Designing Behavior Change Technologies for Workplace Wellbeing

Dissertation

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Abstract

Humans have become exponentially more productive at work due to advances in technology. However, these advances are spurred by a desire to increase output, often without considering wellbeing. Consequently, modern knowledge workers (i.e., occupations primarily involving applying information rather than physical tasks) experience unhealthy conditions such as sedentary behavior, social isolation, and excessive screen time. The consequences of chronic exposure to such conditions can be drastic for users' mental and physical wellbeing. Even when users make efforts to increase healthy behaviors in the workplace, such as by installing standing desks, uptake remains low in practice due to the intention-behavior gap. Technology designers have an opportunity to combat the negative effects of the modern workplace, but they should not degrade productivity for their solutions to be accepted in industrial practice.

Thus, the problem is two-fold: (1) the modern office prioritizes productivity at the expense of wellbeing, and (2) users have difficulty changing their behaviors even when healthy interventions are available. These factors reveal a spectrum of influence connected to both if and how people are motivated to change their behaviors. This thesis navigates along this spectrum by conducting studies and evaluating prototypical systems to build an understanding of this motivation. Consequently, this thesis outlines a vision for a healthy future of work through two approaches. First, we investigate how to design technology to make healthy ways of working a more attractive choice for users. Second, we explore active behavior change technologies that aim to overcome the intention-behavior gap and ethically nudge users to behave according to their own goals.

In the first series of explorations, we investigate technology that inspires users to incorporate movement in the workplace. The works in this section use passive behavior change approaches, aiming to make movement an attractive option that users will choose of their own volition. We used ethnographic methods to understand the needs of users who regularly integrate physical activity into their work routines. Drawing from this knowledge, we developed a tangible prototype to explore technology-supported walking meetings. Finally, we explored using physical exertion as a design element to generate mindful experiences. Overall, these investigations provide a new understanding of how technology can seamlessly integrate physical activity into work routines while creating positive user experiences.

Next, we explore active approaches that nudge users to act in alignment with their own goals. We designed and implemented functional prototypes and conducted mixed-methods evaluations on interventions to increase movement, foster social connectedness, and manage excessive screentime, all of which are issues in the modern office. To increase ecological validity, we conducted three of the studies in the field, including one large-scale longitudinal study. These investigations provide insights into how technology can support users in overcoming intention-behavior gaps to achieve their own behavior goals in the real world.

Based on our investigations, we propose a design framework for behavior change technologies that promote a healthy workplace. The framework draws from related work and incorporates

theoretical concepts from physiology and nudge theory. We designed the framework to be beneficial for researchers and technology designers in creating behavior change technologies.

In all, this thesis contributes the following: (1) prototypical systems to facilitate improvements in physical activity, mindful screen time, and social interactions, (2) field evaluations of workplace behavior change technologies, (3) an actionable design framework highlighting important design dimensions and categorizing literature for future developers of ethical behavior change technologies, and (4) a reflection on ethical behavior change. Finally, we discuss open challenges for the field and deploying research in practice. This thesis demonstrates the potential for technology to support healthier workplaces without sacrificing productivity by providing concrete solutions and ecologically validated field evaluations. By advocating for the integration of wellbeing principles into workplace design and emphasizing user-centered approaches to behavior change technologies, our work lays the groundwork for creating healthier and more productive workplaces in the future.

Zusammenfassung

Die Produktivität der Menschen bei der Arbeit ist durch den technischen Fortschritt exponentiell gestiegen. Diese Fortschritte werden jedoch durch den Wunsch nach mehr Leistung angetrieben, oft ohne Rücksicht auf das Wohlbefinden. Infolgedessen sind moderne Wissensarbeiter (d. h. Berufe, bei denen es in erster Linie um die Anwendung von Informationen und nicht um physische Aufgaben geht) ungesunden Bedingungen wie sitzendem Verhalten, sozialer Isolation und übermäßiger Bildschirmarbeit ausgesetzt. Die Folgen einer chronischen Belastung durch solche Bedingungen können für das geistige und körperliche Wohlbefinden der Nutzer drastisch sein. Selbst wenn sich die Nutzer bemühen, gesundes Verhalten am Arbeitsplatz zu fördern, z. B. durch die Einrichtung von Stehpulten, bleibt die Akzeptanz in der Praxis aufgrund der Kluft zwischen Absicht und Verhalten gering. Technologiedesigner haben die Möglichkeit, die negativen Auswirkungen des modernen Arbeitsplatzes zu bekämpfen, aber sie sollten die Produktivität nicht beeinträchtigen, damit ihre Lösungen in der industriellen Praxis akzeptiert werden.

Das Problem ist also ein zweifaches: (1) im modernen Büro wird der Produktivität auf Kosten des Wohlbefindens Vorrang eingeräumt, und (2) den Nutzern fällt es schwer, ihr Verhalten zu ändern, selbst wenn gesunde Interventionen zur Verfügung stehen. Diese Faktoren zeigen ein Spektrum von Einflüssen auf, die damit zusammenhängen, ob und wie Menschen motiviert sind, ihr Verhalten zu ändern. Die vorliegende Arbeit bewegt sich entlang dieses Spektrums, indem sie Studien durchführt und prototypische Systeme evaluiert, um ein Verständnis für diese Motivation zu entwickeln. Folglich skizziert diese Arbeit eine Vision für eine gesunde Zukunft der Arbeit durch zwei Ansätze. Erstens untersuchen wir, wie Technologien entwickelt werden können, um gesunde Arbeitsweisen für die Nutzer attraktiver zu machen. Zweitens erforschen wir Technologien zur aktiven Verhaltensänderung, die darauf abzielen, die Kluft zwischen Absicht und Verhalten zu überwinden und die Nutzer auf ethische Weise dazu zu bewegen, sich entsprechend ihren eigenen Zielen zu verhalten.

In der ersten Reihe von Untersuchungen erforschen wir Technologien, die die Nutzer dazu anregen, Bewegung am Arbeitsplatz einzubauen. Die Arbeiten in diesem Abschnitt verwenden Ansätze zur passiven Verhaltensänderung und zielen darauf ab, Bewegung zu einer attraktiven Option zu machen, für die sich die Nutzer aus eigenem Antrieb entscheiden. Wir haben ethnografische Methoden eingesetzt, um die Bedürfnisse von Nutzern zu verstehen, die regelmäßig körperliche Aktivität in ihre Arbeitsroutine integrieren. Auf der Grundlage dieses Wissens entwickelten wir einen greifbaren Prototyp, um technologiegestützte Geh-Meetings zu erforschen. Schließlich untersuchten wir die Nutzung körperlicher Anstrengung als Gestaltungselement, um achtsame Erfahrungen zu erzeugen. Insgesamt liefern diese Untersuchungen ein neues Verständnis dafür, wie Technologie körperliche Aktivität nahtlos in den Arbeitsalltag integrieren und gleichzeitig positive Nutzererfahrungen schaffen kann.

Als Nächstes erforschen wir aktive Ansätze, die die Nutzer dazu anregen, im Einklang mit ihren eigenen Zielen zu handeln. Wir haben funktionale Prototypen entworfen und imple-

mentiert und Evaluierungen mit gemischten Methoden zu Interventionen zur Steigerung der Bewegung, zur Förderung sozialer Kontakte und zum Umgang mit übermäßiger Bildschirmzeit durchgeführt - allesamt Themen, die im modernen Büro eine Rolle spielen. Um die ökologische Validität zu erhöhen, haben wir drei der Studien im Feld durchgeführt, darunter eine groß angelegte Längsschnittstudie. Diese Untersuchungen geben Aufschluss darüber, wie die Technologie die Nutzer bei der Überwindung der Diskrepanz zwischen Absicht und Verhalten unterstützen kann, um ihre eigenen Verhaltensziele in der realen Welt zu erreichen.

Auf der Grundlage unserer Untersuchungen schlagen wir einen Gestaltungsrahmen für Technologien zur Verhaltensänderung vor, die einen gesunden Arbeitsplatz fördern. Der Rahmen basiert auf verwandten Arbeiten und umfasst theoretische Konzepte aus der Physiologie und der Nudge-Theorie. Wir haben den Rahmen so gestaltet, dass er Forschern und Technologieentwicklern bei der Entwicklung von Technologien zur Verhaltensänderung von Nutzen ist.

Insgesamt leistet diese Arbeit folgende Beiträge: (1) prototypische Systeme zur Verbesserung der körperlichen Aktivität, des achtsamen Umgangs mit Bildschirmen und der sozialen Interaktion, (2) Feldevaluierungen von Technologien zur Verhaltensänderung am Arbeitsplatz, (3) einen umsetzbaren Gestaltungsrahmen, der wichtige Gestaltungsdimensionen hervorhebt und die Literatur für künftige Entwickler von Technologien zur ethischen Verhaltensänderung kategorisiert, und (4) eine Reflexion über ethische Verhaltensänderung. Abschließend diskutieren wir offene Herausforderungen für das Feld und die Umsetzung der Forschung in die Praxis. Diese Arbeit zeigt das Potenzial von Technologien zur Unterstützung gesünderer Arbeitsplätze ohne Produktivitätseinbußen auf, indem sie konkrete Lösungen und ökologisch validierte Feldbewertungen liefert. Indem wir für die Integration von Prinzipien des Wohlbefindens in die Arbeitsplatzgestaltung eintreten und nutzerzentrierte Ansätze für Technologien zur Verhaltensänderung betonen, legt unsere Arbeit den Grundstein für die Schaffung gesünderer und produktiverer Arbeitsplätze in der Zukunft.

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A Appendix **A 1**
A.1 Declaration on Writing Aids . . . . A 1

Publications

This is a cumulative dissertation made up of research that has been published in peer-reviewed venues. The publications contribute to the overarching narrative and represent the main body of this thesis. When referring to the publications, I use the format "[Core i]", with $i \in [1...8]$.

I also include six complementary publications, which I refer to with "[Pub i]", with $i \in [1...5]$. Specifically, we developed wellbeing interventions in [Pub1, Pub2], representing important aspects of the design framework in Section 4.1. The publications [Pub3, Pub4] contribute to the methodology discussion, and [Pub5] contributes empirical evidence that motivates core publications in this thesis.

[Core3] was honored with a *Best Paper Award* at the 2023 CHI Conference on Human Factors in Computing Systems, and [Pub3] received the *Best Paper Award* at the 2023 MUM Conference on Mobile and Ubiquitous Media.

Due to the collaborative nature of research, every publication was a joint effort with fellow researchers and students. As such, I use the scientific term "we" throughout the thesis except when specifically discussing my collaborations.

Core Publications

[Core1] Haliburton, Luke and Schmidt, Albrecht. 'Technologies for Healthy Work.' In: *Interactions* 27.3 (2020), pp. 64–66. DOI: 10.1145/3386391.

[Core2] Haliburton, Luke, Woźniak, Paweł W., Schmidt, Albrecht, and Niess, Jasmin. 'Charting the Path: Requirements and Constraints for Technology-Supported Walking Meetings.' In: *Proceedings of the ACM on Human-Computer Interaction*. CSCW '21 5.CSCW2 (2021), 347:1–347:31. DOI: 10.1145/3476088.

[Core3] Haliburton, Luke, Bartłomiejczyk, Natalia, Schmidt, Albrecht, Woźniak, Paweł W., and Niess, Jasmin. 'The Walking Talking Stick: Understanding Automated Note-Taking in Walking Meetings.' In: *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. CHI '23. New York, NY, USA: Association for Computing Machinery, 2023, pp. 1–16. DOI: 10.1145/3544548.3580986.

[Core4] Haliburton, Luke, Pirker, Benedikt, Holinski, Paolo, Schmidt, Albrecht, Wozniak, Pawel W., and Hoppe, Matthias. 'VR-Hiking: Physical Exertion Benefits Mindfulness and Positive Emotions in Virtual Reality.' In: *Proceedings of the ACM on Human-Computer Interaction* 7.MHCI (2023), 216:1–216:17. DOI: 10.1145/3604263.

[Core5] Haliburton, Luke, Kheirinejad, Saba, Schmidt, Albrecht, and Mayer, Sven. 'Exploring Smart Standing Desks to Foster a Healthier Workplace.' In: *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*. IMWUT '23 7.2 (2023), 57:1–57:22. DOI: 10.1145/3596260.

[Core6] Haliburton, Luke, Schött, Svenja Yvonne, Hirsch, Linda, Welsch, Robin, and Schmidt, Albrecht. 'Feeling the Temperature of the Room: Unobtrusive Thermal Display of Engagement during Group Communication.' In: *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*. IMWUT '23 7.1 (2023), 14:1–14:21. DOI: 10.1145/3580820.

[Core7] Haliburton, Luke, Lammel, Maximilian, Karolus, Jakob, and Schmidt, Albrecht. 'Think Inside the Box: Investigating the Consequences of Everyday Physical Opt-Out Strategies for Mindful Smartphone Use.' In: *Proceedings of the 21st International Conference on Mobile and Ubiquitous Multimedia*. MUM '22. New York, NY, USA: Association for Computing Machinery, 2022, pp. 37–46. DOI: 10.1145/3568444.3568452.

[Core8] Haliburton, Luke, Grüning, David Joachim, Riedel, Frederik, Schmidt, Albrecht, and Terzimehić, Nađa. 'A Longitudinal In-the-Wild Investigation of Design Frictions to Prevent Smartphone Overuse.' In: *Proceedings of the CHI Conference on Human Factors in Computing Systems*. CHI '24. New York, NY, USA: Association for Computing Machinery, 2024, pp. 1–16. DOI: 10.1145/3613904.3642370.

Complementing Publications

[Pub1] Sakel, Sophia, Blenk, Tabea, Schmidt, Albrecht, and Haliburton, Luke. 'The Social Journal: Investigating Technology to Support and Reflect on Social Interactions.' In: *Proceedings of the CHI Conference on Human Factors in Computing Systems*. CHI '24. New York, NY, USA: Association for Computing Machinery, 2024, pp. 1–18. DOI: 10.1145/3613904.3642411.

[Pub2] Terzimehić, Nađa, Haliburton, Luke, Greiner, Philipp, Schmidt, Albrecht, Hussmann, Heinrich, and Mäkelä, Ville. 'MindPhone: Mindful Reflection at Unlock Can Reduce Absentminded Smartphone Use.' In: *Designing Interactive Systems Conference*. DIS '22. New York, NY, USA: Association for Computing Machinery, 2022, pp. 1818–1830. DOI: 10.1145/3532106.3533575.

[Pub3] Haliburton, Luke, Rossmy, Beat, Schmidt, Albrecht, and George, Ceenu. 'An Exploration of Hidden Data: Identifying and Physicalizing Personal Virtual Data to Extend Co-located Communication.' In: *Proceedings of the 22nd International Conference on Mobile and Ubiquitous Multimedia*. MUM '23. New York, NY, USA: Association for Computing Machinery, 2023, pp. 210–224. DOI: 10.1145/3626705.3627788.

[Pub4] Van Koningsbruggen, Rosa, Haliburton, Luke, Rossmy, Beat, George, Ceenu, Hornecker, Eva, and Hengeveld, Bart. 'Metaphors and 'Tacit' Data: the Role of Metaphors in Data and Physical Data Representations.' In: *Proceedings of the Eighteenth International Conference on Tangible, Embedded, and Embodied Interaction*. TEI '24. New York, NY, USA: Association for Computing Machinery, 2024, pp. 1–17. DOI: 10.1145/3623509.3633355.

[Pub5] Chiossi, Francesco, Haliburton, Luke, Ou, Changkun, Butz, Andreas Martin, and Schmidt, Albrecht. 'Short-Form Videos Degrade Our Capacity to Retain Intentions: Effect of Context Switching On Prospective Memory.' In: *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. CHI '23. New York, NY, USA: Association for Computing Machinery, 2023, pp. 1–15. DOI: 10.1145/3544548.3580778.

1 INTRODUCTION

Advances in technology have transformed the modern office; knowledge workers (i.e., those dealing with information rather than physical tasks) complete more tasks in less time than ever before [161]. However, these advances are primarily propelled by a drive to boost productivity while the long-term wellbeing of those doing the work is often not sufficiently taken into account [129]. The modern office is highly digitalized with minimal physical movement, which improves efficiency and short-term comfort at the expense of long-term wellbeing [80]. Knowledge workers spend most of the day sitting at desks [37], working on computers [150], and communicating digitally [30]. This enables tasks to be completed faster and with less effort, but this rise in efficiency results in knowledge workers experiencing chronic sedentary conditions [37, 39, 40, 183], excessive screen time [92, 150], and social isolation [54, 104, 198], all of which have well-documented negative health implications [26, 29, 176, 177, 183, 192, 195, 199]. Any solutions to improve workplace wellbeing face the challenge of maintaining productivity in order for them to be adopted in industrial practice. One optimal solution is to incorporate healthy practices directly into work routines, which would benefit both employees and employers [35].

While the productivity-focused nature of the modern office can negatively impact wellbeing, many workers and employers take steps to improve work environments and create opportunities for healthy behaviors. The prevalence of standing desks in offices is one example. However, even when such solutions are present, uptake remains low in practice [194]. This mismatch between desired and actual behavior is known as the intention-behavior gap [53, 169]. According to behavior change theory, this gap can be overcome by combining sufficient motivation, abilities, and cues [56, 125]. We have seen in other areas, such as dieting [191] and fitness [190], that technology can help users overcome intention-behavior gaps, which motivates us to investigate technological solutions.

Together, workplace wellbeing is negatively impacted by two prominent factors: (1) productivity is prioritized at the cost of wellbeing, and (2) even when healthy interventions are present, users find it difficult to change their behavior. These two factors motivate our vision:

> **Vision:** To improve the wellbeing of knowledge workers by designing technology that (1) supports integrating healthy practices into work routines and (2) supports users in overcoming intention-behavior gaps in achieving wellbeing goals.

To strive toward this vision, this thesis considers two approaches: (1) expanding workers' opportunities for physically active ways of working and (2) actively nudging users with technology to overcome intention-behavior gaps. Both approaches attempt to modify worker behavior and are fundamentally behavior change technologies. In the first approach, providing workers with new capabilities to integrate healthy activities into work tasks is a passive approach to behavior change from a technology perspective. The technologies have active functions but do not actively nudge users to change their behaviors. In the second approach, we design active technologies to support users in attaining their behavior goals. The systems in this approach actively respond to users' behaviors and provide nudges at opportune moments. In particular, our work focuses on physical activity, screen time, and social isolation, all of which are documented issues in the modern office [39, 150, 198].

In this thesis, we contribute to workplace wellbeing by investigating the role of technology in supporting healthy workplace activities. In particular, our work is guided by three overarching research questions:

RQ 1: *What are the opportunities for designers to improve workplace wellbeing?*

RQ 2: *How can technology support users in integrating healthy activities into work routines?*

RQ 3: *How can we design technology to actively assist users in reaching their wellbeing goals?*

To answer the first research question, we outline a vision of healthy workplace technologies in an essay [Core1]. Using this vision as a basis, we incorporate perspectives from behavior change technologies, physiology, and other relevant areas of Human-Computer Interaction (HCI) to create a design framework for behavior change technologies. This framework is a tool for technology designers and researchers to identify potential solutions that can be applied to improving workplace wellbeing through technology.

To address the second research question, we conducted a series of investigations aimed at integrating physical activity into work routines. We first used ethnographic methods to gain a qualitative understanding of the needs, practices, and barriers of users who regularly practice walking meetings [Core2], a task that directly incorporates movement into a work routine. The insights from this investigation provided foundational knowledge about the requirements and constraints for technology-supported walking meetings. Based on these insights, we designed, implemented, and evaluated a tangible prototype that supports note-taking during walking meetings [Core3]. The results provided insights into how technology supports the integration of physical activity into work routines and how such technology can have a positive impact on the primary task. Following this, we explored whether physical exertion can be exploited as a design element [Core4]. We showed that physical exertion can create a sense of accomplishment and lead to mindful experiences for users. Exertion can, therefore, be used as a tool to enhance primary tasks or facilitate restorative breaks and create positive user experiences. The investigations in this segment are passive behavior change mechanisms in that they make healthy practices a more attractive option without actively nudging users or adapting to their behavior. The aim is for users to choose active ways of working of their own volition when the expanded capabilities are present. Overall, we provide an understanding of how to design technology to support users in integrating physical activity into work routines.

To answer the third research question, we conducted a series of investigations that employ active behavior change mechanisms. These mechanisms actively steer users toward specific behaviors but ultimately leave the decisions with the users. In our work, we take an ethical approach to nudging [179], where users are 'self-nudged' (e.g. [64]) toward their own behavior goals rather than toward the desires of an external party. In particular, we developed and evaluated solutions targeting three prominent issues in modern offices: physical activity [39], social isolation [198], and excessive screentime [198]. We first designed and implemented an autonomous standing desk controller and evaluated it with standing desk users in their workplaces [Core5]. We then used a thermal bracelet to provide real-time social signals to presenters during hybrid meetings to increase social connectedness [Core6]. Next, we designed a self-control box that helps users with excessive screen time and deployed it in the field [Core7]. Finally, we conducted a large-scale longitudinal field evaluation of a mobile app that aims to improve excessive screen time [Core8]. The first two investigations nudge users to increase their desired behaviors, while the last two help users to decrease their undesired behaviors. Three of the investigations were conducted in the field to increase ecological validity and understand how self-nudges impact user behavior in practice. Our findings provide insights into the effectiveness of self-nudge technologies and user preferences for adaptability and autonomy. When employed in an ethical manner, active behavior change technologies can be a powerful tool to help users achieve their behavior goals.

The structure of the thesis according to the three research questions, along with the corresponding chapters, are presented in Figure 1.1. Research questions 2 and 3 both have three additional sub-research questions introduced in their corresponding sections.

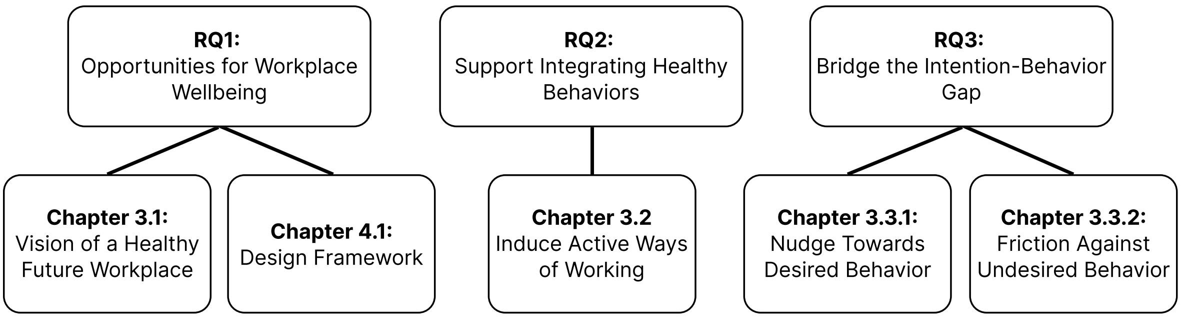

Figure 1.1: The structure of this thesis according to the three main research questions.

In all, this thesis contributes the following to HCI and the future of work: (1) technical prototypes designed to improve physical activity, mindful screen time, and social connectedness, (2) field evaluations of workplace behavior change technologies, (3) an actionable design framework that identifies key design dimensions to benefit future designers of ethical behavior change technologies, and (4) a reflective discussion on ethical approaches to designing behavior change technologies. We also discuss open challenges for increasing the real-world impact of research in the field. The work in this thesis makes strides toward our vision of a healthy and productive future workplace.

1.1 Research Approach and Methods

In the following section, we outline the methods employed throughout the investigations and reflect on our research approach at a high level to provide context for more specific discussions later in the thesis. Our work relies on fundamental research in HCI, psychology, design, computer science, and engineering. All of our research projects grew out of an examination of closely related literature to identify gaps where we could contribute knowledge.

1.1.1 Research Methods

We used a variety of methods in the contributing publications depending on the nature of their respective research questions. We used primarily qualitative methods when seeking to contribute constructive knowledge in formative studies such as [Core2, Pub3, Pub4]. We employed quantitative methods when seeking to quantify the impact of a system on users, such as in [Pub5]. Primarily, however, we used mixed-methods approaches to collect qualitative context for quantitative measurements, as in [Core3, Core4, Core5, Core6, Core7, Core8, Pub1, Pub2]. In the following, we will highlight particular methods used throughout this thesis and explain why they were chosen:

Controlled studies: In [Core3, Core4, Core6], we conducted our investigations in controlled or semi-controlled environments. In [Core3], it was essential for the participants to conduct walking meetings in a safe, outdoor space that was public but not overly busy. As the study used a between-subjects design, we deemed it important for the environmental experience to be relatively consistent across subjects, so we conducted the experiment in a semi-controlled outdoor space. In [Core4], our experiment required specialized equipment, including a Virtual Reality (VR) setup, a large treadmill, and a safety harness. Conducting this experiment in our lab was, therefore, not only a way to standardize the experience across users but also practically expedient. In [Core6], we created a simulated hybrid meeting scenario in the lab to mimic a real-life experience while enabling us to control the environment, audience, and other relevant variables.

Field Studies: We conducted field investigations in [Core5, Core7, Core8]. While field studies are less controlled relative to lab studies, they have increased ecological validity and allow us to investigate how users interact with technology in their regular routines and normal daily contexts [141, 154]. In [Core5], it was crucial for us to understand how the standing desk prototype functioned in the users' real workplaces and routines. For [Core7, Core8], both investigations concerned everyday phone use, so understanding how our systems impacted user behavior in the real world was a vital aspect of the respective contributions.

Questionnaires: We used questionnaires in every study included in this thesis. The questionnaires were typically a combination of demographics, standardized scales such as the NASA-TLX [77, 78], and custom questions relating to the specific research question. These enabled us to compare user perceptions and evaluate usability, cognitive load, and user experience, among other variables.

Log Data: We collected log data, information that is automatically and passively tracked throughout the study without requiring explicit user input, in [Core3, Core5, Core8]. We used multiple methods of obtaining logs, depending on the metrics required for each study. In [Core3], we recorded participant interactions using our prototype and analyzed the resulting conversation dynamics. In [Core5], we logged users' standing desk behaviors, and in [Core8], we logged smartphone interactions. In each case, the logs enabled us to observe user behavior without the filters or recall biases that may occur when participants complete questionnaires or interviews. Combining these logs with additional information from questionnaires and interviews results in more in-depth and meaningful insights.

Interviews: We conducted in-depth interviews as one of the primary methods in [Core2], and also included exit interviews in [Core3, Core4, Core5, Core6, Core7, Core8]. We recorded and transcribed all interviews and analyzed them through iterative coding processes with discussions in line with recommendations from Blandford et al. [19]. We used interviews to understand the experiences of expert participants in [Core2, Core7] and also to gain contextual understanding and qualitative insights into users' experiences when interacting with our prototypes and technological systems in the remaining publications.

Prototypes: We took inspiration from research-through-design approaches [201], whereby the process of designing and testing prototypes is used to learn about a topic. This approach could be similarly called research-through-prototyping or research-through-making [162]. In [Core3, Core4, Core5, Core6, Core7, Pub1, Pub2] we developed custom prototypes for the investigations. Using prototypes enabled us to gain a deep understanding as users interacted with our systems and contributed generalizable knowledge beyond the usefulness of the specific prototypes.

1.1.2 Reflection on Methods

We place a strong emphasis on mixed-methods evaluations in our work, especially for empirical contributions where the aim was to either learn more about people or about how people use a system [Core3, Core4, Core5, Core6, Core7, Core8]. This emphasis is important because there are complimentary advantages and disadvantages to both quantitative and qualitative approaches. We used quantitative methods based on measurements from sensors, logs, and validated scales. We employed statistical methods to identify variances and argue about performance and other important metrics. What was missing from quantitative data was additional context explaining the observed variances and the *why*. Qualitative methods, on the other hand, were well-suited to uncover contextual information and understand the motivations and perceptions of users. Based on their complementary strengths and weaknesses, it is clear that a combination where quantitative methods uncover significant variances and qualitative methods triangulate motivations and contexts to explain these variances is a potent approach to user research.

We also contribute several field studies, specifically in [Core5, Core7, Core8, Pub1, Pub2]. Prior research in HCI has called for more longitudinal and "truly in-the-wild" studies [101], while others have noted that long-term investigations are needed but rare in the field [153, 181]. Field studies are crucial to understanding how users interact with technology in the real world — it is the primary method for researchers to investigate how technology integrates into users' everyday routines and contexts [107]. In relation to the intention-behavior gap, lab studies could result in observing intentions without capturing real behaviors. As such, we made a point of incorporating field studies over relatively long time periods (2–15 weeks) compared to other HCI investigations, which often take place in a single session [101]. Due to this focus on field studies over longer terms, we contribute findings with high ecological validity that provide insights into user interactions with technology *in practice*.

We followed ethical and privacy-preserving approaches in all our research projects. We sought approval from our internal Ethics Review Board for all studies and followed standard procedures for informing participants about data collection and storage processes. All data are anonymized and stored in password-protected locations. We were particularly careful in designing a privacy-first approach in [Core8], which involved over 1,000 users of a commercial app. In this project, users were recruited through a pop-up banner in the app, and their data was completely anonymized from the outset, even from the researchers.

1.2 Research Context

This thesis is built on work that was conducted at the Chair for Human-Centered Ubiquitous Media and the Media Informatics Group at LMU Munich over approximately four and a half years. My work was primarily supervised by Prof. Albrecht Schmidt, who is the head of the research group. Throughout this time, I collaborated with researchers and project partners across multiple institutions to conduct studies, co-organize events, and co-author papers. These collaborations are highlighted in Table 4.3 at the end of the thesis.

Bavarian Research Alliance — ForDigitHealth: The majority of the work in this thesis was conducted in association with the Bavarian Research Alliance — ForDigitHealth. The ForDigitHealth research association connected five Bavarian universities across eleven project teams. In project *D10: Human-Centered Design Process to Improve the Impact of Digital Technologies* *on Mental Health*, we investigated how the design of digital technologies can be improved to account for the long-term wellbeing of users. The work conducted with ForDigitHealth resulted in several publications [Core1, Core2, Core3, Core4, Core6, Core7, Pub2, Pub5, 69, 70, 71, 73, 74].

Munich Center for Machine Learning (MCML): The final portion of this thesis was conducted as part of the Munich Center for Machine Learning (MCML) at LMU Munich. The MCML connects fifty principal investigators and over 100 PhD students from LMU Munich and TUM who are researching AI-related topics. Within project *C5: Humane AI*, we investigate human-computer interaction and other human-centered AI topics. The work conducted with MCML resulted in several publications [Core5, Core8, Pub1, Pub3, Pub4, 67, 68, 72, 84].

1.3 Summary and Overview of the Thesis

This thesis is organized into four chapters. Chapters 1 and 2 introduce the main topics of the thesis, outline important foundational concepts, and provide other relevant background information and definitions. Chapter 3 introduces the core publications and outlines how they contribute to the research questions. The publications make theoretical, empirical, artifact, and opinion contributions [196] to the field, as outlined in Table 1.1. In Chapter 4, we construct a design framework, reflect on our contributions to HCI research, outline a research agenda for future work, and provide concluding thoughts.

1.4 Papers and Contributions

The methods and contributions for each core publication are summarized in Table 1.1. The contributions are based on the classifications developed by Wobbrock and Kientz [196].

Table 1.1: Methods and contributions for each of the contributing publications.

Paper	Methods	Contributions [196]
	RQ1: What are the opportunities for designers to improve workplace wellbeing?	
[Core1]	Essay and philosophical exploration	*Opinion:* Criticism of status quo & vision for a future with healthy work technology
	RQ2: How can technology support users in integrating healthy activities into work routines?	
[Core2]	1. Online questionnaire (N=91), expert interviews (N=6) 2. Design fictions, online questionnaire (N=80), expert interviews (N=4)	*Empirical & Theoretical:* Interviews & Requirement space for technology-supported walking meetings
[Core3]	Outdoor lab study (N=60) with logs, questionnaires, interviews	*Artifact & Empirical:* Walking Talking Stick prototype & mixed-method lab study
[Core4]	Lab study (N=24), VR on a treadmill with questionnaires, interviews	*Artifact & Empirical:* Custom VR environment & mixed-method lab study
	RQ3: How can we design technology to actively assist users in reaching their wellbeing goals?	
[Core5]	Nested within-between-subjects field study (N=15) in users' places of work, with questionnaires and interviews	*Artifact & Empirical:* Standing Desk Controller prototype & mixed-method field study
[Core6]	Lab study (N=20), presentations with eye-tracking, questionnaires, interviews	*Artifact & Empirical:* Thermal bracelet controller & mixed-method lab study
[Core7]	1. Expert interviews (N=6), online questionnaire (N=71) 2. Within-subjects field study (N=10) with questionnaires and interviews	*Artifact & Empirical:* Phone Box prototype & mixed-method field study
[Core8]	Longitudinal field study with mobile logging data (N=1,039), survey (N=249)	*Empirical:* Mixed-method longitudinal field study

2 BACKGROUND AND DEFINITIONS

"The first misconception is that it is possible to avoid influencing people's choices."

– Richard H. Thaler.
***Nudge: Improving Decisions About Health, Wealth, and Happiness*.**
2009.

This chapter delves into two central themes: behavior change and technologies for healthy work. We first provide an overview of behavior change theories and discuss delivery modes, ethics, and evaluation methodologies. We then expand on workplace wellbeing technologies and related work in HCI. Relevant related work is also presented in the respective publications.

2.1 Behavior Change Foundations

Historically, behavior change stems from the psychological concept of behaviorism [79], which posits that human behavior is determined by conditioning. Behaviorism claims that we can modify behavior in a predictable manner by adjusting the conditions to which an individual is exposed, meaning behaviors can be generally predicted and trained. Relatedly, operant conditioning [175] treats behavior as unconscious responses to external stimuli.

Other theories more directly consider internal factors. The Theory of Planned Behavior (TPB) [4, 41], for instance, claims that intentions are the best predictor of behaviors. Intentions are impacted by behavioral attitudes (personal beliefs towards the behavior), subjective norms (social support), and perceived behavioral control (expected capabilities to perform the behavior). In Persuasive Computing, Fogg [56] identified three key factors for a behavior change: motivation, ability, and a trigger. Similarly, Michie et al. [125] identify motivation, capabilities, and opportunity as the core sources of behavior in their Behavior Change Wheel.

According to Self-Determination Theory (SDT), there are three basic psychological needs that drive our motivation: autonomy, competence, and relatedness [157, 158, 159]. Autonomy is the need to make our own choices, competence is the need to feel that we are capable, and connection is the need to feel that we belong. These three factors appear frequently throughout this thesis in the design of prototypes and in ethical discussions in Section 4.2.

More recently, researchers have combined elements of existing theories to create integrated behavioral models. The Transtheoretical Model (TTM) (a.k.a. the states-of-change model) [143] draws from several previous theories and defines five stages describing how behavior is adopted: pre-contemplation, contemplation, preparation, action, and maintenance. Similarly, Hagger and Chatzisarantis [65] proposed the Integrated Behavior Change

Model (IBCM), which incorporates concepts from both the TPB and SDT. The IBCM has been show to have greater predictive power for initiating behaviors compared to the TPB [127]. Other researchers combined the TPB and SDT to develop interventions based on autonomous motivation and found that this improves intentions, but fails to change behavior in a randomized control trial [28]. This misalignment between intentions and behaviors is a phenomena known as the intention-behavior gap [53, 169].

Recently, Rapp and Boldi [148] proposed a new existential model of behavior change that incorporates life circumstances and personal meaning into behavior decisions, attempting to account for both internal and external factors that influence motivations and behaviors. Their approach takes a phenomenological perspective that aims to consider users' lived experience of behavior change, rather than treating behavior as an independent quantity.

2.1.1 Behavior Change Technology

In HCI, designers and researchers operationalize cognitive and behavioral theories into technological implementations. Developers create systems to support users in changing their behaviors. Recent reviews on workplace sedentary behavior [45] and health behavior change technologies [188] report that the TTM [143] is commonly employed in HCI research on behavior change technologies. Other recent reviews (e.g., [135, 140, 153]) additionally found the Health Behavior Model (HBM) [156], dual system theory [91], the Social Cognitive Theory (SCT) [11], goal setting theory [111], and operant conditioning [175] to be the most common theories referenced in behavior change HCI.

Pragmatically, behavior change technologies are any systems that work to modify users' behaviors from an initial state towards a desired state, using various behavior change techniques. This high-level definition of behavior change technology is represented in Figure 2.1.

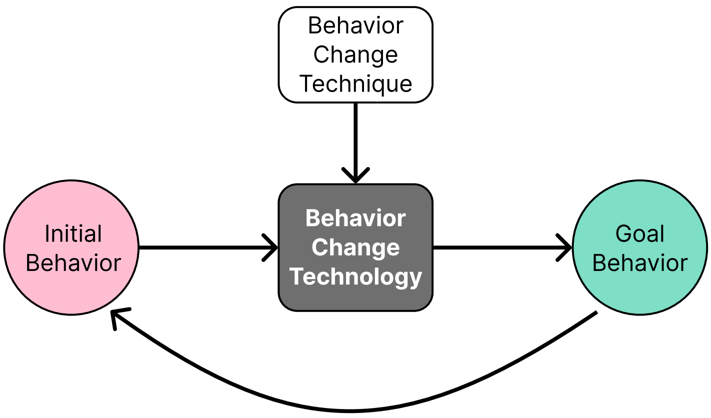

Figure 2.1: Behavior change technology, at a high level, is the technological implementation of behavior change techniques to steer an initial behavior toward a goal behavior.

Michie et al. [124] developed the Behavior Change Technique Taxonomy (BCTTv1)[1], a hierarchical taxonomy of 93 distinct behavior change techniques in an effort to standardize reporting on interventions. Two reviews in HCI have used the BCTTv1 to classify behavior change technologies for physical activity [185] and general health [188]. However, the BCTTv1 was not specifically developed from a technological perspective, and according to Wang et al. [188], HCI researchers often additionally use terminology from Persuasive System Design (PSD) [132] and Persuasive Technology [55]. One review incorporates the BCTTv1 with other frameworks [85], while others use different classifications and terms for behavior change techniques, such as processes of change [21], persuasive design [135], or a combination of sources [45]. While the lack of consistent terminology can make reporting on techniques difficult, we will use the BCTTv1 by Michie et al. [124] as it is established and comprehensive.

Behavior change technologies are relatively common in health- and wellbeing-focused research in HCI. In such applications, researchers investigate how different methods of interaction impact the behaviors of users and attempt to steer them toward healthy behaviors. For example, one group used an interactive painting to nudge users toward healthy eating habits [130], while another found that reminders and gamification were effective for diabetes-related applications [106]. Multiple researchers have developed tools to aid users in managing smartphone overuse (e.g., [82, 97, 98]). We also contributed in this area by developing a mobile app, MindPhone, which interrupts users when they unlock their phone and poses questions about their intended behavior either on the phone or in real life in an attempt to make smartphone use more mindful [Pub2]. Further, in this thesis, we contribute an investigation of a physical prototype [Core7] and a large-scale longitudinal in-the-wild evaluation of a commercially available mobile app [Core8], both targeting smartphone overuse.

Behavior change technologies influence users to varying degrees depending on their mode of action. This spectrum of influence is nuanced, personal, and context dependent. For example, the standing desk controller in [Core5] directly influences users. The *Walking Talking Stick* [Core3], conversely, does not adapt to behaviors, and is designed to inspire users to walk more often rather than actively nudging them. However, the degree of influence of the *Walking Talking Stick* can vary significantly depending on workplace culture and an individual's position within the social constelation. If a manager starts using the stick regularly, this may apply hierarchical pressure to others in the office. If one employee does not want to use the stick, but all their coworkers regularly use this, that person may feel socially isolated in the office. In this manner, the spectrum of influence is not solely delineated by the design of the technology, but is influenced by various contextual factors.

2.1.2 Nudging

One prominent mode of action for behavior change is called "nudging." Nudging, borrowed from behavioral economics, is a behavior change tool that works by influencing an individual's

[1] https://www.bct-taxonomy.com

choice architecture in a way that predictably impacts their behavior [179]. A nudge should not completely block or forbid an option or fundamentally change the incentives to choose a certain option. A cash reward, for example, would not qualify as a nudge. Placing an item at eye level in a supermarket to encourage users to purchase it would be an example of a nudge. Nudging has been effectively employed in policy [9, 76], marketing [179], and technology design [42, 133]. For example, a systematic review evaluating whether nudge strategies are effective in changing dietary choices found a 15.3% increase in healthy food decisions [9].

Definition — Nudge

A **nudge** is anything that influences choice architecture in a way that predictably alters people's behavior without strictly forbidding options or markedly changing their economic incentives. Nudges, according to nudge theory, allow individuals to maintain freedom of choice but influence the parameters that impact said choice. Nudges should be relatively easy to avoid if a person chooses but will increase their likelihood of behaving in a specific manner.

Nudging is centered around the concept of choice architecture, which represents the structure in which a choice is presented to an individual. It follows that the manner in which a choice is presented will impact the resulting decision [179]. In any given decision, there are numerous factors that impact the choice, and nudging attempts to manipulate some of these factors to predictably influence the choice an individual makes. Nudging can impact decisions positively or negatively. For example, providing a 'default' option modifies choice architecture. In a positive implementation, countries where people are enrolled as organ donors by default have significantly more organ donations compared to those where people must opt in [88, 170]. Default architecture can also be used as a dark pattern. We see that users are significantly more likely to consent to cookie banners and share data when the "accept" button is highlighted as the default [14].

HCI researchers have applied the nudge concept to numerous behavior change interventions. Purohit et al. [144] nudged users away from social media addiction and Jurczyk et al. [90] nudged workers to take more breaks. A systematic review by Caraban et al. [25] classified 23 nudge mechanisms into three types of triggers: sparks, facilitators, and signals. Sparks increase motivation, facilitators make tasks easier, and signals provide cues. These triggers directly map to the behavior change framework by Fogg [56] introduced earlier, which outlines motivation, ability, and prompting as necessary for a behavior to occur.

2.1.3 Ethics of Nudging

Nudging approaches are closely related to Persuasive Technology, which has been criticized in HCI literature for practical and ethical reasons, particularly for infringing on individual autonomy [152, 171, 174, 200]. Similar ethical discussions can be found in prior work on nudging. Proponents of nudging maintain that the aim is to improve the direction of decisions while maintaining freedom of choice [179]. On the other hand, some researchers claim that nudging is always manipulation, even when it is well-intended [193].

Nudges can be classified on a spectrum ranging from simply providing information to full-on behavioral manipulation [10]. Hansen and Jespersen [75] argue that nudges can be classified into four categories with varying degrees of acceptability. The classification has two dimensions: Non-transparent to Transparent and Type 1 (automatic) to Type 2 (reflective). The Type 1 and Type 2 dimensions are tied to dual systems theory [91], where Type 1 represents fast, automatic, intuitive decisions and Type 2 represents slow, reflective, conscious decisions. The four classifications from Hansen and Jespersen [75] are (1) Transparent Automatic nudges, which influence behavior; (2) Transparent Reflective nudges, which prompt reflective choice; (3) Non-Transparent Automatic nudges, which manipulate behavior; and (4) Non-Transparent Reflective nudges, which manipulate choices. The four categories are shown in Figure 2.2. The latter two classifications (i.e., all non-transparent nudges) are essentially paternalistic interventions. Although they may be well-meaning, non-transparent nudges are problematic because they reduce user autonomy. An individual may choose a different behavior, but the lack of transparency makes this unlikely. Transparent Reflective nudges, on the other hand, may actually *increase* the agency of the user. As implemented in our work in [Core8, Pub2], nudges can be designed to interrupt automatic thinking processes to give the user space to reflect and make conscious decisions about their actions.

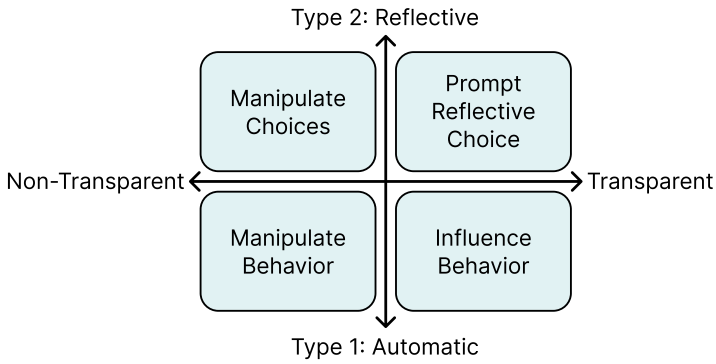

Figure 2.2: Four categories of nudges based on transparency and decision-making system. Adapted from [75].

In communication science, it has been said that “one cannot not communicate” [189]. We communicate information even when we avoid responding to a question. Regardless of our actions, explicit or not, we constantly communicate some information. We argue that a similar claim can be made for nudging: *one cannot not influence.* We are always influencing the decisions of others, whether we intend to or not. If a designer creates a recommender system to show healthy food first in an online store, they influence users toward choosing those items. If the designer chooses not to optimize for healthy food and instead displays items randomly, that is also a choice — the designer is, in fact, choosing *not* to emphasize healthy food. Any decision that is made has an influence on the choice architecture of the end user. This idea is supported by Thaler and Sunstein [179], who claimed it was impossible to avoid influencing users' choices. Additionally, this aligns with [151], who argued that design is *inherently* persuasive.

Beyond maintaining transparency, our work makes use of 'self-nudges,' which implies that the nudges are at some point initiated by the user and align with their own behavior goals rather than being influenced by an external party. Self-nudging has been used in related work on smartphone overuse [64] As an example, users in [Core8] are employing behavior change technology to curb their own excessive smartphone use, which would be categorized as a self-nudge. As a non-technological example, an individual could place their running shoes beside their bed before going to sleep to self-nudge themselves toward running more often. We argue that, in general, self-nudges are ethical nudges because they inherently maintain user autonomy and align with the users' values by definition.

Definition — Self-nudge

A **self-nudge** is any behavior an individual undertakes in order to influence their own choice architecture in a way that predictably alters their own future behavior without strictly forbidding options. Self-nudges may make use of tools and other active means but should be consciously initiated by the individuals themselves.

2.1.4 Technology Initiative in Behaviour Change

One fundamental dimension of behavior change technology is whether the technology plays an active role in the intervention. This is related, but not directly equal to, the Type 1 and 2 interventions proposed by Hansen and Jespersen [75]. While Type 1 and 2 refer to whether the intervention targets automatic or reflective decision-making, initiative refers to whether technology plays an active or passive role. In general, passive behavior change technologies will target reflective decision-making, while active technologies can more easily target automatic systems. For example, Fortmann et al. [58] used light-based cues to actively remind users to be physically active at work. Conversely, Damen et al. [46] developed a physical object that is available in meeting rooms to encourage standing and other active positions but does not feature active technology that pushes users towards specific behaviors.

Other previous work has categorized the activeness of technology as "pushing" or "pulling" [119]. A push-based nudge is active and provides a cue or nudge toward a specific behavior. Push-based approaches are likely to target automatic decision systems. Conversely, a pull-based nudge modifies choice architecture by making a specific choice more attractive, convenient, or beneficial, which motivates the user to select that option. Pull-based approaches typically target reflective decision-making. There are exceptions to this rule, however. For example, in [Pub2], we actively interrupted the user with the aim of short-circuiting the automatic decision-making process and giving users the opportunity to engage in reflective thought and make more conscious decisions.

In this thesis, we use passive approaches in our work on making walking meetings more convenient in [Core2, Core3], and using walking as a design element [Core4]. These projects target reflective decision-making and aim to induce change indirectly. We employ active methods to nudge users to stand more often in [Core5], helping users feel socially connected to virtual audience members in [Core6], and helping users manage excessive smartphone use in [Core7, Core8]. In these active approaches, the technology is directly involved in steering behavior change and aims to help users overcome intention-behavior gaps.

2.1.5 Evaluating Behavior Change Technology in HCI

Several researchers have criticized current methods of evaluating behavior change technologies in HCI. Klasnja et al. [102] notes that although there are numerous novel behavior change technologies being developed, we have not seen the level of impact that would be expected. They claim that HCI methods are not currently set up to use knowledge across projects and that we should adopt evaluations to focus on proximal outcomes (i.e., direct, observable outcomes on behavior or mechanisms). Specifically, they recommend that we design evaluations to investigate mechanisms and provide evidence for the following questions: *Is there an effect? Does the effect change over time? Who does the technology work for? In what contexts does the technology work?* In a similar line of argumentation, Rapp and Boldi [148] observed that behavior change technologies typically focus on the present moment and ignore meaningful other life circumstances surrounding individual users. In another work, Rapp et al. [149] identified behavior changes as internalistic, multiple, intentional, holistic, and continuous, which should be accounted for in the design and evaluation of behavior change technologies.

Past work has identified that long-term evaluations are scarce but needed in HCI [181]. Particularly in wellbeing and behavior change technology research, there have been numerous calls for more long-term field evaluations [153]. The need for long-term studies is motivated by the fact that the individual goals of users can change over time, and health benefits take time to manifest [131]. In particular, there is a need for more “truly in-the-wild” studies to understand the ecological validity of HCI developments and gain insights into how the technology impacts users in practice [101].

In response to these criticisms of current HCI evaluations of behavior change technologies, we conducted longer-term field studies in [Core5, Core7, Pub1, Pub2], and “truly in-the-wild” study in [Core8]. Conducting field studies over longer time periods enabled us to better understand how the systems impacted our users in their daily lives in practice.

Summary: Designing Ethical Behavior Change Technology

Behavior change technologies use various techniques to influence the choice architectures of users to steer them toward certain behaviors. For an ethical approach, we emphasize self-nudges, where users influence their own behavior rather than coercing users toward the behavioral desires of a third party. Maintaining transparency and steering users toward making more considerate choices can serve to *increase* user autonomy rather than the reduction associated with some behavior change approaches. While designers should aim to maintain as much user autonomy as possible, it must be recognized that every design decision influences users, and it is, therefore, our responsibility as designers to be intentional about how that influence impacts user behavior. Later in Section 4.2.1, we will further critically reflect on potential consequences of behavior change technologies and ethical approaches to designing them.

2.2 Technology for Workplace Wellbeing

Agreeing on a single definition for 'healthy work' presents a challenge, and we argue that the utility of such a definition is potentially questionable. A consensus definition would likely be either too prescriptive to apply to all users or contain so many caveats that it lacks any weight as a definition. Instead, it is more feasible to identify facets of 'unhealthy work,' which is typically characterized by excesses and insufficiencies. Unhealthy workplaces feature excess sedentary behavior, screen time, social isolation, psychological pressure, and unhealthy food, coupled with insufficient physical movement, social interaction, psychological resilience, nutrition, and sleep.

There is myriad evidence supporting the negative health outcomes of these unhealthy work characteristics. For example, excessive sedentary behavior (sitting too long, too often) has proven consequences for cardiovascular health [57], diabetes [195], chronic pain [12], dementia [147], and overall mortality [138]. Similarly, all-cause mortality is increased by excessive screen time [29, 176, 177, 192], insufficient social interaction [15, 83, 163], and insufficient (or excessive) sleep [59, 62, 86]. Evidently, the consequences of unhealthy work can be significant, and all of these facets are often exacerbated in the modern workplace [23, 37, 54, 89, 139].

Consequently, rather than working toward an intangible ideal of a 'perfect workplace,' our work aims to mitigate unhealthy workplace characteristics. We consider healthy work to be a direction rather than a destination. In this manner, we are moving toward healthier working conditions without being limited to a single definition of a perfect end state. Our research recognizes that developing a healthy workplace is an ongoing endeavor requiring continual adaptation and improvement as technology, policy, and workplace cultures evolve over time.

2.2.1 Knowledge Worker Productivity

Traditionally, productivity was defined as the ratio of outputs to inputs [142]. According to the U.S. Bureau of Labor Statistics, labor productivity is total output per hour of labor[2]. More

[2]U.S. Bureau of Labour Statistics: `https://www.bls.gov/k12/productivity-101/home.htm#what-is-productivity/what-is-labor-productivity/2`.

recently, however, researchers have recognized that productivity is multifaceted and difficult to measure depending tasks, output, affective states, and other factors [100]. Compared to factory workers, for whom the traditional definition was developed, defining outputs for knowledge workers is especially challenging in terms of abstractness, intangibility, autonomy [34, 51, 87]. Given these factors, a fuzzy definition for knowledge worker productivity is the effectiveness with which an individual uses their time, resources, and skills to accomplish work-related goals. The diverse nature of knowledge work means that these goals could be planning, problem-solving, decision-making, researching, analyzing, or networking, among others.

2.2.2 Dimensions of Healthy Behavior

In designing for wellbeing in the workplace, we argue that a holistic approach should include all aspects of health. One useful framework is the in5 model proposed by m.c. schraefel [164], which defines five fundamental processes that are core to healthy human functioning. The in5 model consists of the following five dimensions: *move* (physical activity and sedentary behavior), *eat* (nutrition), *engage* (social interaction), *cogitate* (thinking, considering, mental processing), and *sleep* (quantity and quality). To consider workplace wellbeing holistically, designers should aim to optimize and balance each of these dimensions.

HCI researchers have investigated each of the five dimensions in the in5 Model [164]. For example, encouraging walking at work [3], motivating healthy eating [130], enabling reflection on social interactions [126], investigating the impact of air quality on concentration [172], and developing sensor-feedback systems for reflection on sleep habits [94]. In our work, we investigate technology within the *move* [Core2, Core3, Core4, Core5], *engage* [Core6, Pub1], *cogitate* [Core7, Core8, Pub2, Pub5], and *sleep* [Core7] dimensions.

2.2.3 Workplace Physical Activity in HCI

One of the primary ways that modern offices adversely impact knowledge worker wellbeing is through chronic sedentary behavior [39]. Most office workers do not get enough activity [40] and spend the majority of the day sitting [37, 183] despite well-documented evidence of the associated negative health outcomes [26, 96, 128]. The prevalence of physical activity as a target behavior in HCI is highlighted in a recent scoping review by Damen et al. [45], which analyzed tools to increase physical activity or reduce sedentary behavior in the workplace. Another recent review by Brombacher et al. [21] identified tangible behavior change interventions for the workplace and found approximately two-thirds of the papers targeted increasing breaksense, increasing physical activity, or incorporating physical activity into work tasks.

The most straightforward solution to sedentary office behavior is for workers to take more breaks from work routines, which has been shown to be effective [24, 105, 113]. A recent systematic review found that introducing active microbreaks improved worker wellbeing without degrading productivity [146]. However, a clear drawback of this approach is that it can interrupt and reduce productive time. Recent work shows that the number of projects aiming to increase the opportunities for physical activity in the office beyond taking breaks is relatively sparse [45].

One other approach in HCI to increase physical activity in the workplace is through information visualization. In particular, three projects used persuasive ambient light displays to increase reflection and physical activity by communicating physical activity [58], computer activity [22], or sitting time [120]. Using similar approaches, Moradi and Wiberg [126] developed two ambient displays based on a conceptual framework that describes movement patterns in a workplace, and Menheere et al. [122] created an ivy-growing chair to visualize sitting time. These visualizations aim to make workers more aware of their sedentary time, with the goal of encouraging them to take action and be more physically active. These approaches are passive, meaning that they do not directly nudge users toward a particular activity but rather provide them with information for reflection that they may not otherwise be aware of.

Another promising approach is integrating physical activity into work routines. As an example, a series of works in HCI investigates technology-supported walking meetings, which combines physical activity with productive meetings. One group developed a persuasive approach to nudge users into conducting walking meetings using a mobile app [1, 2, 3]. Another group investigated barriers and motivators [48] and went on to develop infrastructure-based solutions to encourage walking meetings [44] and facilitate periodic note-taking during walking meetings [47]. Our work contributes to this area by understanding requirements and motivations for walking meetings through ethnographic methods [Core2] and exploring a tangible prototype that supports real-time note-taking during meetings-in-motion [Core3]. Beyond walking meetings, other approaches to incorporating physical activity or reducing sedentary behavior during work routines include creating dynamic meeting rooms [46] and office spaces [49] to encourage movement and avoid extended sedentary positions. We also contribute to this area through an active autonomous standing desk that nudges users to stand more often while working [Core5].

Summary: Designing for Workplace Wellbeing

In striving toward a healthier workplace, designers should aim to mitigate unhealthy practices currently exacerbated by the modern office, such as excess screen time and insufficient physical movement. A holistic approach to workplace wellbeing involves optimizing the following five dimensions: *move*, *eat*, *engage*, *cogitate*, and *sleep*. The *move* dimension is particularly important in knowledge work due to the prevalence of chronic sedentary conditions, and the most promising method of increasing movement at work is by integrating it into work routines, which simultaneously benefits both the worker and the employer. In this thesis, we target the *move* dimension in [Core2, Core3, Core4, Core5], *engage* in [Core6, Pub1], *cogitate* in [Core7, Core8, Pub2], and *sleep* in [Core7].

3
DESIGNING BEHAVIOR CHANGE TECHNOLOGIES FOR WORKPLACE WELLBEING

"Thank you for helping Helpers Helping the Helpless. Your help was very...helpful!"

– Mrs. Duong.
***The Weekenders*. 2000.**

In the following chapter, we will introduce the core publications included in this thesis. The chapter is broadly structured by the three research questions, with sub-research questions introduced throughout. We first outline a vision for a healthy future of work, then discuss methods of inducing more movement at work by designing technology-supported methods to incorporate physical activity into work routines. Finally, we discuss active self-nudges to motivate users to achieve their own desired behaviors.

We will present the motivations, study designs, methods, and main findings of each publication throughout the chapter. Full citations are highlighted in grey boxes to clearly demarcate which sections correspond with which publications. A summary of the methods and contributions associated with each publication is presented in Table 1.1. Additionally, as all of the publications were collaborative efforts, the individual contributions of each co-author are clarified in Table 4.3.

3.1 A Vision of a Healthy Future of Work

In this section, we introduce the first included publication [Core1], which outlines a vision for wellbeing in the future of work. Overall, this chapter addresses **RQ1**.

RQ 1: *What are the opportunities for designers to improve workplace wellbeing?*

This chapter is based on the following publication [Core1].

Haliburton, Luke and Schmidt, Albrecht. 'Technologies for Healthy Work.' In: *Interactions* 27.3 [April 2020], pp. 64–66. DOI: 10.1145/3386391

In this paper, we lay out our vision for a technology-supported, healthy office. The motivation in the paper echoes the overall motivation of this thesis: the modern office is designed for productivity without explicitly considering the wellbeing of workers. In practice, this means that the office has been optimized for completing tasks with as little physical movement as possible in an effort to increase productivity. At the same time, much of our work is now fully digital, which drastically increases productivity and flexibility at the cost of reducing important face-to-face social interactions and short-circuiting our psychological reward system. Workers have no tangible evidence of the amount of work they accomplish in a day, which can be demotivating. We argue that much of the progress made in systems to support work has failed to consider the impact on the wellbeing of workers over the long term.

We provide three examples of how we can support a healthy workplace through technology, discussing walking meetings, face-to-face interactions, and increasing tangibility. Developing technology in these three domains could reduce sedentary behavior, increase social interactions, and improve the subjective feeling of accomplishment associated with completing tasks. These examples address three different fundamental human processes according to the in5 model [164]: *move, engage,* and *cogitate*. As introduced in Section 2.2.2, the in5 model is a framework for holistic wellbeing in technology design that defines five fundamental processes to human functioning: *move, eat, engage, cogitate,* and *sleep*. The *eat* and *sleep* dimensions may initially appear to be outside of the scope of healthy work as they are not primarily workplace-associated activities. However, both activities directly impact workplace performance and worker health and are directly affected by work schedules. We argue for a holistic approach to workplace wellbeing, and it is impossible to consider worker wellbeing as a whole without considering all five in5 processes. Consequently, we incorporate all five aspects into a design framework in Section 4.1.

Ultimately, this work calls for deliberately including the wellbeing of workers in the design process for workplace technologies. The vision outlined in this work directly motivated Section 3.2, where we develop technology to support users in integrating healthy behaviors into the workplace. While the primary motivation in [Core1] surrounds productivity-focused workplace progress, there have been numerous efforts recently by both workers and employers to make workplaces healthier [80]. However, due to the intention-behavior gap [53, 169], these developments see low uptake in practice. Overcoming the intention-behavior gap, therefore, comprises the second aspect of our vision for workplace wellbeing, and will be addressed by the works presented in Section 3.3.

3.2 Inspiring Change: Integrating Healthy Activities into Digital Work

In this section, we introduce three publications, [Core2, Core3, Core4], targeting the first part of the vision introduced in [Core1] by integrating physical activity into work routines. By making healthy modes of work more attractive, these works employ technologically passive nudges to induce users into choosing healthy behaviors of their own volition. Overall, this chapter addresses **RQ2** and the associated sub-research questions.

RQ 2: *How can technology support users in integrating healthy activities into work routines?*

3.2.1 Identifying User Needs to Support Meetings in Motion

This chapter is based on the following publication [Core2].

Haliburton, Luke et al. 'Charting the Path: Requirements and Constraints for Technology-Supported Walking Meetings.' In: *Proceedings of the ACM on Human-Computer Interaction*. CSCW '21 5.CSCW2 [October 2021], 347:1–347:31. DOI: 10.1145/3476088

The modern digital workplace features chronic sedentary periods. There is an abundance of evidence highlighting the negative health consequences of sedentary behavior (c.f., [26, 128, 183, 195]). Fortunately, walking counteracts these effects by improving cardiovascular health [128], risk of disease [26], depression [96], happiness [187], and creativity [134], among others. Despite this clear evidence motivating the need to incorporate more physical activity into the workday to break up extended sedentary periods, knowledge workers continue to spend most of the day seated [37, 183]. Recent evidence also highlights a lack of projects aiming to incorporate physical activity into productive office work [45].

In HCI, there has been a recent focus on walking meetings as a promising potential solution. One group used the persuasive method to motivate users to conduct walking meetings [1, 2, 3], and another used infrastructure-based methods to increase visibility [44] and enable periodic note-taking [47]. Walking meetings do not require any advanced technology — workers could simply elect to conduct almost any meeting while walking. However, walking meetings are, presently, not common practice. This mismatch between opportunity and practice suggests that there is more investigation needed, which motivated our work in [Core2]. This work investigates the following research question:

RQ 2a: *What factors motivate or prevent individuals from incorporating physical activity into productive work tasks?*

To address this research question, we used a mixed-method approach to elucidate the requirements and constraints surrounding technology-supported walking meetings. We interviewed users who actively incorporate walking into their regular work routines to establish domain knowledge and understand their practices and needs. We also conducted an online survey with users who had mixed levels of experience with walking meetings to understand a general perspective on the topic. Based on these two initial investigations, we developed four design fictions across two dimensions — space and time — and used them as probes to elicit feedback from the original early adopters via follow-up interviews and from general users via a second survey. Based on our findings, we developed a requirement space for technology-supported walking meetings. In particular, we uncovered several tensions between the needs of users, which could impact technology design decisions. This work contributes a foundational understanding of technology-supported walking meetings to inform future designers.

In line with Oulasvirta and Hornbæk [136], our work in [Core2] builds constructive knowledge that uncovers requirements and constraints applicable to future technology development.

Specifically, our work highlights that one crucial constraint for walking meeting technology is that users do not want it to interfere with the expected benefits of walking. Users want to continue to experience nature, enhanced creativity, and improved conversation dynamics. Another important finding is that note-taking is a key challenge that prevents walking meetings from being more widely applicable. These results motivated us to develop a prototype to support real-time note-taking during walking meetings, which we investigated in [Core3].

3.2.2 Designing Technology to Support Meetings in Motion

This chapter is based on the following publication [Core3].

Haliburton, Luke et al. 'The Walking Talking Stick: Understanding Automated Note-Taking in Walking Meetings.' In: *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. CHI '23. New York, NY, USA: Association for Computing Machinery, April 2023, pp. 1–16. DOI: 10.1145/3544548.3580986

In [Core3], we aimed to operationalize the constructive knowledge generated in [Core2] by designing and implementing a prototype to support note-taking during walking meetings. Past work used an infrastructure-based approach to create hubs for periodic note-taking on the move [47], but there was a lack of work investigating real-time, flexible note-taking on the move while maintaining the immersion and benefits of walking. As such, we conducted a research-through-design investigation to address the following research question:

RQ 2b: *How can technology support the walking meeting experience?*

In this paper, we designed and constructed a shared tangible recording artifact to facilitate note-taking during walking meetings. The artifact, called the *Walking Talking Stick*, is in the form of a height-adjustable walking staff with a 360-degree microphone mounted on the top along with a highlighting button. The device records audio during walking meetings and generates real-time transcripts. Users can press the highlighting button during the conversation to highlight the most recent statement in the transcript. We evaluated the device with 60 participants in a between-subjects study. One group used unobtrusive clip-on microphones to record their meeting, the second group used the *Walking Talking Stick* without the highlighting button, and the final group used the full version of the stick with the button. We found that the recording device gave users the confidence to conduct more complex meetings on the move and freed up cognitive resources as they no longer felt the need to memorize every detail of the meeting. The button induced more interactivity (turns per minute) and lower turn density (words per turn), which is, incidentally, a recommended conversation strategy to improve understanding.

The prototype we developed aligns with the requirements established in [Core2] because users can generate notes while they continuously walk, it does not detract from their experience of nature, and it improves their conversation dynamics. The prototype satisfies the tension identified in [Core2], where users want technology support without diminishing the benefits of walking. This investigation shows that through careful design, technology can improve the experience of walking meetings and increase their applicability to different types of meetings. This represents a practical step toward increasing the opportunities for knowledge workers to incorporate physical activity into work routines. From a social acceptability perspective, using the *Walking Talking Stick* in a real office could signal to other workers that the user is leaving the office for productive purposes rather than simply taking a break.

The approach in this paper is rooted in a pull-based nudge (i.e., the prototype makes conducting a walking meeting more attractive) to motivate behavior change without infringing on worker autonomy. Our work strongly motivates a longitudinal study in industry to investigate whether such a prototype increases how often workers initiate walking meetings in practice.

3.2.3 Using Physical Exertion as a Design Element

This chapter is based on the following publication [Core4].

Haliburton, Luke et al. 'VR-Hiking: Physical Exertion Benefits Mindfulness and Positive Emotions in Virtual Reality.' In: *Proceedings of the ACM on Human-Computer Interaction* 7.MHCI [September 2023], 216:1–216:17. DOI: 10.1145/3604263

Given the power of walking to impact users both physically [26, 96, 128] and cognitively [134, 187], we wanted to explore whether walking could be more than a secondary activity conducted for health purposes. As such, we investigated whether walking could be used as a design element to positively impact users' experiences and benefit primary tasks. Relatedly, previous gaming research found that body movement contributes to engagement and affective experiences [18]. Consequently, [Core4] addresses the following research question:

RQ 2c: *How can we use exertion as a design element to positively impact user experiences?*

We consider VR as a useful context for this investigation. In VR, users can teleport to any location imaginable with the click of a button without the need for effortful travel. In response to this phenomenon, we investigated whether walking up a virtual mountain contributes to the sense of accomplishment you feel when you reach the top. We designed a virtual environment featuring a path leading from a valley to the top of a mountain, looking over a picturesque landscape. Participants either walked (using a treadmill), rode a chairlift, instantly teleported, or teleported with a delay to reach the top. Through this study design, we investigated the impact of physical exertion, time, and visual movement on the experience of reaching the top of a mountain. We found that physical exertion (i.e., walking) significantly benefited mindfulness and wellbeing metrics relative to all other methods of transportation. In the paper, we propose that exertion can be used as a design mechanism to provide wellbeing benefits to users and help them feel more accomplished when completing tasks. In this manner, physical exertion can be used to enhance primary tasks or facilitate restorative breaks.

Movement can enhance work routines in other ways. Body motion is a crucial aspect of non-verbal communication [160], and physical activity enhances cognition [173, 180]. With the increasing prevalence of remote and hybrid meetings, where non-verbal signals are lacking [103], the need to develop methods to incorporate movement into work routines is growing more pressing. Although our investigation in [Core4] was conducted outside of the work context, the results provide insights that can potentially be generalizable. We found that walking can be used as a design element to create mindful experiences and induce a sense of accomplishment. These results suggest that technology designers should investigate methods of not only incorporating physical activity into the workplace but also deliberately using physical activity as an intentional part of their designs. One recent work has taken a step in this direction by introducing a physical step in sending an email [95]. The authors found that users accepted the additional step and had positive feelings toward it, although further research is required to uncover the long-term impact. Their work, combined with the fundamental findings contributed by [Core4], motivates further research in this area.

3.2.4 Summary: Motivating Users to Incorporate Physical Activity at Work

In this section, we presented three investigations contributing to **RQ2** and explored ways of integrating physical activity into work routines (i.e., meetings). We contribute constructive knowledge that informs design, developed a functional artifact, and conducted empirical investigations. In [Core2], we involved early adopters and practitioners of active ways of working to construct domain knowledge. Combining this domain knowledge with feedback from a wider audience enabled us to develop sets of design requirements and user needs before designing prototypes. This user-centric approach ensures that we understand problems and create solutions rather than creating solutions in search of problems.

The research in this section highlights passive pull-based approaches to motivate users to increase workplace movement. Our work, especially [Core3], increases visibility and expands capabilities to make active ways of working more attractive. This can increase motivation and induce users to choose walking meetings as an alternative to seated meetings. However, this method is passive in that we do not actively nudge users toward any decision, and they maintain autonomy. However, our work motivates the need to conduct additional long-term studies in real workplaces to understand whether passive methods lead to increased uptake in practice. Specifically, deploying a prototype similar to the *Walking Talking Stick* in an office could provide insights into initial uptake, usage, and dropout rates after the novelty effect wears off. Additionally, we could understand the practical utility by observing how workers use the prototype in their real work meetings, which have higher consequences than the simulated meetings in our study. These insights and observations would enable us to iterate on the prototype and inform the design of additional supportive technologies.

Incorporating physical activity into work routines synergistically benefits health and productivity goals. By increasing physical activity at work, workers naturally experience health benefits [26, 96, 128]. Additionally, as movement increases creativity [134], cognition [173, 180], and engagement [18, 17], the primary work routine also benefits. Technology designers can intentionally use physical exertion to increase the sense of accomplishment when completing tasks and can design a stronger affective experience [Core4, 18]. Together, the works in this section motivate additional efforts to develop technology-supported physical activity integrated into work routines to benefit all stakeholders in the workplace.

3.3 Prompting Change: Active Technology Approaches to Achieve Users' Behavior Goals

In this chapter, we introduce four publications, [Core5, Core6, Core7, Core8]. In [Core5, Core6], we aim to increase desired behaviors through active nudges, while in [Core7, Core8] we aim to decrease users' undesired behaviors through frictions. Frictions are design elements that intentionally impede users to prompt reflection [43]. The first paper aims to increase standing time without causing frustration, the second supports social connectedness during hybrid presentations, and the remaining two publications target excessive smartphone use. Overall, this chapter addresses **RQ3** and the associated sub-research questions.

RQ 3: *How can we design technology to actively assist users in reaching their wellbeing goals?*

3.3.1 Active Technology Approaches to Increase Users' Desired Behavior

In this section, we developed interventions to actively increase desired behaviors. The two publications in this section address **RQ3a** and **RQ3b**, which will be introduced in the following sections.

Using Adaptive Physical Prompts to Reduce Sitting at Work

This chapter is based on the following publication [Core5].

Haliburton, Luke et al. 'Exploring Smart Standing Desks to Foster a Healthier Workplace.' In: *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*. IMWUT '23 7.2 [June 2023], 57:1–57:22. DOI: 10.1145/3596260

As we have highlighted throughout this thesis, sedentary behavior is endemic in the modern workplace [37, 183], with negative consequences for the health and wellbeing of knowledge workers [26, 128, 183, 195]. One straightforward step to help workers sit less often is to introduce standing desks, enabling workers to periodically shift between sitting and standing while performing work tasks. Standing desks have been shown to reduce sedentary behavior, sitting time, and discomfort [31, 116]. However, long-term studies have found that a small fraction of users actually adjust their desks and use standing mode in practice [194]. This mismatch between desired behavior (i.e., standing desk users want to stand more often) and actual behavior (i.e., standing desk users continue to sit in practice) motivates the use of behavior change technology to encourage users to act according to their own desires. Prior work in HCI reports mixed feelings toward autonomous desks when they move regularly [99] and that interruptions from desks cause frustration [109]. Consequently, we developed an autonomous standing desk controller to investigate the following research question:

RQ 3a: *How can technology actively support users in increasing workplace physical activity without frustration?*

In this paper, we developed an open-source plug-and-play system to control standing desks remotely and enable them to move autonomously. We designed and constructed a custom Printed Circuit Board (PCB) that interfaces with several common standing desk brands, enabling us to imbue the desks with autonomous behavior patterns while allowing users to continue using the manual keypad controls. We recruited participants who already use standing desks and deployed the system in their existing workplaces. For one week, we collected data with the controller to measure users' baseline desk behavior. Following the baseline, users were assigned to one of three groups: interval, adaptive, or smart. In the interval condition, the desk moved to a standing position once per hour. In adaptive, the desk moved once per hour only if the user had not already stood in the past hour. Finally, the smart condition moved the desk when users had no computer activity for three minutes, aiming to move while they were away from the desk. We found that users stood more than baseline in all automated conditions, but interruptions caused frustration. Moving the desk while users were away was the most accepted mode, especially when the transitions to standing aligned with users' own mental model (e.g., wanting to stand after a lunch break). We contribute the open source control system and concrete design recommendations for autonomous standing desk behaviors that increase standing time without frustrating users.

Overall, our investigation uncovered design elements that can enable designers to build nudging systems that encourage users to act according to their own behavior goals without causing frustration. Crucially, as our investigation was conducted in the field in the users' actual workplaces, our findings have a high ecological validity. Avoiding interruptions, adapting to behavior preferences over time, and maintaining autonomy are all key design recommendations for this application. We maintain that the autonomous standing desk system represents an ethical nudge so long as it is used by users on their own desks to help them with their pre-existing desired standing behaviors. Specifically, the target user is a user who purchases a standing desk but finds that they continue to sit more often than they wish. Should such a system be forced on workers by their employers, this would no longer constitute an ethical self-nudge. In all, [Core5] presents a promising approach to reducing sedentary behavior in the workplace without inducing negative feelings for workers.

Using Thermal Feedback to Support Social Connection Across Distances

This chapter is based on the following publication [Core6].

Haliburton, Luke et al. 'Feeling the Temperature of the Room: Unobtrusive Thermal Display of Engagement during Group Communication.' In: *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*. IMWUT '23 7.1 [March 2023], 14:1–14:21. DOI: `10.1145/3580820`

Humans are social beings — social interactions significantly impact physical and mental health [16, 38, 199]. Online and hybrid communications are increasingly commonplace, but they lack many of the social and non-verbal aspects of communication that help us feel connected with one another. As a result, workers feel increasingly disconnected and lonely in the workplace [54, 104, 198]. Recent related work in HCI has investigated methods of sharing emotions and tangibly connecting communication partners over distances. In particular, researchers have used thermal signals to convey emotions. Thermal signals draw from relatable socio-thermal metaphors, where warmth represents closeness and coldness represents distance. Consequently, we developed a system to control a thermal bracelet to communicate affective signals in a hybrid meeting to investigate the following question:

RQ 3b: *How can technology actively support users in maintaining social connectedness over a distance?*

In this paper, we created a custom script to control a thermal bracelet to provide hot and cold signals to participants' wrists. We created a simulated hybrid environment where participants were tasked with giving presentations in front of an audience consisting of both virtual and in-person members. Each participant gave two presentations, one with and one without the thermal signals. We used a Wizard of Oz approach and simulated the affective signals from the audience during the presentations. We collected questionnaire responses and eye-tracking data and conducted exit interviews. We found that users understood the socio-thermal signals and experienced no increase in workload when receiving the signals while presenting. Our results show that thermal signals help users to feel more in tune with their audience, enhancing their perception of group-affective states. We contribute an exploration of thermal signals for group affect communication in a hybrid setting and concrete design recommendations for the field.

This investigation highlights how innovative technology can be used to re-establish social connections across distances, contributing to the second part of the vision introduced in [Core1]. In our setup, the participants received both positive and negative signals throughout their presentations. However, the results showed that negative feedback was distracting, while positive feedback boosted confidence. Based on this knowledge, a similar system could be constructed for co-workers to send supportive signals and foster a culture of social support and connectedness in a geographically distributed working environment. Our findings motivate the need for future research to investigate thermal-social signals in the field to understand the practical applicability of this approach.

3.3.2 Design Frictions to Decrease Users' Undesired Behavior

In this section, we investigated active methods of assisting users in decreasing their undesired behavior, specifically smartphone overuse. Modern knowledge workers conduct most of their work on computers and consequently experience excessive screen time [92, 150]. Chronic exposure to excessive screen time has proven connections with negative health outcomes [29, 176, 177, 192]. Beyond the necessary screen time associated with accomplishing work tasks knowledge workers also experience excessive mobile screen time, technology overload, and general distractions via non-work related content [117, 118, 150]. Past work has additionally shown that the mere presence of a smartphone triggers distraction [5, 182], which can detract from productive activities. Our work also found that short-form video formats, which are increasingly prevalent across media apps, significantly degrade prospective memory, a cognitive function critical for performing well at work [Pub5]. Considering all this evidence, it is crucial to investigate how to support workers in engaging with all forms of screen time mindfully. Together, the following two publications investigate the following research question:

RQ 3c: *How can we design frictions to help users reduce excessive smartphone use in practice?*

Self-Nudging with Physical Design Frictions in the Field

This chapter is based on the following publication [Core7].

Haliburton, Luke et al. 'Think Inside the Box: Investigating the Consequences of Everyday Physical Opt-Out Strategies for Mindful Smartphone Use.' In: *Proceedings of the 21st International Conference on Mobile and Ubiquitous Multimedia*. MUM '22. New York, NY, USA: Association for Computing Machinery, December 2022, pp. 37–46. DOI: 10.1145/3568444.3568452

Numerous past projects in HCI have used behavior change approaches to help users manage excessive screen time [82, 97, 98]. In this area, researchers find that users desire methods of controlling their own smartphone behavior [114, 115] and often regret their screen time in hindsight [112]. Consequently, there is a mismatch between desired behavior (i.e., being in control of when and how long to use a smartphone) and actual behavior (i.e., absentmindedly using a smartphone and being unable to stop). Similar to Section 3.3.1, this mismatch motivates the use of a behavior change approach to assist users in achieving their own behavior goals. While many previous approaches use on-device methods [82, 97, 98], we recognize evidence supporting that the device itself is problematic [5, 182] and therefore developed a physical approach.

In this paper, we investigated the impact of a physical self-nudge to improve mindful smartphone use at bedtime. The bedtime use case was motivated by initial interviews and related work. Phone use at bedtime deteriorates sleep quality and duration [13, 36, 52]. We constructed a simple box for users to place their smartphones in at night. The box does not lock and, therefore, represents a passive physical friction rather than a true preventative measure — users could, theoretically, bypass the box at will. We found that users with a high predisposition for absent-minded smartphone use experienced significant benefits from the box, although they experienced some frustration. Users without this pre-disposition, however, saw no change in their use and still experienced frustration. Our findings suggest that this type of physical friction should only be employed for users who are actively seeking to change what they have identified as problematic smartphone use and should not be used as a blanket measure for all users.

A Long-Term Field Evaluation of Digital Design Frictions

This chapter is based on the following publication [Core8].

Haliburton, Luke et al. 'A Longitudinal In-the-Wild Investigation of Design Frictions to Prevent Smartphone Overuse.' In: *Proceedings of the CHI Conference on Human Factors in Computing Systems*. CHI '24. New York, NY, USA: Association for Computing Machinery, May 2024, pp. 1–16. DOI: 10.1145/3613904.3642370

While push-based self-nudges are relatively common in behavior change technology investigations for wellbeing in HCI (e.g., [82, 97, 98]), there is a lack of long-term "truly in-the-wild" investigations to understand how these approaches work in practice [101, 153]. In response to this, we conducted a study using *one sec*[1], a commercially available mobile app helping users manage smartphone overuse. We selected *one sec* as an appropriate vehicle for research as it has a large user base and uses a design friction approach similar to [Pub2]. Through this approach, *one sec* interrupts the user when they attempt to open a target app and provides them with a default option to dismiss opening the app. The additional waiting time and presentation of a default option both modify the users' choice architectures and enable them to make more rational decisions about their consumption.

In this paper, we conducted a longitudinal field evaluation of a design friction intervention for smartphone overuse with organic existing users of *one sec*. We recruited 1,039 users to contribute their historical usage data, meaning the data represents their behavior before they were aware of being in a study. Additionally, we recruited 249 of those users to provide qualitative feedback through a survey. We analyzed the historical data to understand usage patterns in practice over the long term. We found that *one sec* reduced the frequency at which users attempted to open target apps and led to more intentional app behavior over time. We also found that users took spontaneous breaks from the intervention, typically on the weekend. Users demonstrated a spike in use immediately preceding these breaks, which quickly decreased after returning to *one sec*.

Our results in [Core8] demonstrate that a self-nudge approach can be effective in reducing excessive screen time and that the intervention remains effective over a long time period

[1] `https://one-sec.app/`, last accessed September 17, 2024

when users continue to engage with it. This suggests that self-nudge approaches have real-world applicability, as we have shown that they work in practice with real users who were biased by the presence of a study. We also found that screen time reduces sharply in the beginning and then flattens after approximately three weeks of use. This pattern suggests that conducting field studies for three weeks should be enough to capture the scale of the change in behavior. The investigations in closely related work (e.g., [Pub2, 82, 98, 97]) tend to last between two and four weeks, indicating that the current methods in the field are reasonably appropriate for capturing the magnitude of change. However, neither our work in [Core8] nor in closely related works are designed to characterize attrition rates for behavior change apps. We recruited existing users in our study and, therefore, inherently did not capture any users who dropped out. Other researchers typically recruit users specifically to participate in their studies for a set amount of time. As such, there is a need for further investigation into what proportion of users stick with self-nudge approaches over time in practice.

3.3.3 Summary: Active Behavior Change Technologies

In this section, we presented four investigations contributing to **RQ3** and explored using active technology to assist users in achieving their own behavior goals. In these investigations, we used active self-nudge approaches, meaning that the technology actively steered the user toward a specific behavior. In Section 3.3.1, the interventions aimed to increase desired behaviors, while those in Section 3.3.2 sought to decrease users' undesired behaviors.

Three of the four investigations were conducted in the field, providing insights into their real-world applicability and giving our results high ecological validity. Previous criticisms of behavior change technology evaluations emphasized the need to understand contextual information [148, 149]. In our field evaluations, the users incorporated the technologies into their daily routines, which helped to account for dynamic and individual contexts. The focus on field evaluations is motivated by several calls for more long-term field evaluations in HCI [101, 153, 181]. Our results indicate that the self-nudge approaches employed in behavior change technologies are effective in real-world contexts and persist over long periods.

In three of the publications [Core5, Core7, Core8], there was a mismatch between the users' desired and actual behavior. This mismatch motivates using technology to actively help users act in alignment with their own goals. In [Core6], users lacked the signals required to feel social connectedness, motivating a technological solution to bridge the gap. Across the investigations, we found approaches that users preferred (e.g., adaptive desks and positive feedback) and others that frustrated or discouraged users (e.g., interruptions and negative feedback). These findings can inform future designers of active behavior change technologies. We also found that for users who did not recognize a behavior mismatch in themselves, as in [Core7], the intervention was both ineffective and frustrating. This result and the effectiveness found for other users confirm that nudging should only target behaviors that users are already motivated to change. Overall, we found that adapting to user behavior and focusing on motivated users results in effective behavior modification with minimal frustration.

4
DISCUSSION

"The best way to predict the future is to design it."

– Buckminster Fuller.

The main objective of this thesis is to investigate methods to improve wellbeing in the future of knowledge work through technology. This objective is motivated by the state of the modern office, where advances aim to increase productivity without considering the needs of workers outside of accomplishing their primary tasks. As a result, workers experience chronic sedentary behavior, excessive screen time, chronic sleep deprivation, and a host of other conditions with proven adverse health outcomes. In response, this dissertation outlines a vision for designing a healthy future of work (**RQ1**) and explores two avenues through which technology designers can positively impact the workplace.

The first avenue we explore uses passive approaches to support users in integrating healthy activities into work routines (**RQ2**). Designers can strive to develop technologies that make healthy activities more convenient, visible, and practical. We operationalized this principle in three publications by investigating technology-supported walking meetings and exploring how walking can provide additional benefits to primary tasks. These approaches are inherently passive as they attempt to change user behavior by increasing visibility and convenience while the choice to change behavior remains with the users.

The second avenue through which technology designers can contribute to workplace wellbeing is through active self-nudge methods. In these methods, technology actively modifies the users' choice architectures to steer them toward their own behavior goals (**RQ3**). These methods are appropriate when users' desired behavior is misaligned with their actual behavior. In such cases, technology can be designed to assist users in acting according to their own desires, as opposed to persuading them to act differently. In four studies, we investigated active self-nudge interventions for sedentary behavior, social connectedness, and excessive screen time. We found that self-nudge approaches are effective in practice over time, but only when targeting users with a pre-existing desire to change their behavior.

In the remainder of this chapter, we will first construct a design framework based on the results of our investigations, learnings obtained while conducting the work, and related literature (Section 4.1). We will then reflect on our approach, behavior change technologies, and inclusivity in the future of work (Section 4.2). Afterward, we will outline open research challenges for the field (Section 4.3). Finally, we will discuss limitations to our work that should be considered when interpreting the results (Section 4.4).

4.1 Design Framework for Workplace Wellbeing Technologies

In the following section, we will develop a design framework for behavior change technologies for workplace wellbeing by drawing from our vision in [Core1] and from learnings gained throughout all the core and supporting publications and related literature. The aim is to provide a framework that can be used by future designers as a starting point for inspiration when designing behavior change technologies for the workplace and as a cataloging tool for researchers. This framework contributes to **RQ1** by formalizing the opportunities for designers to improve workplace wellbeing. The design framework has five key dimensions: *behavior*, *direction*, *initiative*, *time*, and *action*.

Behavior The *behavior* dimension is the target behavior the designer wishes to address. We draw from the in5 model by schraefel [164], which describes five primary processes that are crucial to a healthy human life: *move*, *eat*, *engage*, *cogitate*, and *sleep*. These dimensions, shown in Figure 4.1, stem from physiology research and have previously been used as a starting point for design [7, 8, 166, 165, 167, 168]. In this thesis, we target *move* [Core2, Core3, Core4, Core5], *engage* [Core6], *cogitate* [Core7, Core8], and *sleep* in [Core7].

Figure 4.1: Target behaviors for healthy behavior change technologies can be categorized within the five fundamental processes for health according to the in5 model [164].

Direction The *direction* dimension describes the desired direction of behavior change. Designers can determine the direction dimension by considering the differential between the initial and goal behaviors. Generally, a designer will aim to either increase a user's desired behavior or decrease a user's undesired behavior. The publications in this thesis work in both directions. For example, [Core3] aims to increase movement, while [Core8] aims to decrease excessive screen time. In some cases, both directions are sensible depending on the framing of the problem. For example, [Core5] aims to increase standing and decrease sedentary time simultaneously. The direction dimension is represented in Figure 4.2.

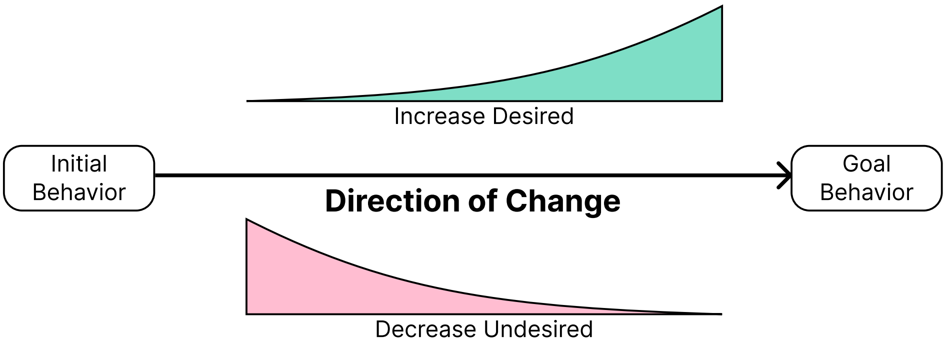

Figure 4.2: The designer determines the **Direction** of change by specifying the initial and goal behaviors. The differential between the initial and goal behaviors determines whether the technology should aim to *increase desired behavior* or *decrease undesired behavior*.

Initiative The *initiative* dimension describes whether the technology is active or passive in the intervention. For example, the box in [Core7] allows users to hide their phone from view and provides passive friction. On the other hand, the standing desk controller in [Core5] moves the desk into a standing position and actively encourages the user to stand more.

The *direction* and *initiative* dimensions can be visualized to describe four quadrants in the simplified module of the design framework. These quadrants represent four strategies for behavior change technologies. The quadrants are visualized in Figure 4.3, including the location of each core publication in the thesis.

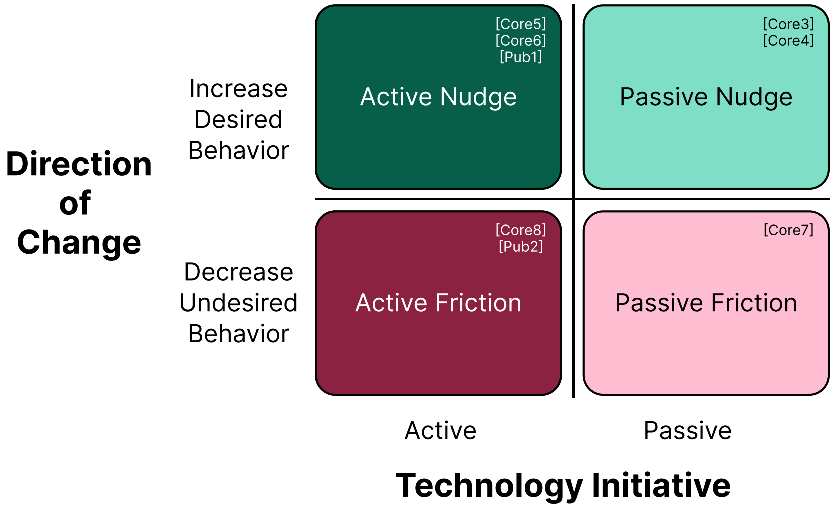

Figure 4.3: The first module of the design framework for health behavior change technologies. A designer first identifies their desired **Direction** of change based on the initial and desired behaviors. The designer can decide whether they prefer the intervention technology **Initiative** to be active or passive. The core (and two supporting) publications of this thesis are also shown in the appropriate locations.

There are additional dimensions beyond the *direction* and *initiative* that can help a designer in creating strategies for a behavior change technologies. These dimensions add complexity to the design framework but enable more specific recommendations for the mode of action. The additional dimensions are *time* and *action* and add to the modular framework.

Time The *time* dimension describes the point in time relative to the behavior when the intervention takes place. The intervention can occur before, during, or after the behavior occurs. For example, the *one sec* app in [Core8] interferes when a user attempts to open a target app and thus intervenes before their undesired behavior occurs. In [Core6], on the other hand, the device provides feedback during presentations and, therefore, influences the behavior as it is occurring.

Action The *Action* dimension describes the mode of action by which the technology interacts with the user. By adding the *time* dimension to the basic framework in Figure 4.3, we can identify twelve different modes of *action*. Each *action* represents a specific combination of *direction*, *initiative*, and *time*. The full design framework is visualized in Figure 4.4, including the thesis publications, and Table 4.1 provides descriptions and examples for each *action*.

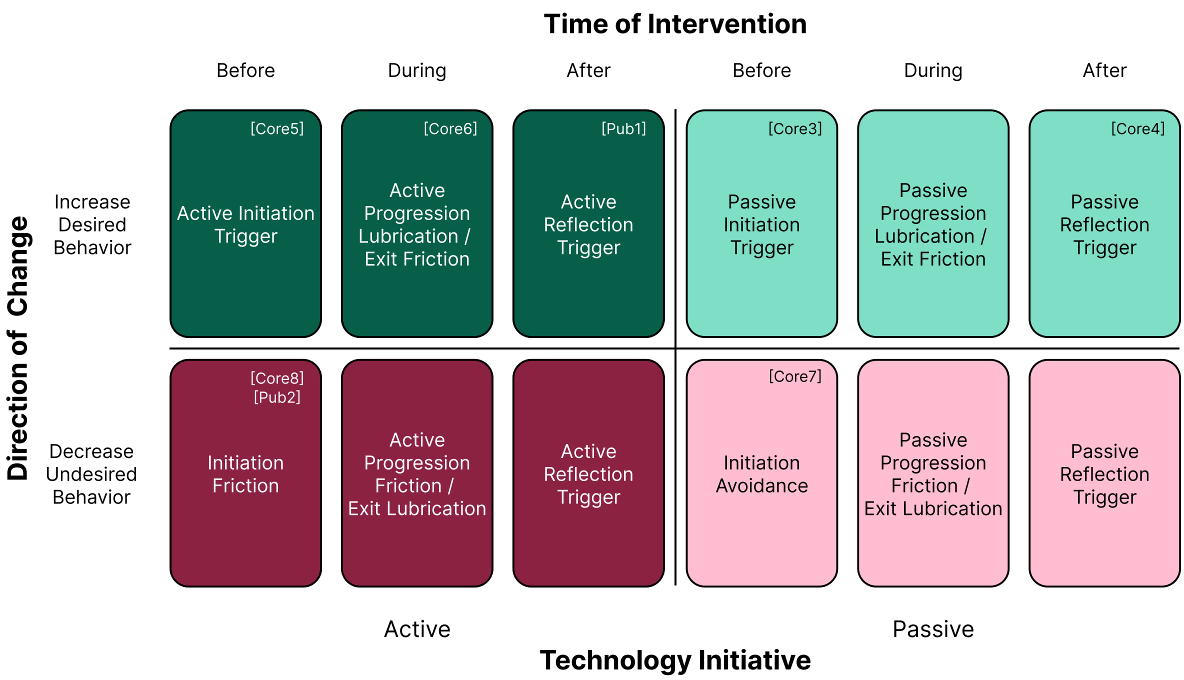

Figure 4.4: A design framework for behavior change technologies. A designer first identifies their desired **Direction** of change based on the initial and desired behaviors. The designer can then choose from 12 suggested modes of **Action** depending on their preference for **Time** of intervention and technology **Initiative**.

Table 4.1: Descriptions and examples for each **Action** in the framework.

Action	Description	Example
Active Initiation Trigger	Actively prompt or motivate the user to initiate the behavior.	[Core5] actively moves the desk to initiate standing.
Active Progression Lubrication/Exit Friction	Actively facilitate continuing the behavior or hinder ceasing the behavior.	[Core6] provides a thermal signal for social connectedness.
Active Reflection Trigger	Actively prompt the user to reflect on increasing the behavior.	[Pub1] reminds and facilitates journaling on social interactions.
Passive Initiation Trigger	Passively prompt or motivate the user to initiate the behavior.	The *Walking Talking Stick* visually triggers walking meetings [Core3].
Passive Progression Lubrication/Exit Friction	Passively facilitate continuing the behavior or hinder ceasing the behavior.	[47] facilitates periodic note-taking to keep walking meetings going.
Passive Reflection Trigger	Passively prompt the user to reflect on increasing the behavior.	[33] uses widgets to prompt reflection on sleep without notifications.
Initiation Friction	Actively hinder the user from beginning the behavior.	[Pub2] interrupts the user at phone unlock to avoid initiating.
Active Progression Friction / Exit Lubriation	Actively hinder continuing the behavior or facilitate ceasing the behavior.	[178] actively suggests real-world activities during smartphone use.
Active Reflection Trigger	Actively prompt the user to reflect on decreasing the behavior.	[6] notifies users about their phone use to prompt reflection.
Initation Avoidance	Passively help the user avoid cues that trigger initiating the behavior.	[Core7] removes the user's phone from sight to avoid initiating.
Passive Progression Friction / Exit Lubrication	Passively hinder continuing the behavior or facilitate ceasing the behavior.	[46] is furniture that subtly encourages users to avoid sedentariness.
Passive Reflection Trigger	Passively prompt the user to reflect on decreasing the behavior.	[155] tracks phone use for reflection without notifications.

The framework is both a tool for designers and a lens through which we can view related literature. In Table 4.2, we classify the system-based publications in this thesis using the framework. Additionally, we created an interactive tool at `https://behaviorchangedesign.net`, where researchers and designers can filter related work using the design dimensions and investigate the associated behavior change techniques according to the BCTTv1 [124].

Table 4.2: Classifying each of the system-based publications of this thesis in the design framework.

Paper	Behavior	Direction of Change	Technology Initiative	Time of Intervention
[Core3]	**Move**	**Increase Desired:** Aims to increase workplace movement (specifically walking).	**Passive:** The prototype does not actively nudge users to walk but rather makes walking meetings more attractive by supporting note-taking.	**Before:** The presence of the walking talking stick in the office is a passive cue to start conducting meetings on the move.
[Core4]	**Move**	**Increase Desired:** Aims to increase movement (specifically walking) during primary tasks.	**Passive:** The positive consequences aim to induce users to choose walking more often.	**After:** We highlight the reflective properties of walking, providing positive emotions to encourage repetition.
[Core5]	**Move**	**Increase Desired:** Aims to increase standing time in the office.	**Active:** The prototype moves the desk to nudge users to stand.	**Before:** The prototype nudges users to begin a standing session.
[Core6]	**Engage**	**Increase Desired:** Aims to increase social connection with virtual audience members.	**Active:** The prototype provides a thermal signal to connect the user with the audience.	**During:** The prototype provides real-time feedback throughout presentations.
[Core7]	**Cogitate**	**Decrease Undesired:** Aims to decrease smartphone overuse.	**Passive:** The box does not lock but is a passive barrier and removes devices from sight.	**Before:** The prototype aims to prevent the start of absentminded smartphone sessions.
[Core8]	**Cogitate**	**Decrease Undesired:** Aims to decrease smartphone overuse.	**Active:** The app actively interrupts the user with a popup.	**Before:** The app interferes as the behavior is about to begin.

4.1.1 Design Consequences For Workplace Behavior Change Technologies

The framework developed in Section 4.1 consists of actionable design decisions to guide developers of behavior change technologies. In making these decisions, there are several important design consequences that can occur as a result. In particular, this section discusses how design decisions can impact autonomy, workplace integration, and location and how these consequences can feed back into the decision-making process.

Autonomy Autonomy describes the level to which the user maintains control of their own behavior. Autonomy is motivated by different modes of delivering nudges, as introduced in Section 2.1.2. It is a continuum spanning from full autonomy, where users are completely free from external influence, to manipulation, where users are forced to make decisions they would not otherwise choose. Within this continuum is a usable spectrum inversely related to the *initiative* dimension. Passive approaches (e.g., [Core3]) lie at the end of the spectrum with higher autonomy. These approaches attempt to make one choice more attractive to induce users to choose it of their own volition. Conversely, active approaches (e.g., [Core5]) influence users' choice architecture to steer them toward a specific decision. Active approaches remove some autonomy relative to passive ones, but when designed correctly, they ultimately leave the decision up to the user [50, 179].

Integration Integration describes how well the intervention integrates into work routines. Integration is a continuum spanning from interrupting work to benefitting work. Within the continuum, a system might result in some benefit or hindrance to work routines without completely interrupting or benefitting. Technology-supported walking meetings, for example, provide cognitive and social benefits, leading to a net gain for both productive and wellbeing goals. The integration dimension is pragmatically important — interventions that decrease productivity, such as those focusing on increasing breaks beyond a certain limit, are less likely to be adopted in practice. Of course, we do not want to eliminate breaks, and microbreaks have been shown to improve wellbeing without impacting productivity [146]. However, recent work highlights that there are relatively few projects that incorporate physical activity into the workplace beyond taking breaks [45]. The integration dimension, therefore, translates into a design recommendation to *strive towards solutions that maximize benefits and minimize interruptions to primary work routines.*

Location The *location* consequence stems both from literature (e.g., a recent review by Brombacher et al. [21]) as well as from our holistic approach toward human health in the workplace. By considering all aspects of human health as important for workplace wellbeing, including sleep and nutrition, we inherently must consider activities both inside and outside the workplace. Consequently, *location* refers to whether the intervention specifically targets workplace activities or is applicable to life outside of work. Sleep-focused behavior change technologies (e.g., [Core7, 33, 94]) nearly always target non-work locations, but it is clear that work and sleep directly impact one another [20, 110, 186]. Sedentary behavior interventions, on the other hand, can more easily target the workplace directly (e.g., via walking meetings [Core3, 44]). Considering hybrid working models and home offices complicates the *location* dimension and introduces additional design opportunities. Home offices make it difficult to separate work and non-work activities and maintain work-life balance [81, 137]. Consequently, interventions targeting work tasks require additional considerations when workplace and home locations overlap.

4.2 Reflections

In the following section, we reflect on our approach, the ethics of behavior change technologies, and inclusivity in the future of work. It is crucial to critically reflect on any design endeavor, and this is particularly true for behavior change technologies. While we argue that it is important to maintain (or improve) productivity for interventions to be readily adopted in industrial practice, it is crucial that we are not reductionist in the notion of productivity. We should strive for individuals to be valued for more than just their productive contributions, especially since outputs from knowledge work are difficult to measure [87]. In line with this, rather than solely focusing on improving productivity, we aim to develop interventions that either do not interfere with or enhance work routines, with a primary focus on wellbeing.

Using behavior change technologies to overcome intention-behavior gaps risks creating situations where users depend on technology to modulate their actions without fundamentally changing their mindsets. Many interventions target behavior change without considering attitude change [184]. When we design behavior change technologies without reflection and mindfulness in mind, they tend not to impact attitudes, which breaks down over the long term [145].

In designing for workplace wellbeing, we typically design for the the 'worker.' While the term worker can broadly be interpreted as a 'user in an employment context,' there are additional meaningful implications. Given the hierarchical nature of work, workers experience power imbalances with their employers [123]. Work is also generally necessary to obtain the means to purchase the things we need to survive, which adds additional pressure to these hierarchies. In light of these asymmetrical relationships, the ethical implications of workplace technologies require careful consideration. Many of the same design principles required to make an effective positive behavior change intervention could also be used to develop a manipulative system. Behavior change approaches are powerful and prone to abuse, and this abuse *does* occur, as evidenced by the prevalence of dark patterns in everyday technologies [63]. Given this potential for abuse, it is important to study behavior change technologies to understand the approaches and impacts. We can use this understanding to design positive interventions and build the knowledge required to detect when behavior change approaches are being misused, enabling us to develop appropriate countermeasures. For example, a recent work developed methods to automatically detect dark patterns in mobile applications [32]. When researching behavior change technologies, it is essential that we critically reflect on our approaches. If the research community is working to understand and reflect on behavior change approaches, we can avoid leaving our users vulnerable.

Takeaway: Designing for workplaces involves considering users with asymmetrical power relationships. We must critically reflect when researching and designing behavior change technologies to understand both positive effects and potential avenues for abuse.

4.2.1 Reflection on Designing Ethical Behavior Change Technologies

While proponents of behavior change technologies maintain that they can be implemented ethically [179], they have been the subject of criticism in research communities [10, 75, 152]. The main debate concerns user autonomy and raises the question: *Do ethical behavior change technologies exist?* In the following, we propose design considerations to help designers create ethical behavior change technologies.

The most prominent criticism of behavior change technologies is rooted in their impact on user autonomy. Thaler and Sunstein [179], who popularized nudging, maintain that a properly designed nudge should steer users toward a specific behavior but ultimately leave the choice up to the user. This represents the most fundamental consideration in designing ethical behavior change technologies. Removing any opportunity for a user to decide their own behavior moves beyond nudging toward coercion. It is clear that users should maintain some level of autonomy and freedom of choice for a behavior change system to be considered ethical. Consequently, this raises the first design consideration: **(1) behavior change technologies should preserve user autonomy**.

As outlined by Hansen and Jespersen [75] and detailed in Section 2.1.3, any non-transparent nudge is ethically questionable since users are unaware that they are being manipulated. Transparency ensures that users are aware that technology is attempting to modify their behavior, allowing them to consider and reflect on the situation. Transparent nudges that prompt reflective choice can even increase user autonomy by providing them with an opportunity to make a more conscious and informed decision. This raises another design consideration: **(2) behavior change technologies should be visible and transparent to users**.

Another ethical dilemma arises when behavior change technologies are controlled by a third party. It is ethically questionable if an employer, a government agency, or simply another individual uses behavior change technologies to manipulate the behaviors of others. At best, such a scenario is paternalistic. At worst, this could enable individuals to manipulate users to act against their own interests. This differentiates nudges from self-nudges, which we introduced in Section 2.1.3. Users frequently desire to behave in a certain manner but fail due to the intention-behavior gap [53, 169]. People routinely use self-nudges to overcome this gap, such as when a runner places their running shoes near their bed to nudge themselves toward training more often. This highlights another design consideration: **(3) behavior change technologies should assist users in acting according to their own goals**.

Finally, imagine a company with a well-intended goal to improve the health of its workers. The company notices that although all employees have standing desks and have expressed an interest in standing at work, standing mode is not being used. The company then deploys the standing desk controller [Core5]. The users can adjust the settings for how often the desk nudges them, so they are in control of the technology, and it helps them reach their own goals. At this point, autonomy is maintained, and the technology aligns with the goals of the users. Now, imagine that the company offers better health benefits to users who stand more often or sells the standing behavior data to a health insurance company. Suddenly, the technology has become part of an ethically reprehensible system where users are punished or rewarded based on their standing behaviors. Workplace collection of health data has been shown to raise privacy concerns in workers [60]. Behavioral data is likely to be generated in most behavior change systems, as this data is typically used by the systems to adapt and enact behavior change strategies. This raises an additional design consideration: **(4) users of behavior change technologies should maintain control of their own behavioral data**.

The four design considerations in this section should increase the chances of a behavior change technology contributing positively to the wellbeing of users and minimize the chances of it being used unethically. However, we must always consider that even a carefully designed technology can be abused, which does not make the technology inherently unethical. In any case, as introduced in Section 2.1.3, every design choice ultimately influences users in some manner. We should, therefore, always consider how our designs impact users and strive to steer this influence in a positive and ethical manner. The design considerations outlined here are not exhaustive, and it remains an open research question as to how to ensure that behavior change technologies are designed and deployed ethically.

Takeaway: The ethical standing of behavior change technologies can be improved by implementing the following design considerations: (1) maintain user autonomy, (2) implement interventions transparently, (3) assist users in reaching their own behavior goals, and (4) ensure that users maintain control of their behavioral data.

4.2.2 Reflection on Inclusivity in the Future of Work

It is crucial that we design the future of work to be healthier for everyone. There is a tendency toward ableist solutions in research on workplace wellbeing. Increasing physical activity in the workplace is the most common approach to improving workplace wellbeing in HCI [45], and projects in this area encourage users to walk [Core3, 1, 44], or stand more [Core5, 99]. Wellbeing initiatives in industry regularly feature walking[1] and biking[2][3] competitions. Past work has found that fitness trackers are inaccessible for wheelchair athletes who do not take steps, as steps are the most common measure of activity in modern trackers [27]. In [Core7], we build off of research that highlights the visual distraction of smartphones [5, 182], but research in this field rarely, if ever, considers users with visual impairments.

In [Core2], we propose that walking meetings could be renamed to “meetings in motion” as an initial step toward increasing inclusivity in workplace physical activity research. From a publication perspective, however, changing terminology is inherently discouraged as it is

[1] `https://www.wellable.co/blog/setting-up-a-step-challenge/`, last acessed September 17, 2024

[2] `https://bikehub.ca/bike-events/go-by-bike-week`, last accessed September 17, 2024

[3] `https://bikeleague.org/events/bike-month/`, last accessed September 17, 2024

important to use common terminology and keywords to appear in search results. Beyond this challenge, changing the terminology alone will not solve the problem. Researchers need to make a concerted effort to include diverse user groups in needs-finding research and participatory design sessions to ensure that we design technology that improves the workplace for all. Co-designing with diverse user groups has been effectively employed in HCI for these purposes. For example, McDonnell et al. [121] co-designed video conferencing tools with users of mixed hearing abilities, Lazar et al. [108] co-designed a smartphone-based nutrition management system with users with Down syndrome, and Hakobyan et al. [66] co-designed a nutrition tracker for users with age-related macular degeneration. In industry, workplace wellbeing campaigns should be designed to account for users of all physical abilities and encourage healthy practices in an inclusive manner.

Takeaway: Workplace wellbeing research tends to be ableist in both language and approach. To rectify this, researchers should include users with diverse abilities in both the needs-finding and participatory design stages of their research.

4.3 Outlook: Open Challenges for Deploying Research in Practice

In order for research on workplace wellbeing to have a real impact, it must move from the lab to workplaces and be deployed in practice. This requires an increased focus on translational research [197], a concept borrowed from the medical field aimed at moving research into practice. Translational research, in our context, should be specifically aimed at longitudinal evaluations of workplace wellbeing technologies deployed in real workplaces. This would enable researchers to monitor the impact of the technologies and make adjustments in subsequent design iterations. Ultimately, this translational research is a transition from the novel technology being a *research project* toward being a *product*.

As discussed in Section 4.2.1, there are ethical considerations for workplace behavior change technologies regarding autonomy, transparency, and data privacy. These ethical considerations are already important in academic contexts, as it is crucial to design and evaluate technology with human users in a moral manner. However, these considerations become even more poignant when deploying technology in workplaces because researchers relinquish some control — less monitoring occurs and the consequences increase. Increasing our focus on translational research should work to maximize our understanding of the impact of research technologies in industrial practice and subsequently minimize the risk associated with releasing said technologies to the public. As highlighted in Section 4.2.2, it is crucial for researchers to consider accessibility and inclusivity in workplace wellbeing technologies. Consequently, this translational research should include participants with diverse abilities and backgrounds to holistically understand how users are impacted by the technology.

Previous ethnographic investigations with workers and other stakeholders can inform translational research for workplace wellbeing. Gorm and Shklovski [61] found that the wording used in workplace campaigns impacts worker perceptions. They report that framing a campaign as a health promotion rather than a behavior change effort can enable workers to participate more flexibly and consistently by redefining what "success" means. Kawakami et al. [93] found that workplace sensing is associated with concerns at individual, interpersonal, and organizational levels. The concerns stem from how the data is used and the associated goals. There is clearly a need for more studies that investigate how exactly wellbeing technologies should be implemented in practice, accounting for a diversity of stakeholders and workplaces.

Takeaway: We need an increased focus on translational research that aims to move research projects out of the lab and into real workplaces. This translational research should transform projects into products and consider the needs of relevant stakeholders.

4.4 Limitations

Although each publication in this thesis features a discussion of the respective limitations, there are several overarching factors that should be considered when interpreting the results.

The investigations in Section 3.2 aim to increase workplace physical activity. However, the *Walking Talking Stick* in [Core3] has not yet been evaluated in a real workplace, and the findings from [Core4] have not been operationalized into a work task. Given the emphasis on long-term field studies in this thesis, there is a clear motivation to evaluate these projects in real workplaces in the future. Relatedly, most of the studies in Section 3.3 were conducted in the field where we had less control over potentially confounding factors. In all, lab studies and field studies are complementary, and both should be used in end-to-end research projects.

The majority of the investigations in this thesis focus on sedentary behavior and physical activity. Although we discuss a holistic approach to workplace wellbeing and contribute studies targeting the engage, cogitate, and sleep dimensions, the move dimension receives the most attention. This focus is also reflected in the field as a whole, as highlighted in a recent review by Damen et al. [45]. This motivates future work to enact a more holistic approach to workplace wellbeing that more strongly considers dimensions outside of physical activity.

Additionally, our studies were primarily conducted at LMU Munich in Germany, so the participant pools were relatively homogenous. The participants were mostly from Western countries, able-bodied, and young. This homogeneity limits the potential generalizability of the research results. However, we maintained relatively balanced gender distributions in each project and recruited many participants (N=1,039) for [Core8] to increase diversity and generalizability. Particularly in light of the discussion on inclusivity in Section 4.2.2, there is room for researchers to deliberately include users with more diverse abilities and backgrounds to improve accessibility for all users.

4.5 Closing Remarks

This thesis strives toward designing a healthy future of work. We first provided a critique of the modern workplace, where wellbeing is a secondary concern after productivity, and outlined a vision for a healthy future office. Designing for workplace wellbeing involves creating opportunities to integrate healthy activities into work routines and assisting users in overcoming intention-behavior gaps. Based on these concepts, we introduced three investigations using passive methods to promote incorporating physical activity into work routines. Next, we presented four investigations using active self-nudges to assist users in acting according to their behavioral goals. Based on these investigations and related literature, we constructed a design framework that can serve as an actionable tool for future designers. This thesis also reflects on ethical behavior change technologies and discusses open challenges for increasing the real-world impact of this research field. By increasing the focus on translational research, HCI researchers have the opportunity to steer the future of work in a positive direction. The workplace is constantly changing with rapid technological developments, which are only accelerated by recent advances in artificial intelligence. We argue that if we do not intentionally design the future of work, then wellbeing will continue to be ignored in favor of productivity, and exploitation will only increase. Thus, researchers and practitioners must explicitly consider wellbeing in the workplace and deliberately strive toward a healthy and productive future. To ensure wellbeing in the future of work, we must create it.

Clarification of Contributions

Table 4.3 provides an overview of my contributions and the contributions of my collaborators on each of the core publications included in this thesis. As my primary supervisor, **Albrecht Schmidt** was involved in each project, providing guidance, ideas, and feedback. This role was consistent across projects, so I will not list these contributions individually.

Table 4.3: Clarification of contributions for all core publications included in this thesis.

	My Contribution	**Contribution of Co-authors**
[Core1]	I was the first author of the publication and led the writing. I collaborated with **Albrecht Schmidt** to develop the concept.	**Albrecht Schmidt** provided the initial outline, contributed to writing, and collaborated on developing the vision.
[Core2]	I was the project lead and first author of the publication. I conducted the interviews, contributed to the study design, led the data analysis, and led the writing.	**Jasmin Niess** and **Paweł Woźniak** contributed to the initial idea, study design, interview protocol, data analysis, and writing.
[Core3]	I was the project lead and first author of the resulting publication. I led the writing, conducting the study, and quantitative analysis. I contributed to the study design and qualitative analysis.	**Paweł Woźniak** contributed to the initial idea, study design, quantitative analysis, and writing. **Jasmin Niess** contributed to the qualitative analysis, study design, and writing. **Natalia Bartłomiejczyk** contributed to running the study and writing.
[Core4]	I co-led the project and was the first author of the resulting publication. I led the writing and collaborated on the initial idea.	**Matthias Hoppe** co-led the project and contributed to the initial idea and writing. **Paweł Woźniak** contributed to the study design, data analysis, and writing. **Benedikt Pirker** and **Paolo Holinski** developed the VR scene and conducted the study.
[Core5]	I was the project lead and first author of the resulting publication. I led the development of the control system (firmware and backend) and helped reverse engineer the desk. I installed the system for all participants, conducted the study, conducted all interviews, led the data analysis, and led the writing. I also contributed to the study design.	**Sven Mayer** was the primary supervisor and contributed to reverse engineering the desk, developing the software, the study design, qualitative and quantitative analyses, and writing. **Albrecht Schmidt** helped reverse engineer the desk and provided the wrote the activity detection code. **Saba Kheirinejad** contributed to the study design and writing.

Table 4.4: Continued from Table 4.3.

[Core6]	I led the project and was the first author of the resulting publication. I led the writing, collaborated on the initial idea, and contributed to the study design and analysis.	**Svenja Schött** implemented the prototype, conducted the study, and contributed to the initial idea, analysis, and writing as part of her Master's thesis. **Linda Hirsch** contributed to the study design and writing. **Robin Welsch** contributed to the study design, data analysis, and writing.
[Core7]	I was the project lead and first author of the resulting publication. I conducted the final data analysis, led the study design, and led the writing.	**Maximilian Lammel** carried out the interviews, constructed the prototype, and conducted the study as part of his Master's thesis. **Jakob Karolus** helped develop the study design and contributed to the writing and overall framing.
[Core8]	I was the project lead and first author of the resulting publication. I led the quantitative analysis and writing. I contributed to the study design, analysis strategy, designing the questionnaire, and overall direction of the project.	**Nađa Terzimehić** conducted the qualitative analysis and contributed to designing the questionnaire, the quantitative analysis, and writing. **David Grüning** contributed to the study design, data collection, analysis strategy, and writing. **Frederik Riedel** developed the app, recruited participants, collected data, and contributed to the research discussions.

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Glossary

BCTTv1 Behavior Change Technique Taxonomy

CSCW Computer-Supported Collaborative Work

HBM Health Behavior Model

HCI Human-Computer Interaction

IBCM Integrated Behavior Change Model

PCB Printed Circuit Board

PSD Persuasive System Design

SCT Social Cognitive Theory

SDT Self-Determination Theory

TPB Theory of Planned Behavior

TTM Transtheoretical Model

VR Virtual Reality

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A
APPENDIX

A.1 Declaration on Writing Aids

This thesis is composed of mine and my co-authors original thoughts an comments. As writing aids, I employed DeepL[1] to translate English text into German. I used ChatGPT[2] primarily for ideation.

[1] https://deepl.com/

[2] https://chatgpt.com/

Eidesstattliche Versicherung

(Siehe Promotionsordnung vom 12.07.11, § 8, Abs. 2 Pkt. 5)

Hiermit erkläre ich an Eidesstatt, dass die Dissertation von mir selbstständig und ohne unerlaubte Beihilfe angefertigt wurde.

München, den 29. Mai 2024

Luke Haliburton