cannot do anything but using the client's own remarks as suggested by 4), obviating the risk to refer to something the client has not yet expressed. While our intervention, lacking a mind, cannot simulate an empathetic frame of it as suggested in 5), we can use structure to improve the congruence of the reflections made. A good structure further helps with supporting 7).

Design Decisions to Support Reflection with Josef

Section 3.6 has introduced the challenge of evaluating reflection and our approach of considering the purpose and conditions for reflection, the levels of reflection, and the dimensions of reflection. Now that we have given our design decisions in detail, we can take a closer look at them from this perspective.

Design Decisions	Aspect
D0 Chosen Purpose	Purpose of Reflection
D1 Multi-Platform D2 Structured Dialogue D3 Positive Mood, Encouraging Dialogue	Conditions for Reflection

Table 4.3: Design decisions with regards to the purpose of, and conditions for, reflection

Reflection can serve different purposes, such as empowering, supporting self-development, or helping with resolutions of uncertainty [68]. While each mechanic we introduced to further reflection might serve differently in this regard, we have introduced each one with a deliberate purpose in design decision D0.

Multiple design decisions were made to help with creating the right conditions for reflection. First and foremost, we decided to create Josef as a responsive web app with D1. While this decision has many advantages in regards to Josef's persuasiveness, as described in 4.2, the

platform is equally important in regards to reflection because its choice means our intervention is available whenever our users have time to reflect. Compared with a physical, planned, therapy session, or even a computer-based intervention on a regular desktop PC setup, this makes Josef incredibly flexible. A user can start a session with Josef 24/7, regardless of physical location, and can even pause a session to continue later.

Josef’s dialogue system, where the user is lead through a serious of dialogue questions, was chosen to provide the needed support for reflection in D2. The structure of the dialogue questions itself, given in section 4.2, provided the backbone for this by being open enough for the user to answer according to their needs, but closed enough to keep them thinking about their behavior. With the given flexibility of the responsive web app approach decided in D1, we hypothesized that Josef’s implementation as an responsive web-app could lead to succinct dialogue answers in certain situations. To encourage users to take a step back in such cases, Josef prompts them to *really* think about their answer in a mechanism we have described in detail in 4.2.

Decision D3 was influential mainly during the choice of the intervention theme as a positive and supportive one since this establishes the basis to provide users with a reason to reflect and encouragement to do so.

Now that we have given the design decisions regarding the purpose and conditions for reflection Josef supports, we can look into the design decisions to support the different levels of reflection.

Design Decision	R0	R1	R2	R3	R4
D4 Open Questions	X	X			
D5 Theory-Backed Dialogue			X	X	
D6 Playing Back Recorded Answers				X	

Table 4.4: Levels of reflection and their support by Josef

With design decision D4, Josef uses open questions in the dialogues, allowing for users to answer in-depth. For example, Josef might inquire, “How did your last days go in regards to your physical activity behavior?” instead of asking a closed question. While the user’s answers may be short answers without further elaboration, Josef encourages more in-depth answers by requiring users to take a specific time customized to each question. Josef remembers each answer, so it can be played back to the users when fitting the dialogue’s structure. Letting users answer the questions without restrictions, giving them the option to describe their thoughts and potentially evoking them to give reasons for their behavior falls into levels R0 and R1, and therefore lays the basis for higher levels of reflection.

We decided to base Josef’s dialogue and the used wording on SDT and MI in decision D5. Given the approaches described in MI, Josef’s dialogue is implicitly designed to guide the user through the process of reflecting and to help users to think about a topic and approach it from different angles and as such, can be categorized as dialogic reflection R2. Some of Josef’s questions prompt participants to think about fundamental questions. For example, Josef inquires, “What would be reasons for you to change?” before following up with “Think about what you just described. Why is this important to you?”. Such questions are designed to challenge personal assumptions and may provoke thoughts and answers for transformative reflection respective R3.

As a basis for reflecting on one’s answers, Josef records every answer a user provides, used in the mechanism of automatic summaries, manual summaries, and interwoven past answers described in detail in section 4.2, as part of decision D6. These mechanisms are used to reflect on previous answers.

Let us look at those mechanisms from a perspective of the levels of reflection. The automatic summary shown at a session’s end allows users to look back on everything that was said. Presenting participants with a concise overview that lets them read their answers in their own words could help them to take a step back and look at their behavior from a higher level.

Right after the automatic summary, Josef asks participants to write a summary of the session in their own words, giving participants a chance to write down closing revelations and thoughts. The summary helps to provide a starting point on what may have changed in the participant’s thoughts and behavior since the last session.

During a session, past answers are interwoven in the dialogue structure. Showing participants their previous answers in a new context serves the purpose of providing perspective, may lead to them having a basis to questioning their own, previous assumptions, and as such, is a design decision to further reflection on level R3.

We have not made a design decision to support level R4, critically reflecting on the broader implications. Reaching this level of reflection is reportedly very rare [26], and we decided to focus on helping participants to reach the lower levels of reflection.

In conclusion, we have adhered to Fleck and Fitzpatrick’s guidelines by stating a purpose for reflection, designed for providing the necessary conditions for reflection, and made design decisions to support participants with reaching higher levels of reflection.

Design Decision	Breakdown	Inquiry	Transformations
D4 Open Questions			X
D5 Theory-Backed Dialogue		X	
D6 Playing Back Recorded Answers	X	X	

Table 4.5: Support for the dimensions of reflection by Josef

Next, we will take a look at our design decisions from the perspective of the three dimensions of reflection, breakdown, inquiry, and transformation, as given by Baumer [71].

We have previously discussed how Josef asks open questions with design decision D4, instead of limiting participants to predefined answers. Baumer mentions that designing for transformations is hard; but, “A design, however, often embodies a particular (i.e., single) stance or conceptualization of a situation. Designing for transformation, then, requires that the design be at least comprehensible (and perhaps usable and/or useful) when approached with different conceptualizations.” [71]. Letting people answer Josef’s dialogue questions freely emphasized the point of having a design that can be approached with different conceptualizations. If participants let their mind wander while thinking about their answer, and feel that they should write something down that feels relevant to them, they can do so. Even while Josef asks questions with a particular stance and intention, users can comprehend them differently and answer them according to their own needs. Decision D4, therefore, makes room for transformations.

Our choice to have a theoretical basis and the particular theories we have chosen in decision D5 influenced the support for inquiry. Josef’s questions closely follow the principles of MI and help participants to think about particular aspects of their PA behavior. Doing so supports them in re-examining their existing knowledge about a specific topic, one that they might not consciously think about if not asked directly. This approach helps them to form hypotheses for their behavior, an essential step for the dimension of inquiry and opens up further opportunities with design decision D6.

We have discussed how Josef records answers and plays them back to users by interweaving previous answers and by showing automatic and user-written summaries with design decision D6. Once a participant has formed hypotheses in a previous session with Josef, they can be reviewed, tested, re-examined, or revised when Josef displays them during follow-up sessions, important steps involved with inquiry. Josef shows past answers to questions if they are relevant for the dialogue’s structure. This design resembles a reference example Baumer gave for inquiry—a collaborative civic design described by Arias et al., which includes a reflection space for “present[ing] information related to the problem at hand for exploration and extension” [71] [121]. Baumer presents ConsiderIt [122] as another example in the context of inquiry, a system that shows statements either supporting or opposing state ballot measures and the arguments to support those statements. Josef’s dialogue follows this idea by approaching topics from different angles, such as asking for possible benefits of changing behavior in one question, and possible negative effects of changing behavior in another.

4.4 Technical Prototyping

The reasoning supporting our technical implementation is defined, and we have looked at the involved decisions in detail. We can now introduce our efforts to translate our behavior change intervention into an actual, usable, technical system. This endeavor involves the choice of technical platforms, programming languages, frameworks, data persistence, and network communication.

Especially because our work contributes in a setting where multiple fields contribute, such as psychology and computer science, we need to present the technical implementation of our behavior change intervention.

Platforms, Programming Languages, and Frameworks

The most influential decision in regards to the creation of our prototypes was the choice of platform, given in 4.2. Supporting multiple platforms could mean creating the same software in multiple programming languages as native implementations. Such a scenario could involve, e.g., PHP for the website, Swift for the iOS app, and Kotlin for the Android app. Even in this setting, platforms with negligible market share such as Windows Phone [123] or BlackBerry [124] would be excluded.

We have previously mentioned the lack of technical requirements for our intervention. This circumstance is helpful in this effort because we do not need low-level features specific to a platform or system. Any up-to-date browser can fulfill our needs. This circumstance means

we can use any programming language with which we can create a fairly regular website. In recent years, JavaScript (.js) has gained enormous popularity in that sector [125]. The learning curve of modern JavaScript development is rather involved [126], with a high number of related technologies (see figure 4.8). It requires tangential knowledge such as HTML, CSS, frameworks, package managers, build tools, testing, and possibly even a technological stack of backend development. Nevertheless, this combined knowledge is not uncommon in modern web development.

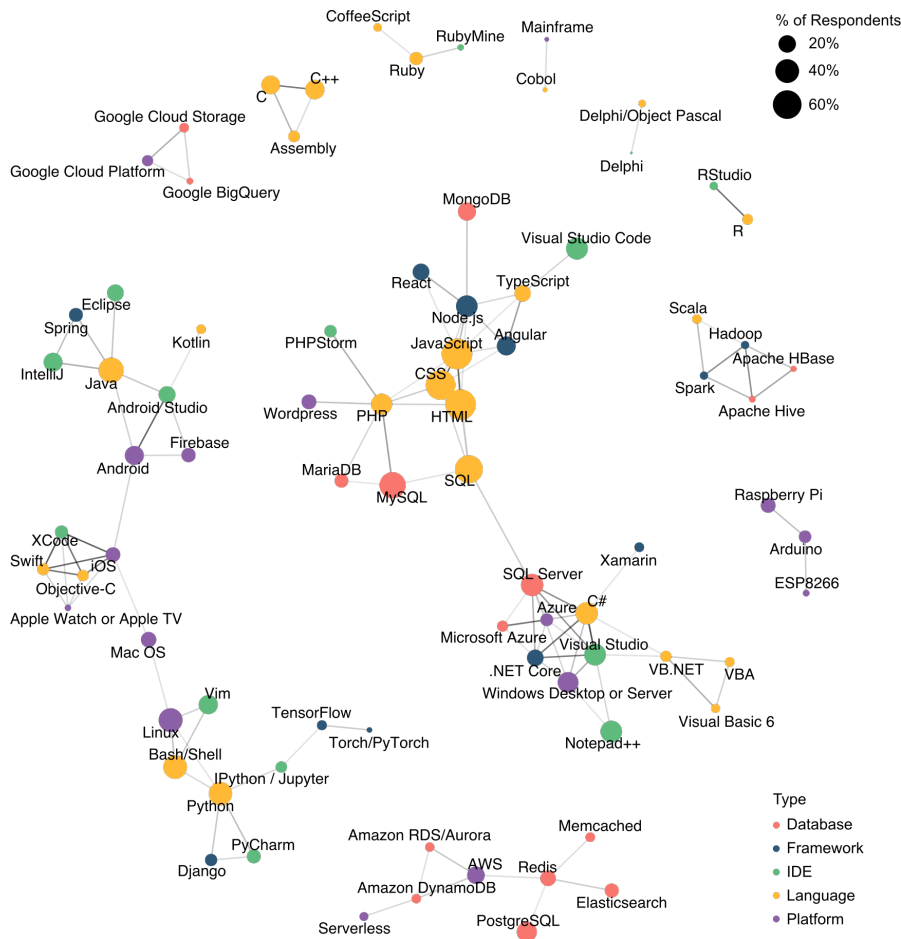


Figure 4.8: Connected technologies from the 2018 Stack Overflow survey with $\geq 100,000$ respondents [125]

We chose JavaScript because it runs in almost any browser, and therefore platform, has an exhaustive choice of popular and well-documented *frameworks* and acceptable tooling. Software frameworks are abstractions providing generic functionality that we can use and change to write application-specific software [127]. They promised efficient development of prototypes and allowed us to be able to create a server backend in the same programming language if needed, reducing friction.

During the decision process, we have built prototypes using *Ember.js* [128] and *volt* [129], before settling for *React.js* [130] for the frontend implementation. This choice was supported by the sheer amount of documentation and programming examples the React ecosystem offers, helping with faster development cycles. Furthermore, React works well in symbiosis with state management technologies, an important factor for our intervention, which will discuss in the following.

Data Persistence and Network Communication

Persistence for our intervention deals with saving the progress of our users, even if they “go away” in-between sessions, e.g., by backgrounding the app or closing the website. Our intervention’s primary data to be saved is the progress in the dialogue system and the related answers. The dialogue system itself is a deterministic finite state machine, meaning that from each current state (and dialogue), we have precisely one state to transition to (next dialogue) for every user input.

This concept works well with *Redux*, a state container for JavaScript apps. Redux advertises itself as being predictable, centralized, debuggable, and flexible [131]. In our case, especially the first two properties are of interest to our dialogue system. Redux, in turn, works well with React [132].

With Redux, our application state is stored as a single object. Modifying that object is done with actions, which describe *what happened* [133]. The *reducer* determines how actions change our application state. In its essence, the reducer takes the current application state, applies the action, and returns a new application state. We have given the core of our intervention’s reducer in listing 4.1. We have actions for handling dialogues, such as setting all dialogues at the application start, for proceeding to the next dialogue, answering a dialogue, and showing another remark in the same dialogue. Furthermore, we have actions for user management, such as registering and logging in.

```

1  let nextState = state;
2  switch (action.type) {
3    case "SET_DIALOGUES": // set the initial dialogues
4      nextState = setDialogues(state, action.dialogues);
5      break;
6    case "NEXT": // proceed to the next dialogue
7      nextState = next(state);
8      break;
9    case "ANSWER": // record an answer to the dialogue
10     nextState = answer(state, action.answer);
11     break;
12    case "FEEDBACK": // display another utterance in the same dialogue
13     nextState = feedback(state, action.feedback);
14     break;
15    case "REGISTER": // user registration
16     nextState = register(state, action.user);
17     break;
18    case "SIGNIN": // user login
19     nextState = signIn(state, action.user, action.data);
20     break;
21  }

```

Listing 4.1: Josef’s Reducer

We have given an example of an action in listing 4.2. Since the reducer uses it, the action has to modify the current state and return the whole application state. To make sure we do not change objects by accident, we used *immutable-js*. This library provides data structures that cannot be changed after creation, making it easy for us to move from one application state to the next without worrying about accidental mutations. The actual logic of the action is rather straightforward—first, it picks the first dialogue from the list of all outstanding *dialogues* as the current *dialogue*, and skips this pick in the next application state’s list of *dialogues*.

```

1  function next(state) { // state is an immutable-js Map
2    const dialogues = state.get('dialogues'); // an immutable-js List
3    return state.merge({
4      dialogue: dialogues.first(),
5      dialogues: dialogues.skip(1),
6    }); // the merged state is returned as a new object
7  }

```

Listing 4.2: Josef’s action “next” for proceeding to the next dialogue

Actions like this are easy to debug and test with a framework such as mocha [134]. A typical test case prepares the starting state, applies the action to test, and checks expectations against the resulting state, such as shown in listing 4.3.

```

1  describe('next', () => {
2    it('takes the next dialogue', () => {
3      const state = Map({
4        dialogues: List.of('Hi', 'How are you?', 'How do you feel?'),
5      });
6      const nextState = next(state);
7      expect(nextState).to.equal(Map({
8        dialogues: List.of('How are you?', 'How do you feel?'),
9        dialogue: 'Hi',
10     }));
11   });
12
13   it("takes the next dialogue even if a dialogue is in progress", () => {
14     const state = Map({
15       dialogues: List.of("How are you?", "How do you feel?"),
16       dialogue: 'Hi'
17     });
18     const nextState = next(state);
19     expect(nextState).to.equal(
20       Map({
21         dialogues: List.of("How do you feel?"),
22         dialogue: "How are you?"
23       })
24     );
25   });
26 });

```

Listing 4.3: testing the action “next”

Managing the state of our application in a predictable and centralized way in a single object does not automatically imply persistence. To that goal, we need to transfer the data to a system that saves it even after our application “goes away.” In fairly standard software architecture, we would have needed to create a backend software application, implemented an API (application programming interface), and saved data to a relational database. Instead, we decided to use the cloud-hosted *Firebase Realtime Database* [135] to persist our data. The choice was supported mainly by two factors. First, the data is stored as JSON, making it easy for us to save our

application data since it is kept as a single JSON object because of our use of Redux. Second, it is easy to synchronize data to connected clients on different platforms with Firebase Realtime Database. Since our users might choose to do the first session on their laptop, and the second session on their smartphone, this property was advantageous in our setting.

By virtue of this decision, our networking logic could be reduced to two small parts, circumventing the necessity of a custom backend implementation completely. Whenever an existing user appeared, we loaded the last persisted application state over the network, as shown in listing 4.4. Then, at the end of every Redux action that changed the user’s application state, we synchronized the complete application state with listing 4.5. We were considering if transferring the whole application state for all actions would cause issues, but have found no issues with that approach with the actual prototypes. For our implementation, this simplification kept the overhead of writing new actions to a minimum and allowed us to focus on the design decisions instead of networking technicalities.

```

1      // load data from firebase
2      firebase.database().ref('users/' + userId).once('value')
  
```

Listing 4.4: Synchronizing Application State for a User over the Network

```

1      firebase.database().ref('users/' + user.get('uid')).set(nextState);
  
```

Listing 4.5: Synchronizing Application State for a User over the Network

4.5 E-Mail Hand-Through Mechanism of Experiment EX2

In section 3.7 we have shown the structure of the second experiment *EX2*. One key challenge to potentially reduce drop-outs in *EX2* was to make users only enter their e-mail once so that we could match the data from questionnaires 1-2 and sessions 1-2 of the same user. Having to re-enter the e-mail address would potentially cause them to enter different addresses in each step, especially when considering the one week break between sessions, which would lead to data we could not properly connect to the same user anymore. To prevent this, we used Typeform [89] for our questionnaires.

Typeform allowed us to redirect to a website with an HTTP query parameter containing previously entered data. We used this to feature to pass along the e-mail the participant entered at the end of the questionnaire, e.g., “https://josef-study.com?email=REMEMBERED_MAIL”.

Our intervention detected that parameter, and automatically registered a user for it behind the scenes, joining together the data of questionnaire one and prototype session one. The same mechanism was used to invite users for prototype session two, this time with a similarly structured link in the e-mail. At the end of prototype session two, users would click a button that redirected to a questionnaire using Typeform’s “hidden fields” feature, which can take input data from an HTTP query parameter, e.g. “https://josef-study.typeform.com/BeEf?email=REMEMBERED_EMAIL”. This mechanism tied together prototype session two with questionnaire two and therefore allowed us to merge data throughout the experiment.

As a safety precaution, we further added an error-mechanism that would get triggered in case a user visited the intervention web app without an e-mail. In that case, we would prompt users for their e-mail and forward them to the appropriate state in the study.

A further hidden complexity of this approach was that users were registered by e-mail behind the scenes. They could potentially use different devices (smartphone, tablet, PC) for sessions or take breaks during a session. To provide users with this flexibility, we had to consider three variables: device used, e-mail provided in URL, previous session found. This combination of variables resulted in 2^3 possible authentication scenarios we had to consider and implement.



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CHAPTER 5

Findings

In section 3.7, we have given an overview of our research approach and detailed its implementation in the last chapter. Now, we can present the results from experiments *EX1* and *EX2* to state our findings. We will first present the experiment demography, before detailing our findings in regards to SDT & MI, reflection and persuasiveness, as well as the possible relationship between those fields we observed.

5.1 Participants & Demography

The first experiment *EX1*, where we did qualitative interviews, was conducted with 6 participants given in table 5.1.

Alias	Gender	Age
Participant A	m	25
Participant B	f	29
Participant C	f	26
Participant D	f	30
Participant E	m	28
Participant F	f	24

Table 5.1: Participant table, experiment EX1

For our second experiment *EX2*, visualised in figure 3.5, it was easier than expected for us to find participants. We even noticed that “word of mouth” seemed to be happening, with new participants joining in even without us taking any further action. We tracked 197 visitors on the first questionnaire, with 94 (48% of visitors) visitors completing it, becoming participants in the study. Ninety (46% of visitors) participants started the initial prototype session, and 75 (38% of visitors) completed it, receiving our e-mail to ask them to continue with the experiment a week

Variable	N	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
Age	94	29,638	0,914	8,860	15,000	23,000	29,000	32,000	62,000

Figure 5.1: Statistics for participant age, experiment EX2

later. To our surprise, the overall completion rate was much higher than we expected, with 39 (20% of visitors) participants fully completing each step in the experiment.

The mean age of our participants was 29.6 (see 5.1). 51% of them identified as female, 46% as male, and 3% as non-binary/third gender or preferred not to say.

As for the choice of device for the first questionnaire, 71% of the participants were using a mobile phone, 26% a PC, and the remaining 3% a tablet or other device. This ratio shifted slightly in the second questionnaire, where 61% of the responses were coming from mobile phones, 38% from a PC, and the remaining 1% from a table or other device.

We gathered responses from 20 different countries. The distribution was 49% USA, 19% Austria, 9% Canada and 23% rest of the world.

5.2 SDT & MI

In our analysis for SDT & MI, we take a closer look at the responses in regards to PA behavior and the motivation people show.

Of the 94 responses to the first questionnaire of *EX2*, 53% perceived themselves to be less active, 19% more active, and 28% as equally active as their peers. These results suggest a good fit of the respondents to our target group, as the social pressure as being less active than peers might contribute towards wanting to change that behavior.

Interestingly, when asked in a multiple-choice question what triggered respondents to start doing PA, 82% of respondents stated that their own motivation, surpassing habit or routine (48%) and friends and family (34%) as the most frequent choice. Wearables (7%) and apps (5%) were rather unpopular choices. It should be considered that the respondents participating will likely have had to show some motivation on their own to participate in this experiment in the first place, which could contribute to making own motivation the most picked option in this question. Nevertheless, this result may indicate that it is worthwhile to elicit more internal motivation as supported by SDT as a trigger to do PA instead of relying on other, external, mechanisms to trigger PA behavior, as it is an already present and frequent motivator. We would, therefore, interpret this as supporting our approach in this regard.

Our questions regarding PA, which we asked in the first questionnaire and again after the use of Josef in the second questionnaire, did follow the trend we intended. Participants had an increase in agreement with getting the exercise they need and considering PA worth their time as well as considering themselves good at their preferred PA. They also felt less pressured into doing PA. Except for a slight decrease in agreement with the statement that PA helps them to reach a personal goal, we did see support of the psychological needs proposed by SDT.

Question	Questionnaire	N	Mean	SE Mean	StDev
I get as much exercise as I need.	1	94	2.223	0.107	1.039
	2	39	2.410	0.167	1.044
Doing physical activity is worth my time.	1	94	4.148	0.0956	0.9270
	2	39	4.154	0.130	0.812
I think I'm good at my preferred physical activity.	1	94	3.245	0.108	1.044
	2	39	3.308	0.181	1.127
Doing physical activity helps me to reach a personal goal.	1	94	3.840	0.102	0.987
	2	39	3.744	0.150	0.938
I feel pressured into doing physical activity.	1	94	2.766	0.125	1.213
	2	39	2.564	0.190	1.188

Table 5.2: Responses to questions related to SDT & MI

Our measurements in that category did not yield statistical significance when doing a paired t-test analysis. The strongest candidates for statistical significance were changes in “I got as much exercise as I need.”, where the mean increased slightly in agreement from 2.231 to 2.410 with $p = 0.147$ and changes in “I feel pressured into doing physical activity.”, where the mean slightly decreased towards disagreement from 2.795 to 2.564 with $p = 0.277$. The first could be interpreted as respondents having made changes in their life where they feel closer to where they want to be in terms of exercise frequency, and the other showing a change in motivation from an externally pressured motivator to internal motivation. Since our experiment used a short one-week intervention usage period, these results could offer indicative data for future research targeting an extended intervention period, even if not showing statistical significance in our setting.

The same statistical insignificance held for the overall changes on the readiness to change ruler we employed, where people rated their readiness to change their PA behavior from 1 to 10, where 1 was definitely not ready to change, and 10 was definitely ready to change. Nevertheless, we found interesting correlations between the responses to the readiness to change ruler and our questions from the SDT & MI section. For analysis, we used Spearman correlation since most responses were to questions using a Likert scale.

For the *ruler in the first questionnaire*, we observed the strongest spearman correlation coefficient ρ between the ruler and “Doing physical activity helps me to reach a personal goal.” ($\rho = 0.441, p = 0.0007$) as well as “Doing physical activity is worth my time.” ($\rho = 0.400, p = 0.008$). When looking at these statements with relation to the theoretical background of SDT & MI, agreement to these statements suggests a stronger internalization of doing PA. Our results seem to support that stronger internalization correlates positively with readiness to change.

There is one further notable result for the question, “I think I'm good at my preferred physical activity.”. Even though it is meant to let us know more about the perceived competence of respondents, which is one of the innate psychological needs presented by SDT, we perceived a lower correlation of $\rho = 0.2435$ ($p = 0.034$) to the readiness to change. One perspective on this result might be that the competence in any present PA behavior is less important when considering readiness to change than it is when trying to maintain behavior. This interpretation would

be supported by our observed correlation between “I think I’m good at my preferred physical activity.” and “I get as much exercise as I need.” of $\rho = 0.517$ ($p = 0.000$) in the first questionnaire. Results seem to indicate that people feeling more confident in their current preferred PA are closer to their desired exercise frequency when starting with the intervention.

The *readiness to change ruler in the second questionnaire*, which was presented after the intervention, yielded the strongest correlation with “Doing physical activity helps me to reach a personal goal.” again ($\rho = 0.445$, $p = 0.005$) and we would again apply the argument that these indicate a higher internalization. In contrast to the first readiness to change ruler, we observed a slight correlation to “I get as much exercise as I need.” with $\rho = 0.367$, $p = 0.022$. Since we did not see that correlation in the first questionnaire, this could suggest that respondents got closer to their desired exercise amount with the intervention. However, the correlation is not strong enough to state this with confidence.

Another interesting correlation in the second questionnaire was the correlation of “Doing physical activity helps me to reach a personal goal.” with both “Doing physical activity is worth my time.” ($\rho = 0.531$, $p = 0.001$), and “I think I’m good at my preferred physical activity.” ($\rho = 0.408$, $p = 0.010$). These results suggest that if respondents consider the target behavior to further a personal goal, a facet of the innate need of autonomy, it also furthers other factors of internalizing that behavior. We consider this in line with our approach of supporting people to reflect and think deeply about their behavior since this might yield new goals or strengthen already present ones.

In summary, we did not perceive any statistically significant change in participants with a paired t-test analysis for answers of the category SDT & MI after a one week intervention period. These findings were unsurprising given the short intervention period. Nevertheless, our results from correlation analysis seem to support that stronger internalization correlates positively with readiness to change. We did further observe statistically significant correlations between multiple factors of this category, which provides new insight in which ways supporting one aspect of SDT & MI might have positive effects on another. Lastly, we noticed the importance of doing PA to further a personal goal and have given our perspective that reflecting on it is worthwhile. This relationship will be further detailed in the next section, where we analyze our results with a focus on reflection.

5.3 Reflection

The second questionnaire of *EX2* contained questions aimed at finding out in which ways Josef helped participants reflect on their PA behavior. We have given an overview of the related response statistics of the participants ($N = 39$) in table 5.3.

Overall, our design to create the right conditions for reflection seems to have shown the wanted results, with a strong agreement ($mean = 4.385$) to the statement “Josef encouraged me to think about my physical activity behavior.”. Nevertheless, the question “Josef helped me structure my thoughts about my physical activity behavior.” resulted in a neutral response ($mean = 3.154$). This outcome was unexpected since the whole dialogue system was designed to help respondents think about PA in a structured fashion. Nevertheless, respondents did not perceive their experience with Josef as helpful as anticipated in that regard.

Question	Mean	SE Mean	StDev
Josef encouraged me to think about my physical activity behavior.	4.385	0.125	0.782
Josef helped me structure my thoughts about my physical activity behavior.	3.154	0.189	1.182
Josef helped me find new reasons to do physical activity.	2.744	0.197	1.229
I have looked at my physical activity behavior from a new perspective.	2.923	0.189	1.178
Josef made me stop and think about my physical activity behavior.	3.538	0.220	1.374
I have considered new alternatives to my previous physical activity choices.	2.897	0.175	1.095
My attitude towards physical activity is still the same as it was before talking to Josef.	3.564	0.159	0.995

Table 5.3: Responses to questions related to reflection, sorted by order in which they were asked

For these responses to Likert scales, it is essential to consider that we move in the field of behavior change in regards to reflection. In section 3.6, we have presented the levels of reflection, where lower levels are prerequisites of higher levels of reflection, and higher levels are considered to be more reflective. We have further presented the three dimensions of reflection: breakdown, inquiry, and transformation. For the analysis, responses should be seen from that perspective, rather than to exclusively look for a mean value that is as high as possible, and to consider the theoretical background of the questions we have given in table 3.5. Since every response agreeing to a statement is indicating specific levels of reflection or dimensions of reflection, the respondent has potentially undergone considerable reflection and has a higher potential for a notable behavior change. Therefore, these results are meaningful even if a question does not have a high agreement rate on average.

Consider the histogram of the response to “Josef helped me find new reasons to do physical activity.” in figure 5.2. We would attribute agreement to this statement to the dimension of *Transformation* as well as reflection level *R3 Transformative Reflection*, indicating that a highly reflective thought process has taken place in respondents agreeing with this statement. So while the mean result of the respondents is slightly below neutral agreement, from $N = 39$ respondents, 12 were agreeing, and two people strongly agreed with that statement, indicating that they reflected intensively – our wanted target behavior.

We would apply a similar argument to “I have looked at my physical activity behavior from a new perspective.”, which is related to *R2 Dialogic Reflection* and the dimension of *Inquiry*, where 26% of the respondents agreed, and 8% or strongly agreed to the statement.

We could observe eight respondents self-reporting a change in attitude towards PA. In general, “My attitude towards physical activity is still the same as it was before talking to Josef.” showed a mean of 3.546, though, meaning that the more substantial part of the respondents did not change their attitude significantly. Since disagreement with this statement would show a very high level of reflection, *R3 Transformative Reflection*, this result is not surprising.

“Josef made me stop and think about my physical activity behavior.” got a favorable agreement with $mean = 3.538$. This result could support that Josef did affect participants in regards to the reflective dimension of *breakdown*.

Eleven participants agreed with the statement, “I have considered new alternatives to my previous physical activity choices.”. Furthermore, the follow-up question “I can envision myself doing one or some of these new alternatives.” yielded general agreement ($mean = 3.636$,

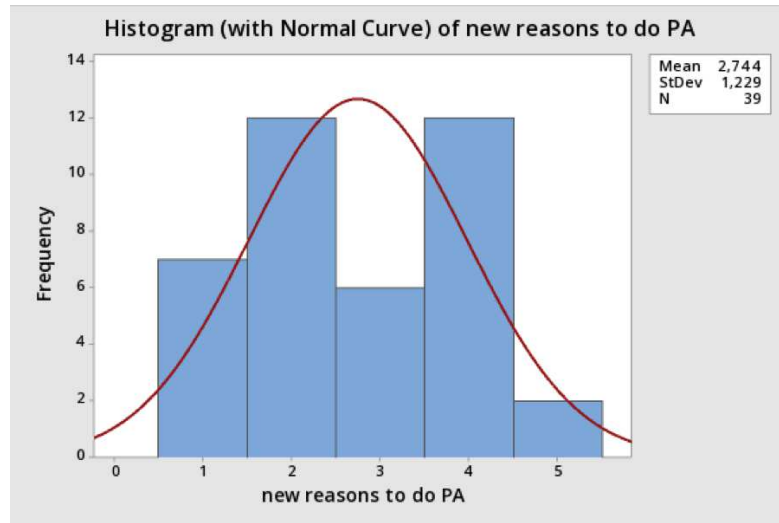


Figure 5.2: Histogram of responses to “Josef helped me find new reasons to do physical activity.”

$SE_{mean} = 0.338$, $StDev = 1.120$). We can conclude that we did support 28% of the respondents with the reflective dimension of *transformations*.

Doing a pairwise Spearman correlation, we observed multiple correlations between our questions regarding reflection. “I have looked at my physical activity behavior from a new perspective.” had the strongest correlation, showing a connection to “Josef helped me find new reasons to do physical activity.” with $\rho = 0.784$, $p = 0.000$, “Josef helped me structure my thoughts about my physical activity behavior.” with $\rho = 0.611$, $p = 0.000$ and “I have considered new alternatives to my previous physical activity choices.” with $\rho = 0.595$, $p = 0.000$. While the first is a correlation between questions indicating a higher level of reflection, the second is to conditions for reflection and the third to the reflective dimension of transformation. We interpret this as having supported both the levels as well as the dimensions of reflection with Josef successfully.

Our previous finding regarding a surprising lack of agreement in regards to the perceived support for structured thinking about PA was also noticeable in the correlation analysis. “Josef helped me structure my thoughts about my physical activity behavior.” showed a negative correlation of $\rho = -0.502$, $p = 0.001$ with “My attitude towards physical activity is still the same as it was before talking to Josef.”.

In summary, we believe in successfully having supported the levels of reflection, as well as the dimensions of reflection. Nevertheless, we were hoping to support a more significant number of participants in their reflective process, as some participants did not perceive the experience as helping them to structure their thoughts. For the participants where Josef seemed to work well, we did find that they reflected on higher levels and more dimensions than expected.

5.4 Persuasiveness

Question	Mean	SE Mean	StDev
How easy/hard was Josef (the robot) to use?	2.385	0.243	1.515
I liked Josef's appearance. (inverted)	4.103	0.141	0.882
Josef was supportive towards me.	3.333	0.144	0.898
I would have preferred discussing my physical activity with a human rather than Josef.	2.795	0.198	1.239

Table 5.4: Responses to questions related to persuasiveness, sorted by order in which they were asked

As for persuasiveness in *EX2*, all people that completed the intervention liked Josef's appearance. When inverting the score of "I disliked Josef's appearance." to our regular scale, we got an agreement of $mean = 4.103$, and not a single answer scoring below neutral. We conclude that our choice of the friendly little blue robot was the right one.

Respondents found Josef somewhat supportive, with $mean = 3.333$ in response to "Josef was supportive towards me.". Since we have chosen the interventions theme to be a positive and supportive one, we would have liked to see stronger results there.

We were happily surprised to see that "I would have preferred discussing my physical activity with a human rather than Josef." showed slight disagreement ($mean = 2.795$). We interpret this as having reached a target group that indeed found Josef the right way to think about their PA, rather than discussing the topic with another human. This result might be related to the stigma related to help-seeking from a mental health professional [136]. It could also mean that users expected the technical intervention to be a somewhat judgment-free environment, where there is no fear of any consequences to them. Participant C might have given a further hint to that reason during the qualitative interviews: "Well, if an app asks me to do it myself, I'll probably answer more honestly than if someone else says: 'How do you actually feel like regarding sports?', I'd say 'Well, hello, it's me. Great of course! (laughing)'". The result does provide more basis for the opinion that there is a target group for technical interventions that would not have sought out other humans in the same situation. If these interventions are designed and built correctly, they will make health advantages available to that target group.

Overall, people found Josef very easy to use, with the question "How easy/hard was Josef (the robot) to use?" scoring a mean of 2.385 on a scale from 1 to 10, where 1 was very easy to use. We can deduct that there weren't any usability problems skewing our results.

We did not see any significant correlation between the different questions within persuasiveness. The same was true for any effects of persuasiveness to the readiness to change ruler. However, there were significant effects on SDT & MI as well as reflection.

The easier respondents found the use of Josef (1 = very easy to use), the more they agreed to "Doing physical activity helps me to reach a personal goal." ($\rho = -0.639, p = 0.000$) after having used the intervention. The ease of use was further found to correlate with "I think I'm good at my preferred physical activity." ($\rho = -0.525, p = 0.001$). We would reason that the more persuasive respondents found Josef, the more goals in regards to SDT & MI were reached.

We observed a similar relation to reflection. The ease of use correlated with “I have looked at my physical activity behavior from a new perspective.” ($\rho = -0.530, p = 0.001$), and “I have considered new alternatives to my previous physical activity choices.” ($\rho = -0.499, p = 0.001$). Responses to the latter question also correlated with “I disliked Josef’s appearance.” ($\rho = -0.449, p = 0.001$). “I have looked at my physical activity behavior from a new perspective.” also showed a strong correlation of $\rho = 0.784, p = 0.000$ with “Josef helped me find new reasons to do physical.” It follows that the ease of use and likability of Josef’s appearance had positive affects on our goals for furthering reflection. Furthermore, gaining new perspectives on the target behavior with Josef is linked to participants finding new reasons to do PA, furthering autonomy of the behavior, and therefore internalized motivation.

We were aware of the importance of persuasiveness for digital health interventions. Nevertheless, we were surprised to see how much the ease of use and likability of Josef affected our results for the theoretical background we have chosen. It was worth the time to make our intervention more persuasive by doing an up-front usability test, allowing participants to use it on the platform they like (and even switch between them), considering responsive design, color choices, and the avatar.

We would go as far as to speculate that a lack of persuasiveness in an intervention might lead to wrongfully concluding that a mechanism did not work (false negatives), even though a lack of persuasiveness might have skewed the results. Consider the related work we have described in section 2.1, of which some were restricted to the possibilities at that time, like feature phones, unwieldy step counters, or working exclusively on a regular desktop computer. It could yield exciting results to create more persuasive versions of past interventions to compare results.

5.5 Response Analysis

A significant advantage of Josef over human therapists is that we can easily track detailed metrics for any number of respondents. We further have access to all answers in text, allowing for an analysis that would be very time-intensive otherwise. In this section, we will take a closer look at the metrics we have gathered, look at the general sentiment of our respondents and then combine the text answers from the second experiment *EX2* with our observations from *EX1*.

During the intervention use, we automatically tracked metrics that would allow us to see if users did contemplate their responses, or rush through without giving them much thought. Filtering for outliers ($N = 6$, time to answer > 450 seconds), which might have occurred if users did something else while keeping their browser window with our intervention open, we observed an average time to answer of 38.24 seconds (see figure 5.3). When considered together with our observation that respondents used an average of 11.7 words in their text answers (see figure 5.4), and the average usage time of 4.6 minutes per session, we can conclude that respondents did contemplate as intended.

For sentiment analysis of the responses, we used *sentiment* [95], a javascript library that does the analysis based on the AFINN-165 wordlist [137] and emoji sentiment ranking [138]. The *sentiment score*, displayed in figure 5.5, adds the score of each recognized word, with words connected to a positive sentiment having a positive value and words with a negative sentiment a negative value. The *comparative value*, displayed in figure 5.6, has a mid-point of 0 and

Statistics

Variable	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
time to answer	38,24	1,64	33,85	10,00	17,00	28,00	47,00	257,00

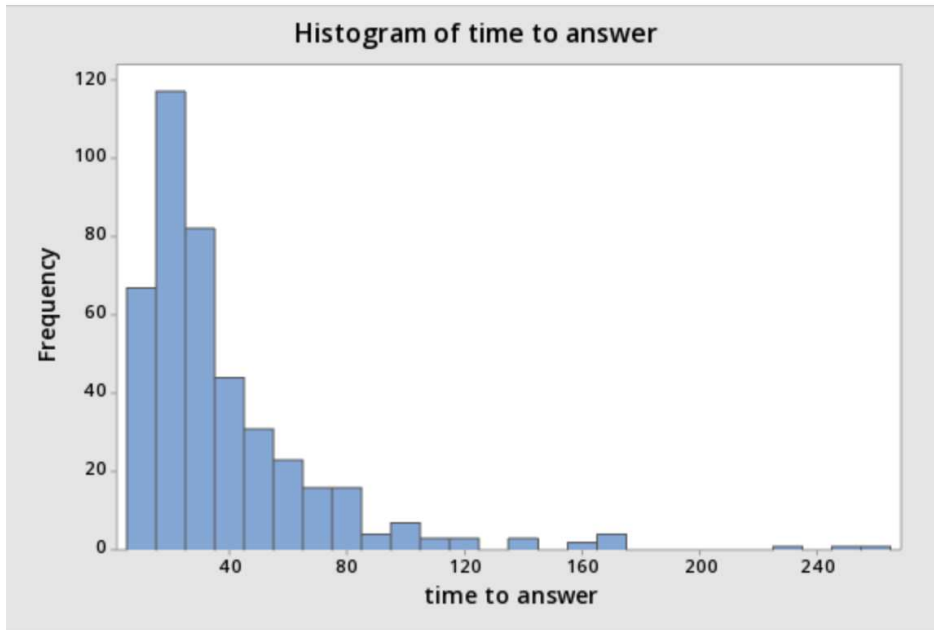


Figure 5.3: Time to answer in seconds

a constrained upper and lower bounds to be positive and negative 5 for positive and negative sentiment respectively. For example, the response “Feeling better, more motivated, stronger, improved quality of life.” had a sentiment score of 11 and a comparative value of 1.22, while the response “Currently, I do physical activity when I need to, and rarely otherwise. This is not so bad when work and errands keep me moving, but without those I just don’t exercise. I get too bored and give up, even though I want to be healthier. I am losing faith that I will find away around that problem, but am still searching for a solution.” had a sentiment score of -7 and a comparative value of -0.11 .

Overall, both the sentiment score and the comparative value showed results indicating a slight tendency towards a positive sentiment for text responses.

In figure 5.7 we have created a word cloud of the cleaned-up responses (i.e., the responses without common words like “I’m”, “I’d”, “I’ll” and “e.g.”, which are not useful as results in a word cloud) from EX2 using a publicly available word cloud generator [94]. In section 3.7, we have given our expectation to see contemplative and change words here, as well as words of positive and negative sentiment. Looking at the result, this held true with high occurrences of contemplative or change words such as “change” itself, “want”, “need” or “think”, positive words such as “good”, “better”, “motivation” and negative words such as “little”, “bad”, or

Statistics

Variable	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
words	11,716	0,485	9,934	1,000	5,000	9,000	16,000	67,000

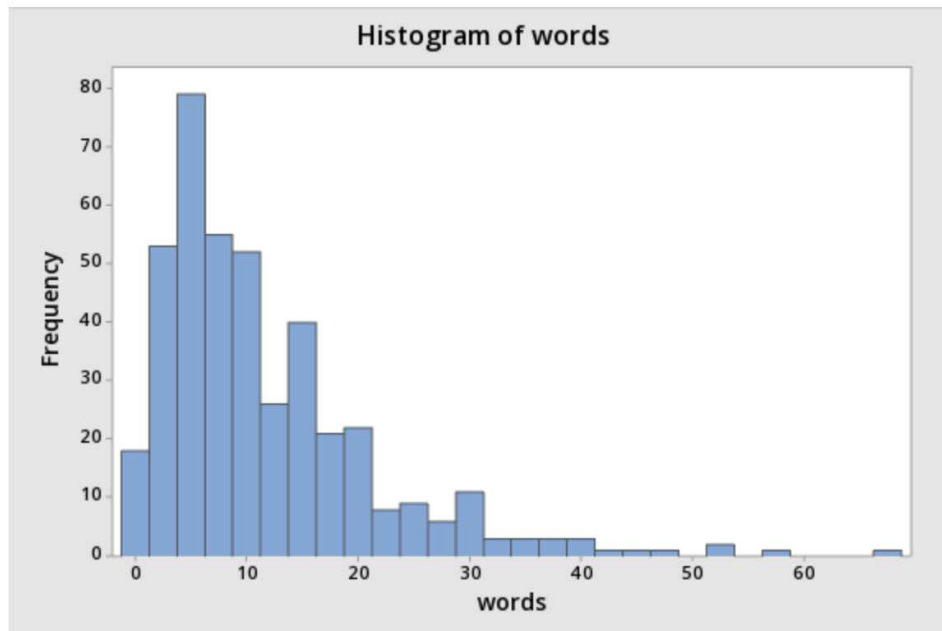


Figure 5.4: Number of words used in text answers

“can’t”. Overall, we see more contemplative, change, and positive words than negative words, which is in line with the results of the sentiment analysis and the goal of our intervention.

We have seen in the responses to the questionnaires that our target group preferred talking to Josef over talking with a human therapist. We would like to know in which ways the sessions with Josef can make the advantages of a therapy session with a human available to that target group. In section 2.3, we talked about how a computer-based intervention can work in ways that humans cannot (see section 2.3), but most prominently want to restate the advantage of scalability. Josef, even with the small scale of this work, has already been made available worldwide and used in 20 different countries.

Statistics

Variable	Mean	SE Mean	StDev	Minimum	Q1	Median	Q3	Maximum
sentiment_score	1,153	0,136	2,788	-8,000	0,000	1,000	3,000	12,000

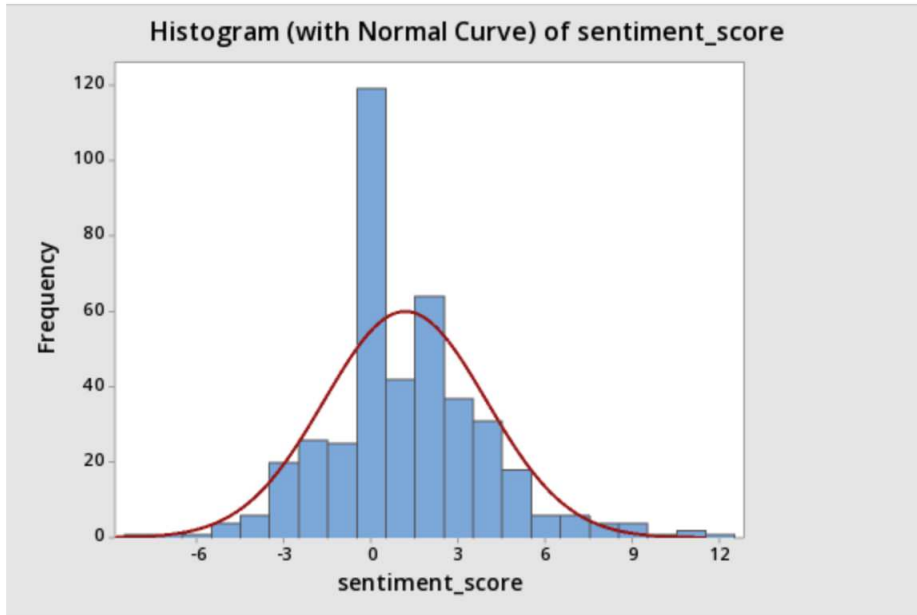


Figure 5.5: Sentiment score of sentiment analysis for text answers

Discussion

At this point, we can contemplate our findings to do a discussion regarding the ways in which our computer-based intervention Josef worked. Our research question considered the effects of components designed to further reflection in a computer-based intervention that aims to elicit long-term PA behavior change. In chapter 4, we presented our design decisions aimed at supporting reflection and described the components resulting from them in detail. Looking at our findings from experiment *EX1* and *EX2*, we have seen substantial indicators that these decisions did help respondents to reflect in terms of dimensions as well as levels of reflection. These results could provide new insights on how to support reflection with technology.

Our empirical trial of the combination of SDT & MI did not yield a statistically significant difference using a paired t-test analysis for questions of that category. Nevertheless, we observed statistically significant correlations that may provide knowledge about how supporting one aspect of SDT & MI might have positive effects on another. Furthermore, we have seen indicators that Josef elicited respondents to answer with positive, contemplative, and change words in their dialogue answers.

Josef avoided being perceived as judgmental, limited, or negative by being restricted to a static image of a robot lacking both animations and sound that communicated its goal, set clear expectations, and was designed to elicit a positive mood. Respondents found Josef to be likable and very easy to use. Even more so, respondents slightly agreed with rather having talked about PA with Josef than with another human being. In regards to our other fields of research, Josef's persuasiveness had a statistically significant effect. Answers to questions regarding persuasive design showed a strong correlation to questions for the fields of SDT & MI as well as reflection.

To consider implications for computer-based interventions that combine SDT & MI in addition to considering which components of Josef affected reflection, we will continue with a topic-specific discussion before looking at our intervention from the viewpoint of the performance objectives that we have given in section 3.2 to give a conclusive overview. The chapter's end will present a critical look at our work and point out its limitations.

6.1 Josef as a Therapist

If our computer-based intervention could show some of the same properties of a human therapy session, it could contribute to making the advantages of such sessions available to a larger and possibly different target group.

The Motivational Enhancement Therapy Manual [108], which draws from MI for the therapist style, describes the therapist as a blend of a supportive companion and a knowledgeable consultant.

As an avatar for the therapist, we opted to use a very minimalistic form – a picture of a friendly-looking robot, without sound or animation. The robot was designed in symbiosis with the colors and dialogue to have an overall positive, non-judgmental mood. For the response options, we opted to use open questions instead of multiple-choice or other forms of closed answers, allowing participants the possibility to interpret the questions to their needs and answer like they wanted, instead of feeling limited. Furthermore, to set expectations for respondents correctly, the robot Josef itself makes it clear at the beginning of the experiment that it is limited in many ways, rather than being a knowledgeable psychologist.

This choice of Josef’s visual design and dialogue-system avoided problems where participants might perceive the intervention not as smart or reactive as they would have expected from a human-like avatar, and therefore seemed to further suspension of disbelief. It seemed like participants filled the limitations of Josef with their imagination, making it more relatable to them. Participant F put it as follows during the qualitative interviews: “Yeah it’s quite nice, that makes it somehow human. Like, he looks like a little robot. Like,... with some things you have the feeling of being brainwashed. But here it’s somehow really human.”

Eliciting self-motivating statements is one of the core skills of an MI practitioner [24]. Our analysis of the interviews of *EX1* and text responses of *EX2*, which we have given in detail in section 3.7, yielded indicators that Josef achieved that goal, even as a computer-based intervention. Some example responses were, “I am tired of making excuses for myself and am ready to start living a more active life. I have gained 20lbs from being inactive and having a poor diet and am ready to stop this.”, “I want to make this happen.”, “I want to change because it would improve my life” or “Overall, I know that my physical activity levels are likely too low, and that continuing at this pace will likely not be enough to keep me healthy and physically fit through adulthood. I want to develop a better relationship with exercise and physical fitness in order to receive the physical and mental benefits of exercise throughout adulthood.”

In summary, Josef avoided being perceived as judgmental, limited, or negative by being restricted to a picture of a robot that communicated its goal, set clear expectations right away, and was designed carefully to elicit a positive mood. Although this was the result of deliberate design, it was surprising to see that a non-anthropomorphic avatar, a static image of a robot lacking both animations and sound, was received in such a positive way by respondents. We were glad to see that we even achieved one of the core skills of a human MI practitioner by successfully eliciting self-motivating statements.

6.2 Expressing Empathy and Reflective Listening

In the last section, we have outlined how Josef works as a therapist, even with just a picture of a friendly-looking robot, without sound or animation, and a dialogue system that allows the presentation of questions and records user input.

The METM states reflective listening as a key skill in motivational interviewing to express empathy [108]. For Josef, we had to find a way to appear like we could do reflective listening while lacking any semantic understanding of the user's answers. Our choice of relying heavily on open questions instead of closed questions was the main challenge in that regard because the responses cannot be unambiguously analyzed.

In chapter 4, we have presented our approach to tackling this issue by designing for reflection. One mechanism we used towards that goal were summaries. Miller and Rollnick put that mechanism in a nutshell by describing it as essentially being reflections that pull together several things that a person has said. They can be affirming because they convey understanding, and they can invite further exploration by shining a light on the client's experiences [139]. In the context of combining MI with SDT, Vansteenkiste et al. argue that summarizing is likely to have similar benefits as reflective listening in that they increase self-awareness, facilitating more autonomous decision-making [140]. Furthermore, summarizing is likely to produce similar benefits as reflective listening. Summary statements are used to link and draw together the material that has been discussed. Such statements also help to increase self-awareness, facilitating more autonomous decision-making. Stated differently, summarizing may help to facilitate the same integrative process that autonomy-support aims to facilitate, and present a pragmatic and dedicated way to do so [62].

Using the METM, we identified how summaries could be implemented in Josef. Summaries are useful, particularly toward the end of a session as an extended reflection of what the client has said. They should include self-motivational statements as well as elements of reluctance or resistance, to prevent a negating reaction from the client. The goal is to let clients hear their own self-motivational statements again.

Josef's summary-mechanism is threefold. Collective summaries of the client's answers in the given session are presented at the end of a session. Linked summaries are provided between questions to add to the dialogue, and client summaries are recorded at the end of the session to be played back in the next session.

In detail, the collective summary requires recordings of the client's every answer. In order to summarize at a later time, we record each answer with a pre-defined reflection statement. For example, the question "What would be reasons for you to change?" is recorded with the reflection statement of "Your reasons to change would be...". When later presented to the client, it is played back in the format "Your reasons to change would be... (the client's answer)". Each session's answers and reflection texts are aggregated and shown close to the session's end in a concise overview.

That (the automatic summary) was cool, too. Because you get to see whole summary of what you always think you should change on just one page. But here its summarized in a way like: „Hey, this is exactly why you think you, or this is exactly why you feel you should start to change and what the good things about that would

be.” And it’s summarized briefly and it makes you think like “Hey... look sharp!”
(Participant C)

So when I read over it I thought hey, I’m actually ready. And in the back of my head I seem to be already set on wanting to change. But yeah, not in the other head... But, that is cool, because you see yourself again. Summarized, as said before. (Participant C)

Linked summaries are used to “remember” relevant parts of what the client has said to link it to the flow of the current dialogues. For example, after asking about the possible negative consequences of not changing the client’s PA behavior, Josef provides a linked summary about what the client has told Josef in the last session about the benefits of changing would be in the client’s own words.

Lastly, just before Josef’s closing words, clients are asked for a summary of the session in his/her own words. This summary is the only one that is not fully automatic. While the collective and linked summaries are created during the session automatically, there is no automation in this step. Nevertheless, Josef presented the automatic summary just before that, making it a bit easier compared to coming up with a summary from scratch. The last summary gives clients the chance to summarize the session in a way they see fit and giving their own reasons. It offers them the choice to think back and write down their own thoughts and interpretations of what happened. This concept largely eludes the chance that they feel misrepresented or misunderstood by Josef. For Josef’s next session, Josef does not show the automatic summary – the client summary is shown. They get to see what they said themselves.

I think that’s really cool. Where he really shows you what you said last week. And, if I exercised during that time, and if I, let’s say, was really motivated and, I don’t know, it was great there or I exercised and then read „See what you’ve said last week.”, yeah, summarized. And if I would read that again now I would think „Yeah, I did it and I did what I said I would do!” and that’s positive. (Participant C)

That was good, because if I think about it,... for me it would be the end of the week and then I think it’s not bad to see „Hey, this is what I said last week.”. That was nice. (Participant D)

I think that was tricky with ‘How would you summarize?’ because I immediately wrote ‘I need to change!’ or ‘It’s time to start’ or ‘It’s time to change!’. Something like that. Because somehow... you really take a close look in the mirror and tell yourself - not somebody else tells you - you tell yourself ‘Look. You yourself said you want that, you’re ready and you want, you want and that’s good. And then you say “Well, what’s the matter? How do you summarize this?”. I like that because you not only get the mirror and the summary, it’s like ‘Well, what do you say? How do you summarize that?’. I think that’s great, because you’re already on the road and think ‘Yeah, that’s true.’ and then you’re taken by the hand and asked ‘Well, what do you say?’ (Participant C)

Looking at the responses from the second experiment round, we see clients using the summary in very different ways. Some leave motivational statements, others look deeper into potential barriers for changing their behavior, and some summarize their own reasons for doing PA. Example responses have been: “I’m very motivated to change and increase my work out routine to improve my overall physical and mental health.”, “Lets start:)", “I know I should change, I want to be more active, but I have never found a form of exercise mentally engaging enough to keep me coming back to it.”, “Need exercise routine, but migraines get in the way. Need exercise for less migraines.”, “Being active is important for physical, mental, and emotional health for me. I have been inactive for a while and am ready to have the benefits of a better diet, weight loss, and more positive outlook on life.”

Josef being a computer-based intervention, is relevant to the summaries themselves as well from another aspect. Miller et al. argue based on Truax that a therapist cannot reflect and summarize everything a client says [141]. Therapists choose to highlight certain aspects of what people say, and pass over others, consciously or not. This circumstance is not the same for Josef. Josef can reflect and summarize with perfect accuracy, his memory spanning all therapy sessions, for answers with effectively unlimited length. It can do that at any time, in every place, whenever the client feels ready for it.

He cannot, however, make a clinical judgment on what to reflect on and summarize. He can choose to present summaries and reflections of the answers to questions that are designed to elicit more positive aspects of change. However, he can not pick out certain aspects in an answer that a human therapist might have interpreted as most relevant.

To summarize, we argued in section 6.2 that Josef does not have any semantic understanding of the client’s answers. Nevertheless, we have shown how to scaffold for reflection through summaries true to the spirit of motivational interviewing. Client answers are recorded with pre-defined reflection statements to be played back as automatic summaries. Linked summaries are interwoven throughout the session at fitting moments in the dialogue-flow, and client summaries elude problems of misrepresenting or misunderstanding a client by offering reflections in the client’s own words.

6.3 Repercussions of Reflection

Josef was designed to elicit a positive mood throughout every session. Nevertheless, we did encounter negative responses both in the qualitative interviews as well as our text responses during reflection.

While reflection is treated as almost universally beneficial and even reflecting on negative experiences does have health benefits [142], Baumer et al. suggested a “dark side of reflection” where reflectiveness may bring with it unintended costs [70]. Reflection can involve a perpetual need for self-improvement that can lead to feelings of self-disapproval and self-rejection [143]. It has even been observed before that reflection can have a profound emotional impact on the person reflecting, and therefore has the potential to be harmful [143].

Some respondents brought up having a guilty conscience or having to beat a weaker self in regards to their PA during the qualitative interviews.

You're never approached by someone like 'How are you in regards to sports'. Nobody asks that! Instead: 'How are you'. Well I'm fine of course! But if someone asks you 'What do you really think about that?' then 'Hm, actually, hmm...' you have to really think and then you think 'Shit'. (Participant C)

It's okay but in the first moment it was like right in the first question like "How do you feel about your exercise?"... hm, well shit! *laughing* (Participant C)

Now I have a really guilty conscience if I don't do anything tomorrow or today. That's mean! *laughing* (Participant A)

The text responses from the second experiment had some examples of negative repercussions as well: "Bad, didn't do anything", "Feeling worse about myself. Not wanting to go for a run or the gym because I feel gross and self conscious. Weight gain, unhealthy", "worsening my already poor relationship with myself."

If respondents are on the edge of deciding if they should continue with the intervention or not, such negative experiences might lead to them dropping out to avoid confronting these emotions. This situation is especially prominent for computer-based interventions such as Josef. Leaving or backgrounding an app, and therefore postponing or even canceling the simulated therapy session, is hardly any effort compared to getting up and leaving a physical therapy session with a human therapist. This issue further underlines the importance of designing for a positive mood in this context.

However, why is it uncomfortable for some respondents to reflect on their behavior? It might be because of an intention-behavior gap, a phenomenon where people develop explicit decisions to change their behavior but do not take action [144]. One reason for this gap might be that choices are often determined by or embedded in the environment rather than being attributable directly to attitude or motivation. This observation was pointed out by Ganglbauer et al. in the context of negotiating food waste. Occasions of food waste were the consequence of other, prior moments, rather than a conscious choice [145]. We can imagine a scenario where a respondent chooses to take action, but when confronted with the complexity of life, does not follow up. When starting the next session with Josef, where the respondent is lead to reflect and might notice this discrepancy, it could lead to a negative experience if left unchecked.

Sadly other appointments were the problem time and time again. Where I thought to myself, *sigh* yeah today it would be nice—to do sports. Then I come home and then—I forgot something, another appointment. (Participant E)

The bad thing was that I couldn't make it, because of the stress that I had for the whole school year, that got less later, that I really didn't do anything. Well not much else as well, yeah? And that I couldn't summon the motivation then. (Participant B)

This Wednesday I thought, uhm about half past two today I sent a message to the [WhatsApp] group "Yeah, today I can make it to Zumba". Yeah, right... What happened—I came home at half past six and Zumba's at seven. That's why I thought,

nah, really, in this case nah, I'm knackered, I have to, I'm starving and if I eat something now I'll have to puke at Zumba. (Participant F)

When considering further possible reasons for an intention-behavior gap, we were pondering if a lack of support in regards to guiding respondents to set realistic goals could attribute to this. Josef did provide rudimentary help for this by asking, "What would be the next step for you to reach those benefits? Try to think of a small, specific step. When, where and how could you make that step?". However, respondents set rather reasonable goals like "on tuesday evening my wife and I could go for a walk and do some exercises at the sports ground", "I suppose a step could be spend a few minutes at the end of each day could be to lift weights that I own at home." or "I can go for a walk on whichever day this week I don't need to do anything else (probably Wednesday or Thursday?).". When respondents reflected on the week before, they mentioned following up on realistic goals, too: "I was running once.", "Not bad! I took some long walks when I was stressed.", "I did some stretches."

When taking into consideration possible repercussions of reflection, we should also take Breakdown, one of the dimensions of reflection we have previously discussed in section 3.6, into consideration. The confrontation with an intention-behavior gap through reflection might lead to a doubtful or puzzling situation, leading to a more transformative process [71]. Josef purposefully furthered this by showing respondents summaries and answers they previously wrote in their own words in the second session. This reflection on the violation of expectations they set themselves might lead respondents to reflect more deeply and strengthen their resolution to change their behavior, even if it is uncomfortable initially.

We conclude that even the repercussions of reflection could have a positive effect in that they further transformation. Nevertheless, especially with a computer-based intervention, it can have considerable risks. In comparison with a traditional therapy session with a human, walking out on the intervention (by backgrounding the app, closing a window, setting aside the device) is very easy. If the repercussions of reflection are left unchecked, this might lead to high drop-out rates or less persuasiveness of the intervention or in the worst case working against our declared goal of supporting a long-term behavior change.

Well this app that I had, where there actually appeared a [push notification] after every 3 days. Where it says "You haven't been here for 3 days, we miss you!". This "we miss you" was always like – it was okay but – this accusation of "You haven't been here for 3 days". It's like a jealous girlfriend, that's like... you're not looking forward to that. I kicked the app. (Participant C)

In the next section, we will take a closer look at the topic of negativity in interventions.

6.4 Positive Reinforcement is Key

Interventions designed to help with behavior change can employ mechanisms that, if employed in an uninformed way or without a theoretical background, lead to alienating their audience. In

our qualitative interviews, two respondents reported receiving messages that resulted in demotivating them, instead of the intended purpose of leading them towards their next workout or more increased PA.

Or like, last time with a running app it said something like “You’ve made two kilometres more last time” in the summary. I thought that well I’m just happy that I made those that I made right now, I don’t wanna see “but last time you made more”. Something like that, because you’re different with the day’s conditions. I don’t react well to that. (Participant C)

And here [when using Josef] it’s like, „Hey, nice, that you’re back!”, „Great, that you put your motivation into this process so far.”. I think that’s cool, because it’s positive and not like “You haven’t been here, tut tut tut you rascal! (Participant C)

I think he’s cool. Because he, well Josef in general, because he, like I said the other’s [Apps] I’ve used so far were like “Come back, come back!” and he says “Hey, it’s nice that you’ve been here. I hope I could help you and see you soon” – or something like that – “and think about it”. And not like “Tomorrow you have to run for three kilometers” or something. But instead, he really sees you off in a positive way. (Participant C)

Participant D reported being back on a Saturday after a run and being presented with the notice in her Garmin-app displayed in figure 6.1, that tried to increase the motivation of the respondent to be a bit more active on Saturdays, but achieved the exact opposite:

I thought “what the heck” I just came back from a run. What’s that supposed to mean. I felt really demotivated. (Participant D)

Messages that inform the user about decreased performance missed workouts, and other adverse events must do so wisely, or otherwise risk very strongly demotivating users or even turning them away altogether. We have previously discussed how the environment of respondents could be responsible for an intention-behavior gap. Our respondents mentioned injuries, family duties, and stress in the qualitative interviews as well as the responses to Josef. If users are presented a misguided message in times when they notice their intention-behavior gap or already feel bad about their lack of action, especially if they have not yet established a regular workout routine, this could result in further increased negativity. Such a situation could lead them to stop their behavior change efforts completely.

Fish’n’Steps, an intervention showing happy or sad fishes according to the PA of the user, observed this effect previously [35].

A finding of particular relevance to our work is that some participants ignored the display when their fish was not happy—punishment seemed to result in avoiding the system rather than encouraging the desired behavior. [35]



Figure 6.1: Example of interventional mechanism that unintentionally demotivates

Consolvo et al. then drew on lessons from Fish’n’Steps [33], Houston [32], and the Healthy lifestyle coach [146] for their decision to design UbiFit to frame feedback exclusively in neutral or positive ways [34]. This design decision has been proposed as a principle for behavior change technologies [43].

Framing feedback content can be an easy way to accommodate for this principle. Positively framed messages (e.g., “Walking can improve health”) are more effective than negatively framed messages (e.g., “Not walking enough can worsen health”) in increasing activity levels of older adults [147]. Negative messages should be rephrased to highlight the positive aspects respondents want to achieve. Instead of “You’ve made two kilometers more last time.” it could be “It’s great that you got that 3 kilometers run in!”, and instead of a message that could be interpreted as “You’re lazy on Saturday.” it could be a more positive one like “Great weather today! Want to go for a run?”.

We get further guidance on the topic by looking at the concept of affirming in motivational interviewing: to accentuate the positive. Affirming is attributed to helping with relationships, reducing defensiveness, and furthering openness to potentially threatening information [104].

When looking at the prospect of providing negative feedback, we have found no arguments stemming from our theoretical background and no indication from both our qualitative and quantitative results in this work to support it as a feasible approach to support maintainable PA behavior change. If wanting to approach that topic, it would have to be a system specifically designed with these circumstances in mind.

6.5 Gridlocked Thoughts about PA

Respondents did not seem to actively think about PA, or why they should be doing PA in the first place. From the qualitative interviews, it gathers that they have a feeling that they would be better off doing more PA, but none of the respondents have stopped to think about why it would be vital for them, personally. This condition could result in them making efforts to increase their PA levels that are rooted in externalized motivation rather than internalized motivation.

Josef was designed to let participants explore their own reasons for increasing their PA to aid level R3 reflections. These reflections are transformative, a perspective transformation for which “it is necessary to recognise that many of our actions are governed by a set of beliefs and values which have been almost unconsciously assimilated from the particular environment” [148]. This is illustrated in the following:

Let’s assume I wrote “because I want to loose weight or because I,... I don’t know,... want to have a six-pack. And then “Hey, why is this really so important for me?”. Why do I want to achieve this goal? Because I want to get in shape for summer? Because I, I don’t know, want to become a model? No idea. I think it’s really important to confirm my own feelings again. (Participant D)

I think that’s cool because I have really started thinking there. I mean, for the reasons. Because I was thinking “Why actually?”. Because... losing weight is the goal for most people probably. But, for me there’s more to it. Physical condition, medical condition and stuff you usually don’t think about at all. And those are really good reasons for wanting to do more of something, or less of something, or whatever. And nobody asks about that. You don’t think about that. Sure, the scales shows something, alright I have to loose weight, I need to do more PA, but that there’s more to it than just loosing weight is at the back of the head at best. (Participant C)

Well,... reasons to exercise, I thought, actually because everyone always says you should exercise more. Brainwashing, I’m telling you. Everyone says you should exercise more. No, and like, to feel better. So actually, I more deeply thought about why really now? (Participant F)

Josef seemed to assist respondents with finding their individual reasons to increase their PA levels, supporting the need for autonomy, and thus furthering internalized motivation.

6.6 Performance Objectives

In section 3.2, we have given our logic model of change. With the model, we presented our performance objectives, defining what participants need to do to perform the behavioral outcomes. We can now discuss in which ways Josef worked from that viewpoint.

The first performance objective we have given in section 3.2 was *PO1*, getting respondents to question their views about PA. In general, the attitude of respondents towards PA stayed

mostly the same as it was before talking to Josef. Nevertheless, the intervention was successful in that people agreed with being encouraged to think about their PA behavior, having stopped and thought about their PA behavior. Some even considered new alternatives to their PA choices that they can envision themselves doing.

In regards to *PO2*, to increase baseline PA, we observed most respondents considering themselves to be less or equally active as their peers. Given that our intervention was only used for a week and was targeted more at long-term behavior change, it was not surprising to find that self-reported changes for related questions were not statistically significant after a week of use. Nevertheless, respondents did agree more with getting as much exercise as they need. This observation could be the result of them having done more exercise after the first session with Josef, because of agreeing more with autonomy related statements such as PA being worth their time and feeling less pressured into doing PA. Especially the increase in perceived competence, being good at their preferred PA, could be helpful towards this particular performance objective.

PO3 was to help people with regularly checking their PA. We did not support this objective directly but rather aimed at furthering the internal motivation of respondents in order to improve their self-regulation of the behavior. For our respondents, this seems to have fit well, since 82% stated that their own motivation was the main trigger for doing PA.

Helping people to start doing PA themselves was the topic of *PO4*. Again, we tackled this goal from the perspective of furthering internal motivators instead of relying on external cues. Some respondents have found new alternatives to their current PA behavior and can envision themselves doing it, which could lead them to pick up a behavior they have thought of themselves, rather than relying on given environments or external cues. Combined with the knowledge that 82% of respondents rely on their motivation to start doing PA, we consider our approach of furthering that motivation in multiple aspects a promising one.

We abstracted social factors for regulating PA behavior with *PO5*, discussing PA with someone. To our surprise, most respondents preferred discussing their PA with Josef rather than with a human. We interpret this as Josef, as a computer-based persuasive intervention, fulfilled this PO for a target group that might not otherwise have discussed their behavior with someone.

Towards *PO6*, feeling competent at doing PA, we perceived a slight increase of agreement in respondents feeling good at their preferred PA, albeit a statistically insignificant one. While this performance objective was not a focus of ours, we did see surprising correlation results for this question. Perceived competence seems to be related to considering PA to help with reaching a personal goal and getting as much exercise as needed. With that knowledge, supporting the perceived competence of a PA behavior might be an unexpectedly worthwhile objective.

We defined re-engaging in PA after disruptions as *PO7*. While we consider this a worthwhile performance objective, our limited scope of doing two sessions with our intervention did not allow us to tackle this topic. While Josef might have helped with the topic in that we aimed to further internalization of PA behavior, looking further into this topic is left for future research.

Overall, Josef tackled the performance objectives less in a direct manner, but instead by furthering internalization of the behavior. This effect was particularly noticeable in our results regarding the correlation between SDT & MI, reflection, and persuasiveness, which we consider to show an overall helpful approach towards PA behavior change, even if not directly supporting one aspect or another. In general, it is questionable if focusing on directly supporting multiple

performance objectives with the expectation of significant changes in all of them is a worthwhile goal. We have previously talked about the intention-behavior gap, and that the environment of people could play a large part in it. It is straightforward to imagine that people will want to support their behavior change in multiple different ways, fitting their environment. They could, for example, use Josef to help them think and reflect on the topic. Having reflected and hopefully changed their perspective on the topic, they could decide to add a workout reminder to their calendar, talk about the topic further with a friend or use another intervention that is better suited for helping with translating the wanted behavior or newfound motivation to more actionable steps. An intervention could be aware of this situation, and instead of trying to do all things at once unsuccessfully, support one aspect of behavior change meaningfully and direct users to other interventions for supporting other aspects.

The one aspect Josef has focused on from that line of argumentation was supporting internal motivation to do PA itself to kick-off and support other steps participants might take towards behavior change. We did see a slight trend for supporting the three innate psychological needs, and Josef worked in promising ways as an MI practitioner by eliciting self-motivating statements. We did further succeed in supporting both the dimensions and the levels of reflection. Lastly, our target group preferred talking with Josef rather than another human being and found Josef both of likable appearance as well as very easy to use. Josef's persuasiveness did further have a considerable correlation with the other fields, so we were glad to see that our intervention was successful in that aspect.

6.7 Critical Reflection & Limitations

The implementation of this intervention was not without shortcomings. This section shall take a critical look at our work and point out the aspects where we see the most room for improvement or that could potentially lead to wrong conclusions if not handled with care.

Scope of the Work

Creating the intervention Josef from scratch coming from a software engineering background meant venturing deeper into multiple complex fields such as persuasive design and psychology. While this combination of fields did, in our case, lead to interesting findings, it bears the risk of overlooking particular aspects or relevances that experts of the respective field would not. Furthermore, it limited how sophisticated our solution could be without the effort going entirely out of proportion.

Consider, for example, the implementation of Josef as a two-session approach with a week-long break in between. Related work such as I Move was conducted with four sessions over three months [64], and even shorter trials like the UbiFit garden field trial was no shorter than three weeks [34]. The METM [108], which guided some of our decisions in regards to the session dialogues, stipulates four sessions with a completion time of under 12 weeks. The shortened 2-session approach might play a large part in why we did not see any statistically significant changes in the questions regarding SDT & MI, and that might lead to wrong conclusions if taken at face value.

Another issue of scope was related to the performance objectives we established as part of the intervention mapping protocol in section 3.2. While we considered them helpful in the design phase of the intervention, they were comparably “high level” in that they focused on more immediate, observable facets of behavior change, while our intervention targeted long-term, “low level” behavior changes affecting attitude towards PA. For example, while reflection could play a part in influencing PO2 “Increase Baseline PA Behavior if below the recommended levels,” the PO is too “high level” to draw more definite conclusions in our work. POs phrased to target the same “low level” we are investigating, such as “Participants strongly agree with being competent in their chosen PA” would supposedly have provided stronger indicators for Josef’s effectiveness in regards to the POs.

All this considered, we can hypothesize that, based on our indicative results and feedback, comparing the results of this work with the results of a version of Josef as a fully implemented four-session, 12-week intervention could yield valuable insights. Combined with a sharpening of the performance objectives towards the measurability of the aspects of interest, the issues described in this section would be mitigated.

Impact Tracking

One feature currently missing from Josef is measuring the actual impact of the behavior change. While using a pedometer could be a reasonable start for PA, one could also tap into platforms like Apple Health or Google Fit. These platforms serve as the central point in which health data from an iOS/Android phone is collected from other apps such as Fitbit, Garmin, Nike Running, iHealth, and many others. Instead of focusing on just one aspect of fitness, e.g., step count, they can potentially provide further data such as the user’s weight, heart rate, or other health metrics. The additional insights that can be gained by having these metrics could help to form an even clearer picture of the intervention’s effects.

Handling Misinterpretations or Negativity without Semantic Understanding

Josef is primarily based on written dialogue, and we have described in section 6.2 how we nevertheless made the avatar seem like it had an understanding of the conversation with the user. While the theoretical background of this work helped with the design, and we observed overall good usability and answers in line with this research, some users missed important words in questions or interpreted questions differently than intended. In some cases, the freedom to answer without restrictions allowed respondents to respond with what was on their minds or what they wanted to answer, even if the answer did not fully meet the invention’s design. While this may seem like it misses the goal, it goes well with supporting reflection. Nevertheless, in cases where respondents should be guided towards a clear path, more succinct and clear dialogue should be used, and essential words should be emphasized. Providing a “clarify” functionality that elaborates the question a bit more could be useful in these cases.

Josef, in the current version, lacked all semantic understanding of the dialogue. As such, there was no way of detecting if users did not understand at all or responded disproportionately detrimental to some questions. If Josef had natural language processing capabilities or even rudimentary sentiment analysis, it would create a whole range of new opportunities to change the

direction of the dialogue according to the answers. Josef could interweave clarifying statements or respond with a dialogue path that is more positively supporting in case Josef is met with considerable negativity. Without these skills, Josef could not support certain users where a human therapist could have intervened appropriately.

Conclusion

In the area of PA behavior change, computer-based interventions offer promising advantages. In comparison to human therapists, they are, amongst other advantages, cheap, offer greater anonymity, and are incredibly scalable. There have been multiple interventions that were successful in increasing the short-term PA behavior of their users (e.g., [33], [34]). This focus on more immediate change does seem to come at the cost of long-term maintainability of the new-found behavior, however. This effect is most noticeable in the consumer market, where solutions to change PA behavior have appeared as wearables, which land in the drawer quite soon after purchase or ineffective apps [16] [17] [7] [19].

Our research focused on the idea of a computer-based intervention that was designed to favor creating a maintainable PA behavior change over showing immediate results. Following this notion, we noticed a lack of respecting the theoretical background of the field, especially in commercial consumer solutions. Furthermore, the analyzed approaches that did not seem to consider the environment of PA behavior change to the necessary degree to be effective over more extended periods (see 2.2). To create the computer-based intervention “Josef,” we aimed for an approach that considered a theoretical background that lent itself to create a maintainable, long-term PA behavior and was fitting for the environment of that particular behavior. To progress towards that goal, we focused on the effects of components designed to further reflection in a computer-based intervention that aims to elicit long-term PA behavior change. We took the perspectives of health behavior change and persuasive design into account. This combination is considered to be relevant and necessary for designing successful PA behavior change apps [20]. Furthermore, we provided in-depth detail on the software development process involved in this work to provide a holistic account of the steps needed to create our behavior change intervention that we hope will be useful to inform decisions in the field.

The first perspective, health behavior change, lead us to discover a theoretical background for our intervention. Self-Determination Theory (SDT) was the meta-framework that guided how to support internalization of behavior, which, in turn, lends itself to being maintained easier. Motivational Interviewing (MI) presented an empiric approach that compliments SDT, which helped us to move from a more abstract background to concrete design decisions of how an

intervention could be implemented. We then identified reflection as a core component of our intervention, since it could play a considerable role in furthering autonomy, one of the innate psychological needs presented by SDT, is part of the recommended practice of MI and offers vast potential for computer-based interventions (see 2.3).

With the help of the perspective of persuasive design, we translated our approach to a computer-based intervention using a persuasive artificial agent, “Josef”. We documented the involved design decisions in more detail to create points of reference for other work in the field. Furthermore, we have documented the process of choosing the intervention theme, the appearance of the agent, color selection, dialogue system, and target platforms. We then gave a detailed account of how we considered particular choices to be relevant for furthering reflection.

Having the theoretical background established and the design of the intervention complete, we could transition to the implementation phase, where the perspective of software engineering came into focus. It should be noted that the software engineering aspects were considered rather late in this work. This delay was a conscious decision since software engineering allows the construction of technical solutions in a very effective manner. However, the two aforementioned perspectives are needed to create something that has a higher chance of actually influencing human behavior instead of just throwing technology at a problem. Towards the construction of Josef, we documented our choice of platforms, programming language, frameworks, data persistence concept, and network communication patterns. In comparison to regular software projects, where metric tracking might be as straightforward as tracking visits to a page or clicks on a button, writing metrics that allow us to make statements about behavior change required up-front consideration. Nevertheless, technology offered advantages there as well. Josef saved every response that was given, tracked the time to answer, total usage time, and the average length of text responses. Having all responses at hand was very important to allow us to reason about our findings and allow for more advanced analysis like the word cloud we generated and the sentiment analysis we did.

Chapters 3 and 4 contributed to answering one part of our research questions by giving a detailed account of the design decisions involved with this work and, in particular, how these design decisions related to reflection and the components that we created to support it.

We analyzed Josef with respect to our chosen theoretical background of SDT, MI, and reflection to discover more about computer-based interventions that are aimed at increasing long-term maintainable PA. Section 3.7 showed how we generated the necessary data by conducting mixed-method research. We did qualitative interviews for the initial prototype and ran a second experiment with an improved prototype yielding quantitative data.

Analysis of the responses given during the use of Josef showed in section 5.5 that users contemplated their answers as intended, and overall responded with a slightly positive sentiment. Looking at a word-cloud of the responses showed a high occurrence of contemplative and change-words as intended.

The results we have given in 5.2 have shown that, while we did find indicators that Josef could support SDT, they did not yield statistical significance. This result might be due to the limited time of intervention use, a notion we have discussed in more detail in chapter 6. Nevertheless, we discovered a correlation between question results for this topic. Stronger internalization correlated positively with readiness to change. The perceived competence in preferred PA

correlated with self-reported getting as much exercise as needed as well as considering PA worth their time. This correlation could provide a better understanding of how supporting one aspect of SDT in a computer-based intervention could affect others. These results could lend additional insights to the field of SDT interventions, where operational characteristics have not been fully elucidated as pointed out by previous work [25]. Especially when looking at previous work that combined SDT & MI for behavior change in a computer-based interventions, like a Fruit and Vegetable Intervention from Resnicow et al. [63] or I Move, a web-based computer-tailored PA intervention and the related long-term study by Friedrichs et al. [65], our work could provide a new point of reference. We gave our account of how Josef affected participants in regards to reflection in section 5.3. The intervention did successfully support both the levels of reflection and the dimensions of reflection. Furthermore, participants reflected on higher levels and more dimensions than initially expected. A surprising way in which Josef failed to work is in supporting participants in structuring their thoughts. Our evaluation approach documents an execution of previously suggested evaluation methods for reflection from Fleck and Fitzpatrick [26] and Baumer [71]. Our documented design decisions further provide examples from the field on how technology could support reflection, a need we have perceived when researching the field after becoming aware of the potential of reflection pointed out by previous work [26]. For us, the most surprising part of this work was the importance of taking due consideration of the persuasiveness of a computer-based intervention we perceived in section 5.4. Respondents rated Josef as very likable, and the larger group preferred talking about their PA behavior with Josef rather than another human. The ease of use of Josef correlated positively with questions we asked in the area of SDT & MI as well as reflection. Given the substantial impact persuasiveness had for our computer-based intervention, we hypothesized that it might yield significant results to re-run studies with computer-based interventions that did not achieve their intended results but could have lacked persuasion. A lack of persuasiveness could have lead to false negatives. For us, this confirms the dangers of a disconnect between persuasive design and behavior change techniques pointed out by Thomson et al. [20]. Overall, we were glad to see that considering this work from multiple perspectives was fruitful in that we discovered correlations that we might have otherwise missed. Looking at our results using an explorative approach that combined both qualitative and quantitative results allowed us to make further observations. Josef succeeded in eliciting-self motivating statements, a core skill of MI practitioners (see section 6.1), and the approach of providing different types of summaries succeeded to simulate reflective listening even without a semantic understanding of answers (see section 6.2). In some cases, this reflection had an unintended cost that of making respondents feel bad (see section 6.3), which lead us to consider an intention-behavior gap and to confirm the importance of positive reinforcement in our type of behavior change intervention (see section 6.4). Lastly, we considered how respondents had gridlocked thoughts in regards to PA (see section 6.5) and found that Josef tackled our intervention's performance objectives less in a direct manner, but instead by furthering internalization of the behavior (see section 6.6).

7.1 Future Work

Josef was found to be an easy-to-use computer-based intervention with a likable avatar that works on mobile devices as well as desktop computers (see 5.4). Furthermore, Josef's dialogue system is very adaptable. Therefore, it presents a solid starting point for future work to test hypotheses in the area of dialogue-driven computer-based interventions. For example, take the following hypothesis.

Motives are hypothesized to be particularly facilitating for maintenance if they enable regular gratification from enacting the new behaviour, rather than from the experience of changing. For example, by focusing on behaviour enjoyment, satisfaction with behavioural outcomes, self-determination or if individuals experience congruence of the newly adopted behaviour with their identity, beliefs and values. (Example hypothesis that lends itself to research in Josef's dialogue system [53])

To test this hypothesis, one could design dialogues that help respondents think about behavior enjoyment, satisfaction with behavioral outcomes, and other topics related to the above hypothesis. Creating a version of Josef that uses new dialogues instead of the ones of this work is as easy as changing a text file. Design, software implementation, ensuring persuasiveness, establishing metric tracking, answer collection, and having a way to export answers for analysis would have been taken care of already. This basis could speed up research considerably if found fitting for a topic of research.

The option of using Josef to test other hypotheses is not limited to PA behavior change. Since we primarily based our approach on presenting dialogue, creating a variation of Josef that talks about other health behavior change topics would present little additional effort. One could, for example, replace every occurrence of "physical activity" in Josef's dialogues with "healthy eating" to get started with researching our chosen theoretical background in combination with that topic instead. Going one step further, one could completely change the dialogues, but use the same avatar and UX capabilities such as being available on multiple platforms and supporting advanced dialogue mechanisms to have a more straightforward starting point for future work in comparison to having to create the whole behavior change intervention anew.

For our behavior change approach, in particular, future work could run micro-randomized trials, an approach that involves randomly assigning an intervention option at each relevant decision point we have given [149]. Micro-randomized trials could be an excellent fit to gain more knowledge about the correlations we discovered or to mitigate issues we have experienced (see 6).

Another research opportunity could be to move towards the long-term applicability of Josef for providing continuous guidance of behavior change. Designing a repeatable therapy structure offers considerable potential. If following the approach to help people reflect, dialogues could be varied without obviously doing so. This change could support respondents in their behavior change as long as they need, whenever they need, and even after long breaks/when relapsing. In comparison to human therapists, this support could be made available worldwide, at any time, to any number of clients somewhat easily from a technical perspective.

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The approved original version of this thesis is available in print at TU Wien Bibliothek.

APPENDIX **A**

Appendix

A.1 Handout

Informationsblatt für TeilnehmerInnen

Sie sind als TeilnehmerIn und TesterIn in Bezug auf die Diplomarbeit „Designing for Reflection in a Technological Intervention for Maintainable Physical Activity Behavior Change“ angefragt worden. Die Abfassung der Diplomarbeit erfolgt an der Technischen Universität Wien durch Lukas Nagl.

Ihre Teilnahme an diesem Projekt ist freiwillig. Weiters ist es Ihnen möglich Ihre Teilnahme zu jedem Zeitpunkt, auch ohne die Nennung von Gründen, zu beenden. Die Aufzeichnung und Verwendung Ihrer Daten erfolgt nur nach Ihrer expliziten Einwilligung und ist ausschließlich für wissenschaftliche Zwecke.

Im Rahmen Ihrer Teilnahme sollen Prototypen erprobt werden, welche Ansätze verfolgen, um die körperliche Betätigung zu erhöhen. Die Erfahrungen und Eindrücke, welche Sie während dem Gebrauch der Applikationen sammeln, sollen dabei wertvolle Hinweise und Rückschlüsse auf das grundlegende Potential der Ansätze ermöglichen.

Bitte beachten Sie, dass von Gesprächen (Interviews, Rückmeldungen, etc.) die Ihre Mitwirkung an diesem Projekt betreffen Text- und Audioaufzeichnungen, sowie gegebenenfalls Bildmaterial, angefertigt werden. Die Nutzung der Applikationen an sich wird, in beschränktem Umfang, von diesen selbst protokolliert. Die Übergabe dieser Protokolle obliegt jedoch Ihnen.

Jegliche im Zuge Ihrer Teilnahme erhobenen Daten werden vertraulich behandelt, ausschließlich für die vorliegende Arbeit verwendet und nicht an dritte Personen weitergegeben. Die Analyse und Auswertung erfolgt mit anonymisierten Daten, um gewährleisten zu können, dass keine Rückschlüsse auf die Identität der teilnehmenden Personen gezogen werden können. Die Diplomarbeit, welche letztendlich mitunter Teile Ihrer anonymisierten Daten beinhaltet, ist nach Fertigstellung über die Universitätsbibliothek der Technischen Universität Wien öffentlich einsehbar.

Im Falle von Fragen, Rückmeldungen, Beschwerden oder sonstige die Arbeit bzw. deren Durchführung betreffende Anliegen, kontaktieren Sie bitte jederzeit eine oder mehrere der nachfolgend angeführten Personen.

Durchführung der Diplomarbeit:

Lukas Nagl, BSc. e0825845@student.tuwien.ac.at

Betreuung der Diplomarbeit:

Univ.Prof. **Geraldine Fitzpatrick**, Phd. geraldine.fitzpatrick@tuwien.ac.at

A.2 Letter of Agreement

Einverständniserklärung

Bitte lesen Sie alle nachfolgenden Fragen sorgfältig und beantworten Sie diese wahrheitsgetreu. Es ist nicht erforderlich alle Fragen mit „Ja“ zu beantworten um teilnahmeberechtigt zu sein.

- a. Ich habe das beigelegte Informationsblatt für TeilnehmerInnen erhalten, vollinhaltlich gelesen sowie verstanden und möchte bis auf weiteres teilnehmen.
Ja [] Nein []

- b. Ich bin mir der Möglichkeit bewusst, dass die im Rahmen meiner Teilnahme zu testenden Applikationen gegebenenfalls Einflussnahme auf meine gewohnte körperliche Betätigung ausüben.
Ja [] Nein []

- c. Ich bin einverstanden, dass Teile meines Nutzungsverhaltens von den zu testenden Applikationen automatisiert aufgezeichnet werden, wobei die Weitergabe dieser Aufzeichnungen mir selbst obliegt.
Ja [] Nein []

- d. Ich bin einverstanden, dass von Gesprächen die meine Mitwirkung an diesem Projekt betreffen Text- und Audio-Aufzeichnungen angefertigt werden.
Ja [] Nein []

- a. Ich bin einverstanden, dass Bildmaterial angefertigt wird.
Ja [] Nein []

- b. Ich bin einverstanden, dass alle im Zuge meiner Teilnahme erhobenen Daten ausgewertet und in weiterer Folge, in anonymisierter Form, für wissenschaftliche Veröffentlichungen sowie die Präsentationen selbiger genutzt werden.
Ja [] Nein []

Vor- und Nachname: _____

Datum, Unterschrift: _____

Autor

Datum, Unterschrift: _____

A.3 Interview Guide

QUALITATIVE INTERVIEW PROTOTYPE 1

All questions are provided according to the topics we want to learn about, with extending questions *if needed*.

Before the Experiment

- *Einsverständnis*
- Check EN understanding of respondents
- Prepare Experiment-Account for respondent
- Greeting
- Smalltalk - "show that I want to learn and that I'm worth teaching. That I know something, but not everything. So they can inform me, and I'll understand."
Meanwhile get necessary Permissions (+Name, Age, Occupation), Tape Recorder.

Before The Experiment

Introduce to what I mean by physical activity or exercising to make clear that it doesn't have to be high intensity physical activity:

"[...] moderate intensity physical activity – such as walking, cycling, or participating in sports [...]" (taken from WHO http://www.who.int/topics/physical_activity/en/)

- Q: Can you remember the last day you did physical activity? Can you walk me through that day?
 - What was going through your mind when you were doing PA?
- Q: Can you describe a situation in the past when you were thinking about *Can you think of a moment when something made you think about how much exercise you're getting?*
~~(pondering/reflecting on?) your physical activity behavior?~~
 - What lead to that situation?
 - How did your situation change after that?
 - Was there anyone you talked with about that situation?
- Q: Can you walk me through the last time when you tried to increase your physical activity behavior?
 - What did you try?
 - What were the challenges or successes you encountered?
 - Can you remember what your thoughts and feelings were then?

Don't forget questions after
=> injectors

Experiment (Shortened for Pilot Interview)

Present the first prototype session.

Tell them that I'll leave the room so they have peace, that they should take their time, and that they can call me when they're done.

Give the testers a short break (coffee?), maybe smalltalk with them, tell them to imagine a few days having passed.

Second prototype session.

After the Experiment

- Q: Can you walk me through what went through your mind when you were using the app?
 - What stood out for you when you were using the app?
 - Can you give an example of a thought you had about your physical activity behavior during usage that was important or surprising for you?
 - Can you think of a decision you made during usage of the app and go into a detail about how you came to that decision?

Do a quick walk-through through the app (without delays, clean state):

- Q: Is it okay if we run through the app without anything filled out real quick and you tell me what you found important/remember?

• ask about apps/variables

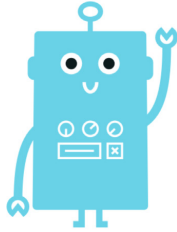
Finish

(still recording) Thank them for their time and effort.

Try to get them to talk some more about the experiment.

Ask them to keep in touch.

A.4 Up-Front Questionnaire



Welcome and thank you for taking your time to take part in this research project about physical activity!

Start press ENTER

1 → General Questions

Before we start, we'd like to give you some information and ask you a few general questions.

Continue press ENTER

“ This study will be done in two parts, with a one week break in between. After you completed the first part, we will notify you by e-mail as soon as the second one is ready.

Continue press ENTER

“ This study will be done in two parts, with a one week break in between. After you completed the first part, we will notify you by e-mail as soon as the second one is ready.

Continue press ENTER

“ Data collected during this research is pseudonymized and used for research purposes only.

You can read the full data usage details at https://s3-eu-west-1.amazonaws.com/josef-app/gdpr_informer.pdf

Continue press ENTER

a. What is your country of origin?

b. What's your e-mail address? *

We use it exclusively to notify you during this study.

c. In what year were you born?

d. What's your gender?

- A Non-binary/third gender
- B Prefer not to say
- C Female
- D Male
- E Other

e. Do you currently use an app or wearable (Fitbit, Apple Watch, ...) to help motivate you to do physical activity?

- A Yes
- B No
- C Don't Know

2 → Questions about Physical Activity

Now we'd like to ask some questions about your life in regards to physical activity.

Continue press ENTER

a. Would you say that you are physically more active, less active or about as active as other persons your age? *

- A More
- B Less
- C Same

b. I get as much exercise as I need. *

To which extent do you agree with this statement?

1	2	3	4	5
Strongly Disagree		Neutral		Strongly Agree

c. Doing physical activity is worth my time. *

1	2	3	4	5
Strongly Disagree		Neutral		Strongly Agree

“ For the next questions, think of your preferred physical activity, e.g. Yoga, Cycling, Boxing...

Continue press ENTER

d. I think I'm good at my preferred physical activity. *

1	2	3	4	5
Strongly Disagree		Neutral		Strongly Agree

e. In daily life, what triggers you to do physical activity? *

Choose as many as you like

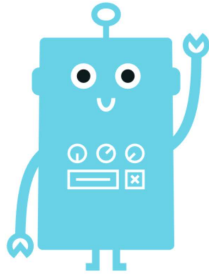
- A my own motivation
- B calendar reminders
- C Friends/Family/...
- D an app
- E a wearable
- F habit/routine
- G Other

f Doing physical activity helps me to reach a personal goal. *

1	2	3	4	5
Strongly Disagree		Neutral		Strongly Agree

g I feel pressured into doing physical activity. *

1	2	3	4	5
Strongly Disagree		Neutral		Strongly Agree




Thank you! In the next step, you will meet "Josef" the robot.

Continue press ENTER

A.5 Josef Session 1

Josef


Hi, I'm Josef. I'm programmed to work with you on your physical activity behavior.



Josef


How do you feel about your current physical activity behavior?

Your Answer




Josef

Before we begin, let me just explain a little about how we will be working together.




Josef

My circuits are very limited. I hope that I can help you think about your present physical activity behavior and consider what, if anything, you might want to do.




Josef

We will steer clear of making an exercise plan, though. Today is all about helping you think about changing.




Josef

But if there is any changing, you will be the one who does it. Nobody can tell you what to do, nobody can make you change.





Josef

The only person who can decide whether and how to change is you.



Josef

How does that sound? Shall we get started?



Josef

That's fine. I'll be here whenever you're ready.

✓

Josef

Do you feel ready to think about your physical activity behavior?

✗ ✓

Josef

How do you feel about your current physical activity behavior?

Your Answer

✓

Josef

What would be reasons for you to change?

Your Answer

✓

Josef

Think about what you just described. Why is this important to you?

Your Answer

✓

Josef

What would some of the benefits of changing be?

Your Answer

✓

Josef

On the following scale from 1 to 10, where 1 is definitely not ready to change and 10 is definitely ready to change, what number best reflects how ready you are at the present time to change your physical activity?

not ready ——— 5 ——— ready

✓

Josef

Higher than one, that's good! Any ideas what might raise your confidence?

Your Answer

✓

A.6 Josef Session 2

Josef

It's good to see you again! I appreciate the motivation you have put into this process so far.

Josef

Today, I'll help you to think about your physical activity behavior some more, and how the first steps towards changing could look like.

Josef

Let me play back the summary of what we've talked about last time.

Your summarization of what you've said is...

[PLACEHOLDER]

Josef

How did your last days go in regards to your physical activity behavior?

Your Answer

Josef

What would be possible negative consequences of not changing your physical activity behavior?

Your Answer

Josef

Here's what you told me last time on what the benefits of changing would be for you.

Benefits of changing would be...

[PLACEHOLDER]

Josef

What would be the next step for you to reach those benefits? Try to think of a small, specific step. When, where and how could you make that step?

Your Answer

Josef

On the following scale from 1 to 10, where 1 is definitely not ready to change and 10 is definitely ready to change, what number best reflects how ready you are at the present time to change your physical activity?

not ready ——— 5 ——— ready

Josef

What would it take to move a bit higher on the scale?

Your Answer

✓

Josef

Let me play back some of the things you said.

Benefits of changing would be...

[PLACEHOLDER]

Your physical activity behavior the last days went...

[PLACEHOLDER]

Possible negative consequences of not changing your physical activity would be...

[PLACEHOLDER]

✓

Josef

How would you summarize what you've said?

Your Answer

✓

Josef

I'm glad you took your time with me, and hope I could help you with thinking about your physical activity behavior.

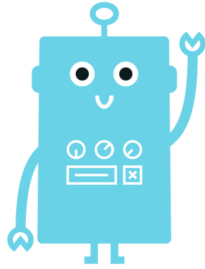
✓

Josef

For the next and final part of this research project, we'd like to ask you a few questions about your experience.

[GO TO FINAL PART](#)

A.7 Post-Experiment Questionnaire



Welcome back! In this final part of the study, we'd like to learn more regarding your thoughts about physical activity and your experience with Josef the robot.

Start press ENTER

1 → Questions about Physical Activity

Continue press ENTER

a. I get as much exercise as I need. *

To which extent do you agree with this statement?

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

b. Doing physical activity is worth my time. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

“ For the next questions, think of your preferred physical activity, e.g. Yoga, Cycling, Boxing,...

Continue press ENTER

c. I think I'm good at my preferred physical activity. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

d. Doing physical activity helps me to reach a personal goal. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

e. I feel pressured into doing physical activity. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

2 → Questions about “Josef” (the robot)

We would like to start by asking a few questions about Josef itself.

Continue press ENTER

122

a. How easy/hard was Josef (the robot) to use? *

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----

Very easy to use Neutral Very hard to use

b. I disliked Josef's appearance. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

c. Josef was supportive towards me. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

d. I would have preferred discussing my physical activity with a human rather than Josef. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

3 → Your Experience with “Josef” (the robot)

Now some questions about your experience with Josef.

Continue press ENTER

a. Josef helped me structure my thoughts about my physical activity behavior. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

b. Josef discouraged me from thinking about my physical activity behavior. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

c. Josef helped me find new reasons to do physical activity. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

d. I have looked at my physical activity behavior from a new perspective. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

e. Josef made me stop and think about my physical activity behavior. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

f. I have considered new alternatives to my previous physical activity choices. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

g. I can envision myself doing one or some of these new alternatives. *

1	2	3	4	5
---	---	---	---	---

Strongly Disagree Neutral Strongly Agree

h. My attitude towards physical activity is still the same as it was before talking to Josef. *

1	2	3	4	5
---	---	---	---	---

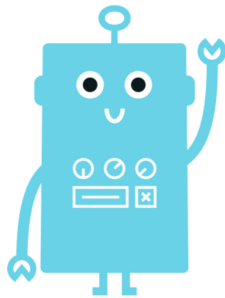
Strongly Disagree Neutral Strongly Agree

i. If we have follow-up questions for this research, would it be okay if we contact you?

A Yes

B No

C Other



That's it! Thank you so much for taking part in this research. You've been great!

A.8 GDPR Informer

(ENGLISH)

Information for collection and processing of personal data

As part of my master's degree in Software Engineering & Internet Computing at the Vienna University of Technology (hereafter referred to as "TU Wien"), I am currently working on my master's thesis.

The writing of this scientific work involves the collection and use of personal data.

The processing of personal data must be in accordance with the applicable data protection rules, therefore I may inform you in accordance with § 13 EU General Data Protection Regulation (GDPR) on data processing as follows:

Responsible for the Data Processing

1. Author of the master thesis and responsible for the data processing in terms of of § 4 clause 7 GDPR.

Lukas Nagl

2. contact details

e0825845@student.tuwien.ac.at

Subject of the Master's Thesis

1. Title of the master's thesis

Designing for Reflection in a Technological Intervention for Maintainable Physical Activity Behavior Change

2. Description of the master's thesis

Simply throwing technology at the problem of physical activity behavior change doesn't achieve the wanted long-term results. Our research considers how a technological intervention could look like that would, based on theory and with consideration of the target groups environment/social world, be designed to create a more maintainable physical activity behavior change.

Type of Personal Data Processed

The following personal information about you will be processed as part of my scientific work:

Personal information, in particular:

- e-mail
- gender
- age

Purpose of Data Processing

To contact you during the experiment period of the software "Josef". Evaluation of surveys and research data which is recorded during the use of the software "Josef" (such as response texts and response times, hereinafter referred to as usage data) on the subject of physical activity and processing of the collected data as part of my master thesis with the title "Designing for Reflection in a Technological Intervention for Maintainable Physical Activity Behavior Change".

Description of Data Processing

Survey results and usage data are pseudonymised and evaluated. In the master thesis, answers are only quoted in extracts in order to ensure to third parties that the resulting overall context of events cannot lead to an identification of the person. Personal contact data is kept separate from usage data and inaccessible to third parties.

Legal Basis

The legal basis for the processing of this personal data is Art. 6 para. 1 lit c GDPR in conjunction with Art. 81 UG (University Law) Master's Thesis.

Art. 6 para. 1 lit c GDPR regulates the processing of personal data in order to fulfil a legal obligation to which the person responsible is subject.

§§ 80ff UG represent the legal obligation. A distinction is made according to the type of scientific work:

- § 80 UG concerns the bachelor theses (Art 6 para 1 lit c GDPR in conjunction with § 80 UG);
- § 81 UG concerns diploma and master theses (Art 6 para 1 lit c GDPR in conjunction with § 81 UG);
- § 83 UG concerns dissertations (Art 6 para 1 lit c GDPR in conjunction with § 83 UG)

The data protection justification for the processing of the data is not the consent of the data subjects.

Data-Recipients and -Transfers

As a matter of principle, only authorised persons who are bound to secrecy have access to the personal data processed in the course of preparing and supervising the master's thesis, and only to the extent necessary.

Your personal data will be transmitted or may be transmitted to the following recipients or categories of recipients:

- to the university concerned (TU Vienna), in particular the supervisor of the scientific work and his/her staff
- successfully concluded master theses to the University Library of the Vienna University of Technology, Resselgasse 4, 1040 Vienna, for the purpose of publication according to Art. 6 para. 1 lit c GDPR in conjunction with § 86 Universitätsgesetz (UG) (University Law)
- successfully concluded master theses (name of the student as well as title of the thesis and the name of the supervisor) to the Austrian National Library, Josefsplatz 1, 1015 Vienna, according to Art 6 para 1 lit c GDPR in conjunction with §86 UG
- to Google Firebase and Typeform for collecting and processing study data. Google Firebase is provided by Google LLC, 1600 Amphitheatre Pkwy Mountain View, California 94043. Google LLC complies to the EU-US Privacy Shield (<https://www.privacyshield.gov/participant?id=a2zt000000001L5AAI>). Typeform is provided by TYPEFORM, SL, Bac de Roda 163, 08018 Barcelona, Spain.

Storage Period

As proof of good scientific practice and for the verifiability of the chosen method and the results obtained, the recording and documentation of the scientific procedure is stored on durable and secure data carriers. This is done in compliance with data protection regulations and is inaccessible to third parties. Data storage is governed by the statutory provisions and is carried out in accordance with Section 2f (3) of the Forschungsorganisationsgesetz (FOG, Research Organisation Act) for a maximum period of 30 years.

Rights of the data subject

According to the GDPR, you as the person concerned are entitled to the following rights:

- Right of access to the personal data concerned (Art. 15 GDPR)
- Right to rectification (Art. 16 GDPR) or erasure (Art. 17 GDPR) or restriction of processing (Art. 18 GDPR) under the conditions described in the provisions cited.
- Right of complaint, which must be submitted to the Austrian Data Protection Authority, Barichgasse 40-42, 1030 Vienna, telephone: +43 1 52 152-0, e-mail: dsb@dsb.gv.at as the competent supervisory authority.

Article 11 GDPR also provides that a separate traceability of data to individuals does not have to be guaranteed only in order to protect the rights of the data subjects.

To assert your rights, please contact me as follows:

e0825845@student.tuwien.ac.at

(DEUTSCH)

Information zur Erhebung und Verarbeitung personenbezogener Daten

Im Rahmen meines Master-Studiums Software Engineering & Internet Computing an der Technischen Universität Wien (in der Folge kurz als „TU Wien“ bezeichnet) arbeite ich gerade an meiner Masterarbeit.

Das Verfassen dieser wissenschaftlichen Arbeit ist mit der Erhebung und Verwendung personenbezogener Daten verbunden.

Die Verarbeitung personenbezogener Daten hat in Entsprechung der geltenden Datenschutzbestimmungen zu erfolgen, daher darf ich gemäß Art 13 Datenschutz-Grundverordnung (DSGVO) über die Datenverarbeitung informieren wie folgt:

Verantwortliche_r für die Datenverarbeitung

1. Verfasser_in der Masterarbeit und Verantwortliche_r für die Datenverarbeitung iS von Art 4 Zif 7 DSGVO
Lukas Nagl
2. Kontaktdaten
e0825845@student.tuwien.ac.at

Gegenstand der Masterarbeit

1. Titel der Masterarbeit
Designing for Reflection in a Technological Intervention for Maintainable Physical Activity Behavior Change
2. Beschreibung der Masterarbeit

Technologie scheint nicht das Allheilmittel zu sein, um nachhaltig körperliche Betätigung zu steigern. Unsere Forschung beschäftigt sich damit, wie eine technologische Intervention gestaltet werden könnte, welche die psychologische Theorie des Verhaltens sowie das Umfeld unserer Zielgruppe berücksichtigt, um dadurch eine nachhaltigere Verhaltensänderung zu erwirken.

Art der verarbeiteten personenbezogenen Daten

Folgende personenbezogene Daten zu Ihrer Person werden im Rahmen meiner wissenschaftlichen Arbeit verarbeitet:

persönliche Angaben, nämlich insbesondere:

- E-Mail
- Geschlecht
- Alter

Zweck der Datenverarbeitung

Kontaktaufnahme während der Dauer des Experiments mit der Software „Josef“. Auswertung von Umfragen sowie Forschungsdaten, welche während der Verwendung der Software „Josef“ aufgezeichnet werden (wie beispielsweise Antworttexte und Antwortzeiten, im fortfolgenden als Verwendungsdaten bezeichnet) zum Thema körperliche Betätigung und Verarbeitung der erhobenen Daten im Rahmen meiner Masterarbeit mit dem Titel „Designing for Reflection in a Technological Intervention for Maintainable Physical Activity Behavior Change“.

Beschreibung der Datenverarbeitung

Umfrageresultate, sowie Verwendungsdaten werden pseudonymisiert und ausgewertet. In der Masterarbeit werden Antworten nur in Ausschnitten zitiert, um gegenüber Dritten sicherzustellen, dass der entstehende Gesamtzusammenhang von Ereignissen nicht zu einer Identifizierung der Person führen kann. Personenbezogene Kontaktdaten werden von Verwendungsdaten getrennt für Dritte unzugänglich aufbewahrt.

Rechtsgrundlage

Die Rechtsgrundlage zur Verarbeitung dieser personenbezogenen Daten stellt Art 6 Abs 1 lit c DSGVO in Verbindung mit § 81 für Masterarbeiten UG dar.

Art 6 Abs 1 lit c DSGVO normiert die Verarbeitung personenbezogener Daten zur Erfüllung einer rechtlichen Verpflichtung, der die_der Verantwortliche unterliegt.

§§ 80ff UG stellen die rechtliche Verpflichtung dar. Es wird je nach Art der wissenschaftlichen Arbeit unterschieden:

- § 80 UG betrifft die Bachelorarbeit (Art 6 Abs 1 lit c DSGVO iVm § 80 UG);
- § 81 UG betrifft Diplom- und Masterarbeiten (Art 6 Abs 1 lit c DSGVO iVm § 81 UG);
- § 83 UG betrifft Dissertationen (Art 6 Abs 1 lit c DSGVO iVm § 83 UG)

Die datenschutzrechtliche Rechtfertigung für die Verarbeitung der Daten ist nicht die Einwilligung der Betroffenen.

Übermittlungsempfänger_innen und Drittstaatenübermittlungen

Grundsätzlich haben nur autorisierte und zur Verschwiegenheit verpflichtete Personen im Zuge der Erarbeitung und Betreuung der *Masterarbeit* Zugang zu den verarbeiteten, personenbezogenen Daten, und dies nur in dem erforderlichen Umfang.

An folgende Empfänger_innen oder Kategorien von Empfänger_innen werden Ihre personenbezogenen Daten zulässigerweise übermittelt oder können übermittelt werden:

- an die betroffene Universität (TU Wien), insbesondere der/dem Betreuer_in der wissenschaftlichen Arbeit und dessen Mitarbeiterstab
- positiv beurteilte Masterarbeit an die Universitäts-Bibliothek der TU Wien, Resselgasse 4, 1040 Wien, zum Zwecke der Veröffentlichung gemäß Art 6 Abs 1 lit c DSGVO iVm § 86 Universitätsgesetz (UG)
- positiv beurteilte Masterarbeiten (Name der/des Studierenden sowie Titel der Abschlussarbeit und der Name der_des Betreuer_in) an die Österreichische Nationalbibliothek, Josefsplatz 1, 1015 Wien, gemäß Art 6 Abs 1 lit c DSGVO iVm § 86 UG
- Zur Aufnahme und Verarbeitung von Forschungsdaten, Google Firebase and Typeform. Google Firebase wird von Google LLC, 1600 Amphitheatre Pkwy Mountain View, California 94043 zur Verfügung gestellt. Google LLC entspricht dem EU-US Privacy Shield (<https://www.privacyshield.gov/participant?id=a2zt000000001L5AAI>). Typeform wird von TYPEFORM, SL, Bac de Roda 163, 08018 Barcelona, Spain zur Verfügung gestellt.

Speicherdauer

Zum Nachweis der guten wissenschaftlichen Praxis sowie für die Nachprüfbarkeit der gewählten Methode und der erzielten Ergebnisse, wird die Protokollierung und die Dokumentation des wissenschaftlichen Vorgehens auf haltbaren und gesicherten Datenträgern gespeichert. Dies erfolgt datenschutz-konform und gegenüber Dritten unzugänglich. Die Datenspeicherung richtet sich nach den gesetzlichen Bestimmungen und erfolgt entsprechend § 2f Abs 3 Forschungsorganisationsgesetz (FOG) für die Dauer von maximal 30 Jahren.

Betroffenenrechte

Gemäß der DSGVO stehen Ihnen als betroffene Person folgende Rechte zu:

- Recht auf **Auskunft** über die betreffenden personenbezogenen Daten (Art 15 DSGVO)
- Recht auf **Berichtigung** (Art 16 DSGVO) oder **Löschung** (Art 17 DSGVO) oder 1auf **Einschränkung** der Verarbeitung (Art 18 DSGVO) unter den in den angeführten Bestimmungen beschriebenen Voraussetzungen
- **Recht auf Beschwerde**, welche bei der Österreichischen Datenschutzbehörde, Barichgasse 40-42, 1030 Wien, Telefon: +43 1 52 152-0, E-Mail: dsb@dsb.gv.at als zuständige Aufsichtsbehörde einzubringen ist.

Artikel 11 DSGVO sieht zudem vor, dass eine separate Rückführbarkeit von Daten auf Personen nicht gewährleistet werden muss, nur um die Betroffenenrechte wahren zu können.

Zur Geltendmachung Ihrer Rechte wenden Sie sich an mich wie folgt:

e0825845@student.tuwien.ac.at