Systems for Managing Work-Related Transitions

by

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This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Statement of Contributions

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The following list serves as a declaration of the Versions of Record for works included in this dissertation:

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Abstract

Peoples' work lives have become ever-populated with transitions across tasks, devices, and environments. Despite their ubiquitous nature, managing transitions across these three domains has remained a significant challenge. Current systems and interfaces for managing transitions have explored approaches that allow users to track work-related information or automatically capture or infer context, but do little to support user autonomy at its fullest.

In this dissertation, we present three studies that support the goal of designing and understanding systems for managing work-related transitions. Our inquiry is motivated by the notion that people lack the ability to continue or discontinue their work at the level they wish to do so. We scope our research to information work settings, and we use our three studies to generate novel insights about how empowering peoples' ability to engage with their work can mitigate the challenges of managing work-related transitions.

We first introduce and study *Mercury*, a system that mitigates programmers' challenges in transitioning across devices and environments by enabling their ability to continue work on-the-go. Mercury orchestrates programmers' work practices by providing them with a series of auto-generated microtasks on their mobile device based on the current state of their source code. Tasks in Mercury are designed so that they can be completed quickly without the need for additional context, making them suitable to address during brief moments of downtime. When users complete microtasks on-the-go, Mercury calculates file changes and integrates them into the user's codebase to support task resumption.

We then introduce *SwitchBot*, a conversational system that mitigates the challenges in discontinuing work during the transition between home and the workplace. SwitchBot's design philosophy is centered on assisting information workers in detaching from and reattaching with their work through brief conversations before the start and end of the workday. By design, SwitchBot's detachment and reattachment dialogues inquire about users' task-related goals or user's emotion-related goals. We evaluated SwitchBot with an emphasis on understanding how the system and its two dialogues uniquely affected information workers' ability to detach from and later reattach with their work.

Following our study of Mercury and SwitchBot, we present findings from an interview study with crowdworkers aimed at understanding the work-related transitions they experience in their work practice from the perspective of tools. We characterize the tooling observed in crowdworkers' work practices and identified three types of "fragmentation" that are motivated by tooling in the practice. Our study highlights several distinctions between traditional and contemporary information work settings and lays a foundation for future systems that aid next-generation information workers in managing work-related transitions.

We conclude by outlining this dissertation's contributions and future research directions.

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Dedication

I dedicate this thesis to my partner, Roya, who offered an unparalleled level of love, support, understanding, and flexibility in support of my pursuit of my doctoral degree.

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Chapter 1

Introduction

> What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it.
>
> – Herb Simon, 1969. [242]

Today, work is ever-populated with interruptions [263]. While working, for example, people may arbitrarily choose to pause one task to work on another task [178]. Alternatively, they may step away from their work entirely to temporarily distance themselves from their work mentally [254]. Often times, interruptions can be beyond the control of the individual, stemming from external sources such as an unexpected instant-message from a colleague [60] or office visit from a manager [87]. Regardless of why they arise or how they take shape, interruptions require oversight, management, and support to handle effectively.

Research has demonstrated that peoples' inability to navigate and manage interruptions effectively can yield significant consequences. Observational studies of information workers found that interrupted tasks can take upward of 25 minutes to resume [178]. Similarly, task interruptions lasting as little as three seconds can double peoples' likelihood of making errors in their work upon resumption [10]. Characterizing the problem beyond the scope of task interruptions, a 2005 study from Basex Research suggests that work-related interruptions cost the US economy approximately $588 billion a year [260]. With the rise of mobile computing experiences that sustain engagement through a barrage of notifications and alerts, it is not unrealistic to expect that interruptions and distractions may be even more substantial today.

Importantly, the impact of inadequately managed interruptions extends beyond the lens of efficiency and productivity. Studies in occupational health psychology suggest that people who more frequently experience task interruptions experience a 9% rate of work-related exhaustion and a 4% increase in physical health problems [168]. Beyond the work context, work often goes unfinished as people conclude their workday, which can challenge their ability to separate their work and personal spheres [253, 248, 255]. Beyond the workplace, the World Health Organization to recognize burnout as a "syndrome conceptualized by chronic workplace stress that has gone unmanaged" in 2019. [292] It is generally well-understood that interrupted work naturally yields increases in work-related stress, which is worsened further by interruptions that are inadequately managed [162, 179].

Interruption management, at its core, relies on a person's ability to manage their attention effectively. When experiencing an interruption, a person undergoes a *transition* – a process in which they subconsciously or consciously orient their attention away from what is at hand toward that which is interrupting. Theories and observational inquiries characterize the process as one that is cognitively challenging for people to perform due to the constraints and limitations of human cognition [8, 273]. Quantities of systems and interface research have explored techniques for mitigating the effects of interruptions by automatically offloading cognitive processes and maintaining an awareness of the user's context and state [19, 119, 120]. The majority of these systems were aimed at supporting scenarios that predate the fragmented nature of work today, which often not only takes place across a number of work-related tasks, but also across multiple devices and environments.

In this work, we explore two types of interactive systems that support peoples' work-related transitions. The foundation of these systems is built on the common goal of empowering peoples' ability to decisively reorient their attention both across and between different tasks, devices, and environments. Fundamentally, there are two strategies that can be employed for systems that enable such support:

- A system can better support people in discontinuing their work in such a way that allows them to orient themselves toward a different task, device, or environment; or
- A system can better support people in continuing their work in such a way that allows them to maintain their orientation to the task, device, or environment at hand.

Here, we explore these two strategies from implementation to inquiry. Our system designs are motivated by prior research aimed at better understanding the challenges of managing interruptions and transitions in practice. We translate these findings into opportunities for supporting transitions with new systems, tools, and techniques.

With this framing in mind, I now present the central thesis of this dissertation.

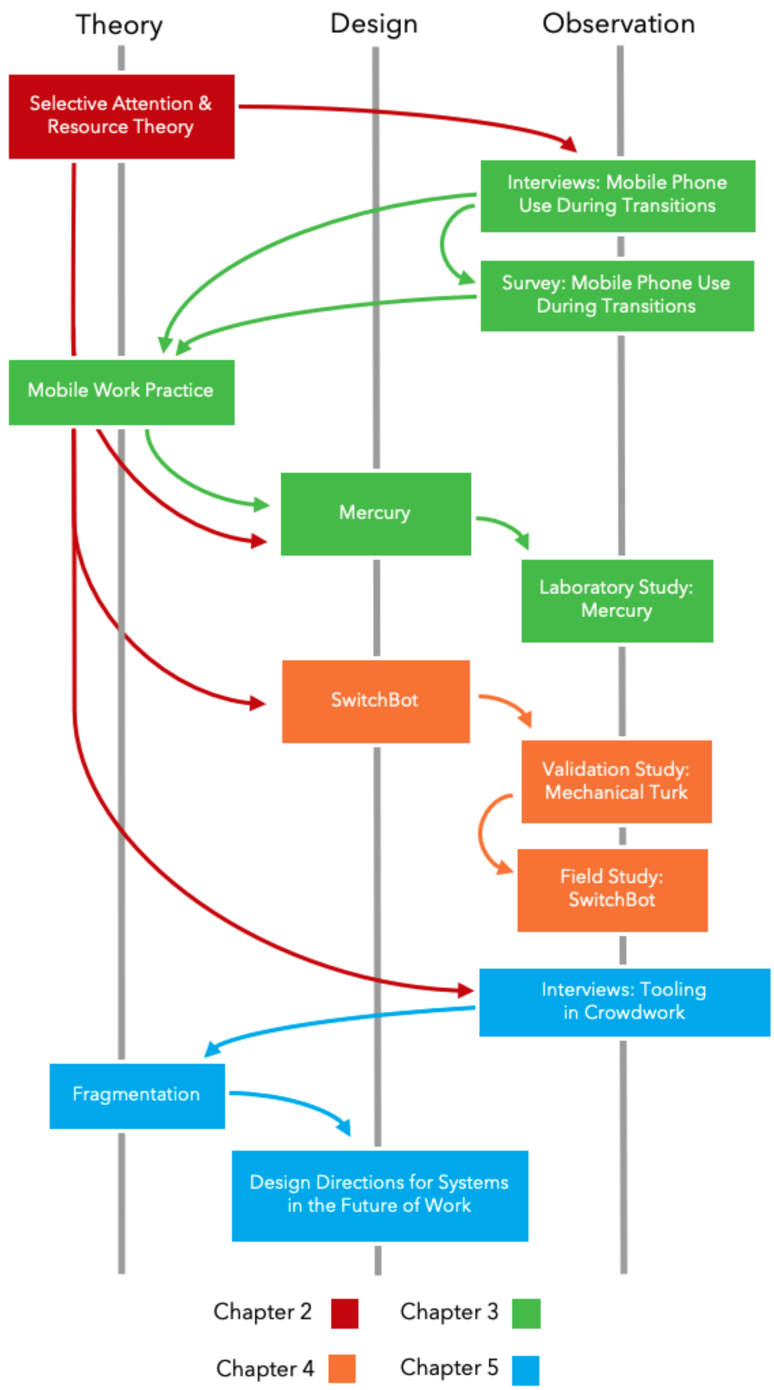

Figure 1.1: Research included in this dissertation, coloured by chapter.

1.1 Thesis Statement

The remainder of this dissertation is structured around the following thesis statement:

> *Peoples' work-related and personal spheres are inundated with interruptions. These moments rely on the ability to reorient one's attention across different environments, devices, and tasks. Systems, and interfaces can mitigate the cognitive burden that stems from these transitions by better providing new techniques for engaging with work or disengaging from work more effectively. The expected advantages of these systems is that they enhance task engagement, improve productivity, and create opportunites for improving personal well-being.*

To defend this statement, the work in this dissertation addresses the following research questions:

1. How do we design systems that help people manage their work-related transitions?
    a. What work-related transitions are people experiencing in their work?
    b. What are the challenges of managing work-related transitions?
    c. How do these challenges affect peoples' productivity and well-being?
    d. How do these challenges vary between traditional and newer forms of work?
2. How do new experiences for on-the-go work support the desktop-mobile transitions?
    a. How do we design tasks that enable productivity, yet require little attention?
    b. What are the subjective reactions to such types of tasks?
    c. How does a new experience for on-the-go work affect the resumption of a task?
    d. How would such experiences be used in practice?
3. How does a conversational agent support the home-work transition?
    a. How does such a system support peoples' ability to disengage from their work?
    b. How does such a system support peoples' ability to re-engage with their work?
    c. How does the effect of a conversational agent vary with its choice of dialogue?

Next, we provide a summary of the specific research contributions that we have made through the work presented in this dissertation. Later in this chapter we summarize the specific research activities we carried out to answer these questions.

1.2 Research Contributions

In this dissertation, we make the following research contributions:

1. We argue that the challenges stemming from transitions are motivated by an inability to effectively continue or discontinue one's work. We argue that designing systems for continuing or discontinuing work hinges on understanding these challenges.

2. Based on a contextual inquiry with 10 participants, we provide evidence that suggests transitioning between the desktop and mobile context is a significant challenge for programmers who have a desire to continue or access desktop work on-the-go.

3. We extend our contextual inquiry with an online survey in order to characterize programmers' existing and desired mobile practices. We provide insight to the nature of these practices and their support of programmers' work-related transitions.

4. We present Mercury, a mobile programming tool that mitigates transitional overhead by enabling programmers with the ability to continue their work on-the-go with microtasks that require little attention, effort, and context to complete.

   a. We present evidence from a laboratory study that demonstrates how Mercury allows programmers to engage with work can mitigate the costs that stem from interrupted work, particularly in scenarios of brief interruption.

   b. We contribute a novel discussion on the ethics of introducing systems, like Mercury, that allow people to work anywhere, noting their potential for negative impacting peoples' work and personal spheres despite being well-intentioned.

5. We present SwitchBot, a text-based conversational agent that aids people in psychologically detaching from their work at the end of the workday and psychologically reattaching with their work upon returning to the workplace.

   a. Based on joint findings from a crowdsourced study and a field study, we present evidence that suggests using SwitchBot's dialogue paradigm was successful as a tool for aiding people in their transitions, though this varied heavily bsaed on participants' existing practices.

6. Based on an interview study with 21 crowdworkers, we provide a thorough analysis of the work-related transitions that crowdworkers experience through the lens of tooling. We find that crowdworkers' current tools amplify the cognitive impact of work-related transitions, contributing to the "fragmentation" of their work practice.

7. We coalesce the findings from our studies to highlight directions and opportunities for future research aimed at supporting work-related transitions both in traditional and emerging work contexts.

1.3 Research Scope

We begin this dissertation by defining the scope of research. Here, we clarify the problem we aim to solve, the scenarios in which we seek to provide support for the problem, and the population we wish to target in our research.

1.3.1 Information and Knowledge Workers

The goal of the research presented in this dissertation is to assist people in managing the cognitive overhead of the transitions they experience related to their work. We scope our research to the collective of job roles labeled as "information work" and "knowledge work".

Information work has been defined conceptually as "work as part of the everyman" [104] and primarily centers around the notion of making use of information to support decision-making. In contrast, knowledge work has yet to be succinctly defined, but is generally recognized as a practice centered around the not only using information, but also creating it [72]. Across both classifications of work, job roles can range from simple data entry to information-driven research. Labor reports suggest that information and knowledge work professions accounts for nearly half of the full-time workforce in the United States, making the collective of workers ideal candidates for thorough inquiry and clear impact [194, 202].

In general, our study population can be characterized by the following:

- They use information to assist in making decisions or taking actions.
- They create information that informs the decisions or actions of others.

The Changing Nature of Information and Knowledge Work

An important facet of both information and knowledge work is that their nature has changed substantially over the past two decades. New styles of work, more ubiquitous computing devices, and an ability to effectively work remotely have created have contributed to re-conceptualizations of how the "workplace" should be defined. [170].

In this research, we consider the perspectives, challenges, and opportunities of both traditional and contemporary information workers. To provide insight into the experiences of more traditional information work settings, we first examine the multi-device practices of programmers. We then examine the broader work practices of crowdworkers to better understand the work-related transitions they encounter from the perspective of their work-related tooling. For brevity, we refer to our study population as "*information workers*".

1.3.2 Work-Related Transitions

The goal of the research presented in this dissertation is to assist information workers in managing the cognitive overhead of the transitions they experience related to their work. In practice, transitions are the product of interruptions, which may be initiated through internal sources (e.g., pausing a task due to boredom) or through external sources (e.g., pausing a task due to an unexpected visit from a colleague). The characteristics of these transitions can vary heavily based on whether the interruption is planned or unplanned.

Here, we focus on and advocate for designing and understanding systems that help people manage transitions related to their work at three different levels:

- **Task Transitions**: Task switching is a natural facet of information work [263]. Despite its centrality, the process itself is recognized as a significant cognitive challenge for information workers both in traditional and contemporary workplaces [179, 151].
- **Device Transitions**: Modern information work is not fueled by one computing device, but instead a family of computing devices [41]. People utilize collectives of workstations, mobile computers, and other devices to accomplish meaningful work.
- **Environment Transitions**: Transitioning between work and personal environments is an every-day task for people. Advances in mobile computing have made information work increasingly portable, which has blurred the boundary between these environments and made it increasingly more taxing to transition effectively.

Importantly, our motivation to emphasize these three types of transitions is rooted in their commonality to all forms of information work, regardless of the particular style of information work a person may be engaged in professionally. Further, these types of transitions are not mutually exclusive in practice.

Settings of Interest

In this work, we focus on two fundamental work-related settings that are cross all embody all three characterizations of transitions as mentioned above:

1. Transitioning between Desktop Work and Mobile Work
2. Transitioning between Work and Personal Environments

Our research for each of these settings is motivated by thorough inquiries of work practice. We discuss pathways for supporting transitions beyond these two settings in Chapter 6.

1.3.3 Designing Systems for User Autonomy

The research presented in this dissertation introduces a set of systems for managing work-related transitions. A key characteristic of these systems is that they, by design, prioritize user autonomy. Specifically, system operations are reactive to the user's interaction. While the systems described in Chapters 3 and 4 are not "intelligent", they are designed to respond to a user's intent to reach a particular *goal*, whether it be a particular task, device, environment, or a combination of the three. We discuss opportunities for leveraging users' context to support and augment our proposed systems as a significant frontier for future research in Chapter 6.

1.4 Thesis Overview

In this section, we provide an overview of the research included in this dissertation. Here, we present the triangulation of our methods using Mackay and Faynard's three perspectives of theory, design, and observation [174]. Figure 1.1 presents a visual representation of these perspectives, hightlighting the connection between the different stages of this work.

This document begins by outlining the related literature that the work presented in this dissertation both draws from or builds on. We then present a series of chapters that contribute toward the goal of designing, engineering, or understanding systems for managing work-related transitions.

Chapter 3: We present the joint findings from a contextual inquiry and a consecutive online survey aimed at understanding the current and desired mobile work practices of programmers. Based on these findings, we design, build, and study *Mercury*, a mobile programming tool that enables programmers with the ability to continue their work on-the-go. We discuss important findings from a laboratory study that examined Mercury's utility not only as a tool for completing work while away from the desktop, but also as a tool for mitigating the overhead of transitions at the task, device, and environmental levels.

Chapter 4: We design, build, and study *SwitchBot*, a conversational system that supports people in psychologically detaching from their work when they leave their workplace and psychologically reattaching with their work when they return to their workplace. We first discuss the findings from a validation study that assesses SwitchBot's dialogue design and subsequently detail the findings from a two-week long field study with SwitchBot deployed in a workplace setting.

Chapter 5: We present the findings from an interview study aimed at understanding the work practices of crowdworkers. Through the lens of work practice, we find that tool use contributes greatly to the fragmentation that crowdworkers experience within their tasks, their work-life separation, and their social circles. The overarching goal of the study was to not only understand the tools that crowdworkers employ in their practice, but how these tools affect the work-related transitions they experience in their work.

Chapter 6: Finally, we contextualize the impact of the research presented in this dissertation, clarifying the dissertation's main contributions and takeaways. We also discuss the frontier of directions this work enables and detail projects of interest for future work.

Appendices:

- **Appendix A**: We present the full survey used to understand programmers' current and desired mobile work practices used to motivate Mercury's design in Chapter 3.
- **Appendix B**: We provide the study materials for Mercury's laboratory study in Chapter 3, including the pre-study questionnaire, the study information document, and the post-study questionnaire.
- **Appendix C**: We provide the post-study questionnaire used to understand how SwitchBot influenced participants' perceptions of work-related disengagement and re-engagement in Chapter 4

1.5 Terminology

Before we continue, it would be useful to define a series of terms that are used throughout this dissertation:

1. *task* – We use the term "task" to refer to any activity undertaken to achieve a desired goal. This particular definition is highly generalized and is widely used both in task modeling [201] and in organizational psychology [299].

2. *device* – We use the term "device" to refer to any type of computer that a person has at their disposal. Examples of devices include, but are not limited to workstation computers, laptop computers, mobile smartphones, and wearable smartwatches.

3. *environment* – We use the term "environment" to refer to a physical place or location that a person can inhabit. Work-related environments, for example, include a home office, a large office building, or an open-office space. For brevity, we refer to the primary environment in which a person's work operates simply as their "*workplace*".

4. *interruption* – We use the term "interruption" to refer to the suspension of one stream of work prior to completion, with the intent of returning to and completing the original stream of work. This definition was posed by Boehm-Davis and Remington [32] and is frequently utilized in the literature on interruptions and multitasking from cognitive science and human-computer interaction.

5. *transition* – We use the term "transition" to refer to any experience in which people physically or mentally orient themselves from one state to a different state. Our work focuses specifically on transitions that are related to the tasks, devices, and environments related to peoples' working spheres. We succinctly describe these transitions as *work-related transitions.*

Chapter 2

Background Literature

Our work draws from several areas of literature, namely human-computer interaction, cognitive science, and occupational health psychology. We begin by discussing the theoretical foundations of our work and then provide an overview of prior research exploring these theories from the lens of understanding and support in HCI.

2.1 Theoretical Underpinnings of Transitions

From a theoretical perspective, interruptions, in whatever form they may arise, are disruptions to an individual's *attention*. Here, we discuss theoretical perspectives of attention as it relates to building systems that support peoples' work-related transitions.

2.1.1 Attention

In 1890, William James, the Father of American Psychology, proposed what many believe to be the first "formal" definition of *attention*:

> *"Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one of what may seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others."*

Over the course of the last half-century, a multitude of definitions of attention have been proposed as the term often refers to many types and levels of psychological processes ranging from biological arousal or alertness to high-level conscious awareness [16]. To facilitate our discussion around the topic, we employ a definition that is frequently used and referenced within the field of psychology today: *"a concentration of mental activity that allows you to take in a limited portion of the vast stream of information available from both your sensory world and your memory"* [187, 240, 264]. Importantly, this particular definition characterizes attention as a gatekeeper that holds the responsibility of filtering out information that is irrelevant or unimportant to an individual's current goals.

Attention is generally viewed as a multi-dimensional construct composed of three key dimensions [16]. Each dimension is distinct in that it describes a particular cognitive process related to the overarching task of filtering information. The first dimension of attention is *concentration*, and "refers to a person's deliberate decision to invest mental effort on what is most important in any given situation" [199]. The second dimension of attention is *selective attention*, and refers to an individual's ability to hone in on certain kinds of information "while ignoring other ongoing information" [187]. The third and final dimension of attention is *divided attention*, which refers to an individual's ability to coordinate two or more actions at the same time, and has been studied thoroughly in HCI research (e.g. in driving scenarios [123, 122]). Beyond this accepted model of attention, alternative perspectives have been proposed that generally align more appropriately with systems research in human-computer interaction as detailed below [53].

Transitions are scenarios that require people to migrate their attention from one context to another. In undergoing this process, people leverage their ability to orient themselves in such a way that hones in on the information most relevant to the context in which they are transitioning to. From this point forward, our review of the literature will therefore focuse specifically on the aforementioned second dimension: *selective attention*.

2.1.2 Selective Attention

Metaphors have been used substantially to conceptualize how people selectively direct their attention toward a particular stimuli while simultaneously ignoring irrelevant stimuli [77]. Generally, three specific metaphors have had a lasting influence on how researchers and practitioners study and consider attention: (1) the filter theory [39], (2) the resource theory [129], and (3) the spotlight metaphor [128].

The Filter Theory

In 1958, Broadbent et al. [39] introduced the filter theory as one of the earliest modern theories of selective attention. The theory posits that a hypothetical filter limits the quantity of information to which an individual can pay attention to any given time [39]. The primary characteristic of the hypothetical filter is that it permits only a single channel of information to pass through to a person's center point of cognitive processing. Across half a decade of research, the theory has been heavily criticized for its extreme perspective on cognitive architecture, which fails to explain how people process multiple information sources or handle "channel disruptions" (e.g. the cocktail party phenomenon [54]).

The Resource Theory

In 1973, Kahneman et al. re-conceptualized attention as a "currency" by introducing the resource theory [129]. The defining characteristic of the theory is that it argues that attention is a single resource divided among an individual's tasks in different capacities, resembling "a pool of undifferentiated mental energy that can be allocated to concurrent tasks depending on various strategic principles" [200]. These principles primarily revolve around an individuals' mental effort and how it shapes their attentional capacity. Arguably, the most important feature of the resource theory is how it theorizes how attentional capacity is allocated with "momentary intentions" (i.e., factors that are deemed important at the time, like the decision to pay attention to whoever is speaking to you at a party) and "enduring dispositions" (i.e., factors that are always important to you, like the sound of your own name) [129].

The resource theory has served as an important foundation for subsequent research. Wickens' multiple resource theory extended Kahneman's resource theory by suggesting that attention is not one resource, but multiple resources that is allocated for different contexts [293]. Wickens' theory inspired hypotheses to describe how people recover the attentional resources they expense: the Effort-Recovery Theory [195] and the Conservation of Resources Theory [105]. Collectively these theories posit that individuals tax their mental and physical resources throughout the workday and are inherently motivated to regain the lost resources [62], otherwise if they continue to expend these resources they will never fully recover [195, 244]. If individuals seek to regain their expended work-related resources, they should therefore avoid work both physically and mentally.

The Spotlight Metaphor

In 1980, Posner et al.[226] made the first known reference to the spotlight metaphor. The metaphor is driven mainly by intuition around visual attention, and suggests that a person's selective attention resembles a mental beam that illuminates a circumscribed part of the visual field and information lying outside the illuminated region is ignored. The metaphor's central tenet is that this attentional beam can be redirected voluntarily to other locations in space, and that one's visual focus can be categorized based on an individual's context [209]. Extensions of the spotlight metaphor suggest that the spotlight may vary in size based on context (i.e., the zoom-lens metaphor [74]) or that the spotlight's attentional resources are allocated in a radial shape around a center point (i.e., the gradient model [149]). Applications of the spotlight metaphor have been extensive, ranging from athletic sport [200] to human-computer interaction systems research as we detail in Section 2.3.

2.1.3 Attentional Reorientation

Alongside their discussion of the spotlight metaphor, Posner et al. [226] posed one of the earliest hypotheses for explaining is the underlying process of attentional reorientation (e.g., when switching tasks [126]). Specifically, they posited that the cognitive process of reorienting attention can be characterized into three, distinct stages: (1) disengaging or taking away attention from where it is currently directed, (2) the shifting on one's attention from one stimulus to another, and (3) attention would be engaged on a new focal target. Studies of Posner's model have specifically focused on the observability of attentional shifts, primarily finding that visual attention can be expressed both "overtly" and "covertly" [66, 106, 146]. This ideology of attentional shifting has inspired more exploratory theories of attentional focus (e.g., the "Moving Spotlight" theory [150, 258]).

Research in cognitive science has leveraged modeling to better understand Posner et al.'s reorientation theory. Specifically, these extensions characterize the reorientation process around the notion of *goals*, which Trafton and Altman define as "intents to perform some action in the future" [273]. Altmann and Trafton [8] introduced the popular *Goal Activation Model* (GAM), which models goals in terms of the general memory constructs of activation and associative priming. The model was drawn from preexisting frameworks, namely ACT*, that sought to unify theories of cognition to explain the human mind more accurately. The GAM is unique in that it provides a theoretical framework for interrupting and resuming tasks based on the recent "use" of attentional artifacts. Studies of the framework's practical utility advocate for externalizing the processes that would otherwise happen internally when pausing and later reorienting one's attention [273]. The framework has been used substantially in understanding and modeling task interruptions [38].

Alongside attentional models of cognition, Posner et al.'s reorientation theory has lead to new hypotheses about why the reorientation process itself is challenging. Leroy et al. [162] introduced the notion of "attention residue", a concept in which cognitive resources remain allocated to a task after a person has paused it and oriented their attention elsewhere. Leroy et al. specifically theorized that the presence of attention residue is motivated by two key attributes related to the paused task: (1) the need for completion (i.e., finish a task) and (2) the need for cognitive closure (i.e., stop thinking about a task). The concept of attention residue is grounded in prior theories that examine how people ruminate about thoughts both consciously and subconciously [186]. Observational studies have used the notion of attention residue has been used as a lens to better understand interruptions in practice as we describe in the following section [63].

2.2 Understanding Work-Related Transitions

Transitions are the product of interruptions. Here, we discuss the prior literature that improves our practical understanding of transitions across tasks, devices, and environments. We specifically emphasize studies that demonstrate these scenarios' challenges in practice.

2.2.1 Task Switching and Interruptions

Interruptions research is grounded in an understanding of how people perceive and measure events [302]. In 1973, Newtson et al. [207] introduced the concept of *unitization*, a technique in which people manually judge the boundary between successive events, and demonstrated its use in identifying both large events (i.e., coarse-grained unitization) and smaller events (i.e., fine-grained unitization) in videotaped behavior. Subsequent studies suggest that people are generally consistent in judging event boundaries in terms of where they take place [257] and how long they last [208]. Norman and Miyata [198] speculated that interrupting people during event boundaries, or *breakpoints*, could mitigate the effect of an interruption. Empirical studies have validated this suspicion repeatedly, suggesting that moments of reduced mental workload are opportune for transitioning [20, 117].

The wealth of research on understanding task interruptions has both culminated in and drawn from perspectives that describe the procedural nature of interruption management. Most notably, McFarlane et al. [192] described four unique ways of handling interruptions: (1) *immediate*, i.e. the interruption is managed immediately; (2) *negotiated*, i.e., the interruption is deferred to a more opportune moment; (3) *mediated*, i.e. the interruption is optimized to reduce disruption; and (4) *scheduled*, i.e. the interruption arises at a static time. A comparison of the four strategies suggests that negotiating for opportune moments (i.e., breakpoints) is the generally most advantageous [191]. Supporting McFarlane et al., Iqbal et. al [120] characterized the interruption lifecycle for computing applications into three phases: (1) preparation, (2) diversion, and (3) resumption. This characterization specifically resembles that of cognitive models of task switching, i.e. the GAM [8].

Alongside interruption structure, a center point of research examined the cost of transitioning between and across tasks. Bellotti et al. [26] conducted first-hand observations of information workers' task management practices over a week-long period and found that task interruptions can be influenced heavily by the task's urgency, prioritization, and social ties. Haraty et al. [98] found that personalization influenced task management practices substantially. Mark et al. [178] conducted an observational study of information workers and characterized how co-located information workers experience more interruptions in their work tasks than those that are distributed. Gonzalez et al. [87] corroborated this finding in a study of task switching across project activities, finding that people spend as little as three minutes on a task before switching away from it. In a log analysis study, Iqbal and Horvitz [119] found that it took information workers, on average, 16 minutes to resume their interrupted tasks. Estimates of greater length were reported in other observational studies of other information work contexts [179, 280]. Information workers generally recognize interrupted work as a serious problem in their work as well [158].

Studies suggest that the impact of switching tasks extends far beyond the resumption of the work. Several studies, for example, have demonstrated how task completion time suffers significantly in the presence of an interruption [60, 61]. More broadly, there is evidence that suggests interruptions can negatively influence peoples' task performance [192], affective state [6, 182], and the frequency in which they produce errors in their work [234]. The impact of these interruptions often depends on the context of the interruption, such as one's job role [179] or whether the interruption was self-initiated [63]. Specific contexts of study have primarily focused on workplace settings [179, 62], though more recent studies have explored how interruptions may affect volunteer "work" (e.g. citizen science [75, 239, 238]) or new forms of work altogether (e.g., crowdwork [151]). Despite being generally detrimental in nature, Mark et al. [179], Skatova et al. [243], and Rzeszotarski et al. [230] each separately found evidence that suggests that interruptions may be beneficial if they allow people to recover resources, as previously theorized [129, 293].

Multitasking

Multitasking has served as a topical complement to much of the research on sequential tasking and interruptions [28, 35, 61, 62, 85, 87, 192, 212]. In line with Section 2.1.1's discussion of attention's multidimensionality, Rubinstein et al. [229] and Wickens et al. [294] found that peoples' multitasking behaviors are driven by the belief that multiple stimuli can be given equal attention simultaneously. The promise of multitasking is built on the premise that people will be able to get more done in less time [46] with increased awareness of activities and peripheral information [175]. However, empirical research has demonstrated several counterpoints to the promises of multitasking, showing that it leads to fragmented attention [221], can yield increased stress, frustration and anxiety [19, 182], a lack of performance [19, 172] and reduced focus [184, 183]. Czerwinski et al. [62] characterized difficulties in task switching based on the data collected from a week long diary study and show that task complexity, task type, task duration and number of switches affect the difficulty in managing multiple tasks.

More recent research has sought to better understand how interruptions take place and are managed in the scope of newer forms of work. For example, Lasecki et al. [152] examined task continuity in crowdwork, and found that crowdworkers are more performant when they engage in similiar work continuously. Necka et al. [206] found that crowdworkers engage in multitasking behavior while participating in online experiments. Similar findings were reported by Chandler et al. [51] who found that workers divide their attention between work (i.e. a HIT) and non-work (e.g. TV) while working. Gould et al. [89] conducted a lab study in which they observed that participants switch between tasks every 5 minutes, and that participants expressed a willingness to interrupt their work. Rao et al. [228] introduced "multiplexing" between active and passive tasks to better optimize multitasking in crowdwork. In a survey with 317 MTurk crowdworkers, Lascau et al. [151] mapped crowdworkers' multitasking preferences, finding that a tension exists between the crowdworkers' multitasking preferences and the demands of their crowdwork platforms, and that crowdworkers, on average, employ boundary management strategies that prioritize non-work over work. Relatedly, research has found that autonomy and flexibility play significant roles in the adoption of crowdwork as the work enables crowdworkers to work when they please [141].

In general, interruptions are ubiquitous and can yield significant costs to the individual and their work. Comprehensive analyses of the interruption literature identify supporting the agency of the interrupted person as a key direction of importance [227]. Similar perspectives advocate against changing individuals' behavior, and instead suggest that systems, by design, mitigate the cognitive cost of transitioning between tasks [119].

2.2.2 Multi-Device Usage

Computing across devices and environments is a well-studied topic. Predating the era of smartphones, Perry et al. [222] conducted an interview study with 17 mobile workers to identify trends in data management activities during planned absences, and found that the telephone played an important role in overcoming barriers to data access while away from the workstation. In both an interview study and a diary study, Karlson et al. [132, 133] characterized information workers' mobile work patterns with smartphones, noting that moving transitioning from desktop to smartphone was common practice. They also identified a number of barriers to performing mobile work, including the poor usability of mobile web browsers [130] and issues related to resuming tasks across workstations and mobile devices [133]. Other studies, e.g. Bao et al. [22] and Oulasvirtas et al. [215], suggest that certain work tasks are more appropriate for mobile interfaces than others.

Recent studies of multi-device experiences demonstrate that people are increasingly using multiple devices to support their work and their personal lives. Santosa et al. [233] conducted a series of semi-structured interviews with 22 participants holding various job roles, and characterized the workflows that people utilize in using multiple devices to support their work. Jokela et al [127] characterized peoples' practices for completing tasks across multiple devices, such as workstations, smartphones, tablets, and home media devices, through the lens of a diary study. Similarly, Di Geronimo et al. [68] conducted an online survey with 293 participants to characterize the scenarios in which people use multiple computing devices in their personal environments. Most recently, Brudy et al. [41] conducted a survey of the cross-device computing literature to identify key challenges and opportunities. Each of these studies share the finding that people, specifically information workers [127, 233], have an on-going need to transfer information across their devices.

An often overlooked consequence of cross-device work is how it enables people to engage with their work wherever they may be [50]. For example, a study by the Pew Research Center found that the majority of Americans own a smartphone and more than 90% of them utilize the device for e-mail [3]. Studies have demonstrated that e-mail can significantly influence how people separate their work-related and personal environments [49, 45, 92, 188]. More broadly, recent research has found that many of the challenges for separating work and persona spheres posed by the smartphone are mirrored by the smartphone [48, 58, 237]. Despite having a widespread understanding of the problem space, little research has focused on supporting transitions between devices and environments in support of peoples' well-being.

2.3 Supporting Work-Related Transitions

> Today, it effortlessly (and often unobtrusively) surrounds us. Look around now: How many objects and surfaces do you see with words on them? Computers in the workplace can be as ubiquitous as today's printed matter. In the long run, the personal computer and the workstation will become practically obsolete because computing access will be everywhere: in the walls, on your wrist, and in "scrap computers" (like scrap paper) lying about to be used as needed.
>
> – Mark Weiser, 1993. [286]

The need to support peoples' transitions across devices and environments has been anticipated for several decades. Over this period of time, there has been a tremendous amount of emphasis on building systems that support transitions across tasks, devices, and environments, often as a collective. Here, we provide an overview of these systems.

2.3.1 Resumption Systems and Task Management Tools

Human-computer interaction research has focused substantially on the study of systems that aid people in transitioning between tasks and resuming interrupted work. The simplest types of such systems have sought to provide support through the lens of task management. Consider, for example, the every-day memory aid: the To-Do list [210]. Today, digital realizations of the to-do list (e.g., Wunderlist[1]) are used by millions of people and designed for use across devices ranging from the workstation to wearables [37, 211]. A caveat of these systems is that their practical utility hinges on users documenting relevant information about their on-going tasks, which may happen inconsistently or cease to occur at all [98].

To ease this burden, several studies have explored the utility of system designs that capture task-related information implicitly for later use. Dragunov et al. [71] introduced TaskTracer, which helps discover, locate, and re-use past task-related information, and studied the system's utility in three different interface designs. TaskTracer's primary mechanism was facilitated by grouping digital artifacts and activities together based on observed usage, a concept previously explored in several other systems for niche contexts [70, 80]. Kersten et al. [139] used a similar approach to gather and resurface task context to support programmers in resuming interrupted tasks in development environments. Evaluations of these tools have been generally supported by software infrastructures (e.g. DART [120]) that log both system and user events for future analysis.

[1] https://www.wunderlist.com/

Systems research has generously explored how implicitly captured context can be used in resuming interrupted work visually. Most notably, Baudisch et al. [24] studied Phosphor, a system that modified user interfaces on desktops to highlight changes in widgets that a user would otherwise miss upon returning, and found that immediate visual changes are more advantageous for explaining interface changes than animated transitions. Utilizing the same principles, Mariakakis et al. [177] studied SwitchBack, a system that utilizes gaze tracking with a front-facing cameras on smartphones to dynamically direct attention to a certain area within a task, and found that the system improved average task speed by 7.7% in the presence of distractions. Parnin et al. [217] explored how different visual cues can help support programmers in resuming interrupted work, and found that visual cues of any type are equally advantageous for resumption.

Beyond visual cues, a small body of research has explored alternative interaction designs for resumption, namely *conversation*. Bohus et al. [33, 34] introduced RavenClaw, a dialogue management tool that could generate task-oriented dialogue systems. Aist et al. [7] described the software architecture for the RavenClaw system, noting an emphasis on spoken dialogue. Modern instances of systems that value supporting resumption have primarily taken shape as voice user interfaces (e.g., Lyra [15]). However, these devices are technically limited, making it unclear *how* they should support resumption broadly [225].

A recent avenue of interest for human-computer interaction research has focused on providing cross-device support through design frameworks and other types of development tools. Nebeling et al. [204, 203] introduced and studied XDBrowser and XDBrowser 2.0, a tool collective for easing the design and generation cross-device web page designs. Similarly, O'Leary et al. [214] engineering and studied the Moving Context Toolkit (McKit) to aid designers in supporting "context shifts" commonly found in multi-device use. Park et al. [216] introduced AdaM, a system for automatically adapting the visibility of user interface elements based on the device at hand. Beyond the workstation, Husmann et al. [111] examined pathways for supporting software developers' multi-device use in stationary "ad hoc scenarios", e.g., while at a cafe, and introduced XDE, an integrated development environment that facilitates cross-device software development.

Despite this plethora of systems research, there has been a continued interest in supporting the resumption of interrupted work. This is particularly true for information work settings that are inherently complex, such as programming [43]. Findings from the wealth of systems research have been slowly integrated in newer versions of commercial software for information work (e.g., Microsoft Word's "Pick-Up Where You Left Off" feature). The challenges of resuming interrupted work, however, have continued to persist for the vast majority of information work contexts, due to their complexity or the unavailability of application-specific support for resumption.

2.3.2 Context-Aware and Attention Management Systems

Human-computer interaction research has studied two types of systems at depth that sense or infer users' state to aid them transition across tasks, devices, and environments [27].

The first type of systems are *context-aware systems* (CAS). In 1994, Schilit and Theimer [236] defined a context-aware system as one that "adapts according to its location of use, the collection of nearby people and objects, as well as changes to those objects over time". The term "context" was originally defined to represent a person's location, but has since been revised to refer more broadly to as "any information that can be used to characterize the situation of an entity" [5, 67]. "Context-aware" has since been used to describe the capabilities of software applications [235, 283], computing devices [109, 219], and entire environments (e.g. workspaces) [73, 78]. Across each of these scenarios, the overarching goal of context-aware systems is to adapt to the users current state in such a way that

The second type of systems are *attention management systems* (AMS). Bailey et al. [19] described these systems as a particular type of context-aware system that "computationally seek(s) to balance a user's need for minimal disruption and the application's need to efficiently deliver information". Bearing similarity to context-aware computing, these systems have 5 stages that include sensing, processing, inferring, modelling, and finally managing an individual's *interruptability* [12]. Importantly, these tools can be designed to support attention of one individual (e.g., guiding visual attention, managing turns, interruption decisions, etc. [281]) or a collective of people [14]. Beyond the workplace, the adaptive nature of these systems has yielded a sizeable exploration of their practicality in education and learning contexts (e.g. intelligent tutoring systems) [289].

Both CASs and AMSs operate on the premise that known or inferred information about the user's present state can be leveraged to surface contextually-relevant information from the computer system. A common and practical setting of study of these systems has focused on understanding and supporting the delivery of notifications and alerts at opportune moments [60, 107, 108, 138, 304]. For example, Iqbal et al. [118] introduced the Oasis framework which automatically aligns notification delivery based on the user's perceptual understanding of the task, as modelled by the system. Today, commercially available software for managing notifications (e.g., Windows 10's Focus Assist) is common, though these tools generally do not mirror the context-aware nature of CASs in practice.

A significant branch of research has studied users' ability to understand the behavior of these systems in practice. Bellotti et al. referred to this simply as a system's "*intelligibility*". Lim et al. [166, 167] conducted a need-finding study of intelligibility in these tools, and introduced a subsequent toolkit for building applications centered around intelligbility. With the rise of newer, more integrated computing devices, the notion of context-aware and attention management systems has expanded to newer settings [196].

Both CASs and AMSs have substantial deterrents to practical utility. For example, sensors may be unavailable in practice, and inferences can inaccurately classify users' state [12]. Supporting users' with proactivity may also influence how users perceive the control they have over their interaction, which can contribute to a detrimental user experience [23, 81]. Both types of systems have yet to make their way into practice at scale, though this may change with newer forms of sensing that are both accurate and portable (e.g., sensing affective state with webcam video [190]).

2.3.3 Microwork and Microproductivity Systems

Changing the fundamental structure of information work has been the focus of more recent attempts at supporting work-related transitions. A thematic direction for restructuring work has focused specifically on translating information work into *microwork*, a minimized form of information work in which larger tasks have been subdivided or decomposed into more manageable *microtasks* [268]. Teevan et al. [267] labeled the space of collective research as "microproductivity", which they formally defined as "the transformation of large tasks into smaller microtasks for productivity purposes".

Recent research has explored the advantages and disadvantages of microproductivity-based approaches at depth. In contrast to their macro-task counterparts, Cheng et al. found that microtasks may be more resilient to interruptions and enable people to yield higher quality work in specific settings [52]. Several studies have also shown that microtasks are advantageous for scaffolding the cognitive process of maintaining and rebuilding context for complex information work tasks [44, 136, 232] and for improving task engagement [83]. Prior work has explored how microtasking can improve the writing process in groups [268], from devices with small screens [205], and for individuals working on their own edits in short bursts of time [116]. Microtasks have also been used to orchestrate teams of actors for specific purposes, such as peer production [278] or scheduling meetings [59], and have been used to systematically perform taxonomy creation [55], for copy-editing [29] and to capture local knowledge [276].

Research has shown that information work professions can benefit from microproductivity-like practices through the lens of crowdsourcing [116, 157]. For example, LaToza et al. [153, 156] demonstrated how key software development tasks (i.e., reviewing, testing, and debugging) can be crowdsourced effecitvely by decomposing them into decontextualized units. Research has reinforced microtask programming's utility in developing small components, showing that contributing code and writing tests through microtasks can be efficient and reliable [155]. LaToza et al. found that proper coordination of crowdwork can overcome traditional knowledge sharing challenges in software teams [154].

In sum, the literature demonstrates that microwork and microproductivity systems are a promising direction for exploration. However, a key challenge in building new microproductivity systems is understanding how traditional information work can be translated to a microwork context [269, 267]. This challenge is equally motivated both by technical feasibility and by the needs and desires of information workers.

2.4 The State of Transitions in Information Work

In this chapter, we reviewed the related literature on work-related transitions from the persepctive of theory, design, and understanding. The main points from our review can be summarized as follows.

- Transitions, in their many forms, rely on an individual's ability to effectively reorient their attention from one stimuli (e.g., task) to another.
- The process of transitioning across tasks, devices, and environments is cognitively taxing and can affect individuals' productivity and well-being at varying scales.
- Current systems and techniques for supporting transitions prioritize resumption and rely substantially on sensing and inferred context to support transitions effectively.

From our review of the literature, we can conclude that the need to support people in transitioning across tasks, devices, and environments is paramount. We distinguish ourselves from the prior literature by designing systems and techniques that empower users' ability in managing their work-related transitions. Specifically, our approach is motivated by the philosophy that users should have the agency and autonomy to transition between tasks, devices, and environments at their own leisure. We discuss opportunities for supporting users' decision-making in Chapter 6.

In the next chapter, we begin our exploration of systems for managing work-related transitions through the lens of task continuation in programming across devices and environments. We then continue our exploration by examining system opportunities for supporting task discontinuation. Finally, we coalesce findings from each of these studies by understanding the continuation and discontinuation of work in the context of crowdwork.

Chapter 3

Empowering Programmers' Transitions in On-the-Go Work

In this chapter, we examine how the continuation of information work while on-the-go can mediate the cognitive costs of work-related transitions. This research focuses specifically on one particular sub-domain of complex information work: programming.

We begin by examining programmers' existing and desired programmers' work practices. Inspired by our observations about these practices, we introduce *Mercury*, a microproductivity system integrated with Visual Studio Code (VSCode) that automatically generates mobile-friendly, short programming-related tasks, or *microtasks*, to support programmers' needs and desires for continuation. We evaluate Mercury with an emphasis on understanding how the system supports task continuation across devices and environments.

3.1 Motivation

There are millions of professional programmers, and their numbers are growing significantly faster than previously predicted [57]. However, programmers are not able to fully take advantage of the added opportunities and flexibility that mobile devices offer in getting things done, due to the challenge of working across devices. From large desktops to small wearables, information workers today often use multiple devices to accomplish their work in the most productive way possible [127, 233, 205, 116], but programming presents a unique set of obstacles, such as the reliance on personalized development environments most suited for large workspaces [111], or on tasks not suitable for limited attention scenarios.

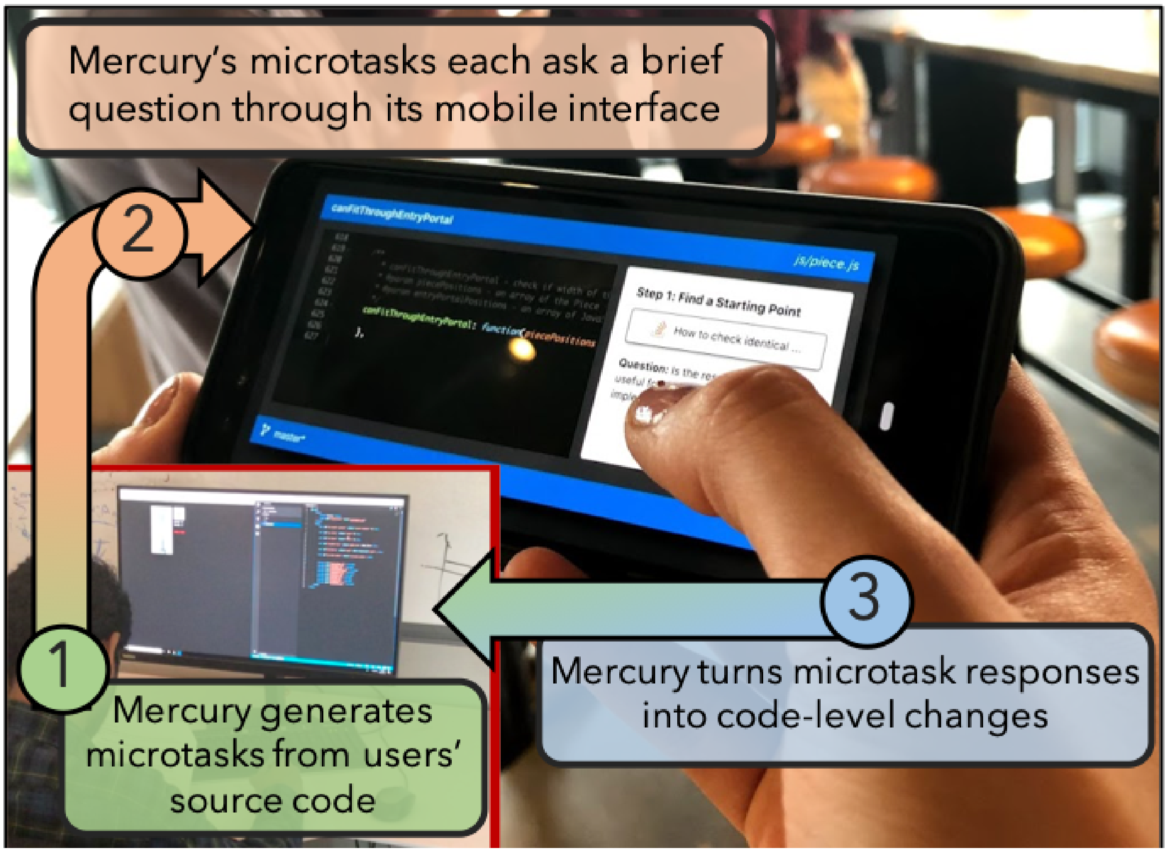

Figure 3.1: Mercury allows programmers to continue their work on-the-go. (1) When a user leaves their workstation, Mercury generates microtasks from their code, (2) then serves the tasks to their mobile device. These tasks are brief and require little attention. (3) Finally, Mercury integrates the user's microtask responses into the their workstation's source files.

We begin this chapter by exploring how to facilitate programmers' mobile work practices. We conducted two pre-studies to understand how programmers currently use their mobile devices for work: a contextual inquiry with 10 software engineers, and a large-scale online survey with 78 software engineers. We find our participants already perform a myriad of programming-related tasks while mobile, many of them *exploratory* (e.g., related to capturing thoughts or conducting online research). However, they also expressed a desire to perform more mobile tasks that are *grounded* in existing code (e.g., conducting code reviews or triaging bugs), but such tasks are not yet well supported by existing mobile tools. Further, many of their tasks while mobile are intended to support the effective continuation of their work upon returning to their workstation.

Recent research suggests that microproductivity is one particularly beneficial design pattern for bringing mobility to otherwise immobile information work [116, 268]. Building on our pre-studies' findings, we developed a system, named *Mercury*, that interfaces with Visual Studio Code to facilitate mobile task completion and real-time cross-device continuation for programmers. As shown in Figure 3.1, Mercury orchestrates programmers' work practices by providing them with a series of auto-generated microtasks on their mobile device based on the current state of their source code. Tasks in Mercury are designed so that they can be completed quickly without the need of much additional context, making them suitable to address during brief moments of downtime. When users complete microtasks on-the-go, Mercury calculates file changes and integrates them into the user's codebase where appropriate. From a user study with 20 participants, we find Mercury's microtask design to be an enjoyable and productive yet lightweight approach to conduct work on-the-go, and one that also aids individuals in resuming their work upon returning to their workstation. In this research, we specifically:

- Present the notion of *exploratory* and *grounded* microtasks based on programmers' existing and desired practices.
- Introduce Mercury, a mobile programming tool that auto-generates microtasks based on programmers' existing code.
- Find that Mercury's microtasking model effectively allows programmers to continue their work on-the-go.
- Observe that engaging with programming-related microtasks via Mercury spurs users' ability to resume their work.

The remainder of the chapter is structured as follows. We describe the findings of the contextual inquiry, and present the results of the online survey. We then present Mercury and its evaluation, then conclude with a discussion of considerations for designing systems that allow programmers to make progress in their work while on-the-go.

3.2 Contextual Inquiry

Before designing a system to empower programmers mobility, we need to better understand programmers' existing mobile work practices and how they complement work practices on primary work devices. We conducted a contextual inquiry [297] to address these questions.

3.2.1 Study Design and Methods

We recruited 10 software engineers (eight male / two female) at a large software company. Each participant was visited in their personal workspace while they were performing a programming-related task (e.g., prototyping, implementing, or debugging). Each inquiry was conducted by one researcher, and lasted approximately one hour. The researcher took written notes, and interviews were audio recorded. Participants were compensated with $10.00 for their time.

To get insights into opportunities for integration of mobile devices into the programming ecosystem, we designed an interview structure that focused on situations that take individuals out of their workplace and require them to pause their work. The researcher initiated the inquiry by explaining our interest in understanding how they work within their workspace. During the inquiry, each participant was told they would be asked to stop working and briefly chat about their mobile work practices 15 minutes after the inquiry had started. This simulated a planned interruption. Participants were interrupted to chat again 45 minutes after the inquiry had started, but were not given advanced notice of this interruption, simulating an unplanned interruption. In both cases, participants were asked to discuss their mobile work practices and their usage of artifacts around the workstation in the context of these interruptions. Participants were also asked about other scenarios that might unexpectedly take them away from their workspace.

The inquiry was concluded with a 10-minute semi-structured exit interview to better understand existing mobile work practices. Interviews began by asking participants to further discuss practices they described earlier in the inquiry, elaborating on the strengths and shortcomings of these practices in accomplishing work on-the-go. Upon concluding this phase of our study, audio recordings were transcribed. Excerpts were iteratively organized into themes following the practice of open coding and affinity diagramming [160].

3.2.2 Findings

Three key themes emerged: 1) participants often engage in activities outside of their primary workspace to make progress of software development tasks using mobile devices, but they rarely interact with code; 2) their existing practices require better support for continuation of programming tasks; and, 3) because of the difficulties in task continuation across devices, they minimize what they need to resume after both mobile and non-mobile work experiences.

Task	Description
Thought Capture	Writing down or recording general thoughts and ideas related to programming tasks.
Email	Using email for a programming-related task (including emailing content to self).
Online Research	Searching or browsing the internet for information related to a programming task.
Bug Triage	Documenting and reporting on bugs.
Code Review	Reviewing or commenting on existing code.
Debugging	Fixing and testing existing code.
Programming	Creating and writing code.

Table 3.1: Tasks currently practiced by programmers while on-the-go.

Understanding Mobile Work Practices

Table 3.1 lists details of the programming-related tasks participants reported currently performing from mobile devices. Other than Email, the two most common task types were *Online Research* and *Thought Capture*. Online Research tasks, reported by 6 participants, focus on identifying valuable directions for future programming-related tasks:

> *"It's almost like priming the pump when I start my day, but sometimes it's like I just don't know how to do this."* (P9)

Examples of online research tasks described by participants include searching for relevant Stack Overflow web pages, reading technical documentation online, and watching technical tutorial videos. Thought Capture tasks, reported by five participants, focus on opportunistically recording ideas. Examples include writing notes in a physical notebook or on their phone. Four participants reported occasionally reviewing code and tracking bug reports while on-the-go, but expressed a strong dislike for "the awful user interface" (P3). Only one participant reported debugging and programming on their phone.

Participants were excited to extend their current mobile work practices with tasks that generally enrich their source code. The most commonly desired tasks identified by four participants were code review and the ability to quickly capture thoughts that "come at the wrong time" (P5), such as while driving. One participant (P2) wanted to monitor long-running compilation processes, while another (P4) expressed an interest in using design-oriented tools on-the-go. Three participants highlighted debugging and programming as tasks they would "never" want to do on the mobile phone. Most identified poor user experience as the primary barrier behind adopting mobile tasks into their personal mobile work practices.

Understanding Cross-Device Continuation

Participants reported challenges with information transfer across devices. Email was used as the primary mechanism for transferring information, typically from their mobile device to their primary workstation:

> *"I emailed myself a few links last night to get them off my plate. It would've been great to have them open automatically when I arrived this morning."* (P7)

Using email as a way to continue work relevant to programming adds extra steps in linking the content back to the primary coding environment. Participants did not report continuing any programming related tasks on their mobile device, primarily because there is no effective functionality for doing so.

Understanding Task Resumption

Almost all participants (8) deferred pausing their work until they came to a good break point to minimize the resumption overhead upon return:

> *"I'm more likely to stop where it'll take less energy for me pick back up. Otherwise, it'll take me longer to connect to the project when I come back."* (P4)

Other participants described similar strategies such as "delaying lunch to continue working on the implementation" (P1) and "leaving work a few hours early because I can't finish it before the end of the day" (P7).

Though resumption of work after some time had passed is challenging, participants did not appear to leave explicit cues in their environment to help them with resumption. Participants stated they "might jot down a word or two if its extremely important" (P2). Four participants believed nothing they could do would make resumption easier, noting that "resumption sucks, but I don't think anything can be done to improve it" (P8). The other six were more optimistic. For example, P2 – who currently has no mobile work practice – said:

> *"If you find something that will help me keep the context alive, I'll definitely start using my phone this way."* (P2)

From the contextual inquiry we see opportunities for more flexibility in task execution and easier task resumption if users are provided support to continue work in some capability while they are away from their primary workspace. This inspired us to further explore the promise of using mobile devices to complement existing programming practices.

3.3 Online Survey

The programmers in our Contextual Inquiry reported using their mobile devices for some tasks and described practices around task continuation and resumption. We conducted an online survey to understand these themes better and generalize them across a broader range of people.

3.3.1 Study Design and Methods

We recruited 78 participants (68 male / seven female / two non-binary) by randomly sampling a company-wide employee list of individuals with job roles that regularly involve programming, including software engineers (70), electrical engineers (3), program managers (2), site reliability engineers (2), and data scientists (1). Participation was voluntary. 71 participants (91%) held at least a college degree, and had three or more years of experience in their current job role. Ownership of a mobile smartphone was the only requirement for participation.

The survey began by asking participants to identify the programming-related tasks that they currently practice while mobile from the task list shown in Table 3.1, including choices for "Nothing" (i.e., they currently practice none of the mobile tasks) and "Other." If participants indicated engagement in any mobile programming tasks, they were also asked to provide additional information about the last time they performed the task while mobile. The survey also asked participants to reflect on a programming project that they had not worked on for longer than a month, and estimate the amount of time they would need to feel prepared enough start making progress. Participants were asked to indicate artifacts they would utilize when resuming the task, and whether they believe the resumption overhead for the task could be reduced with proper tooling. To more concretely understand opportunities for future systems, the survey concluded by asking participants to report the utility of a system that allowed them to perform their desired work practices at their own leisure and seamlessly continue work across their devices. Utility was measured with a subset of questions of the Technology Acceptance Model [64], aimed at measuring *perceived usefulness*. A copy of the survey questionnaire is included in Appendix A

3.3.2 Findings

Extending our analysis of the three themes from our contextual inquiry, we find that 1) participants' existing mobile work practices are mainly exploratory while their desired

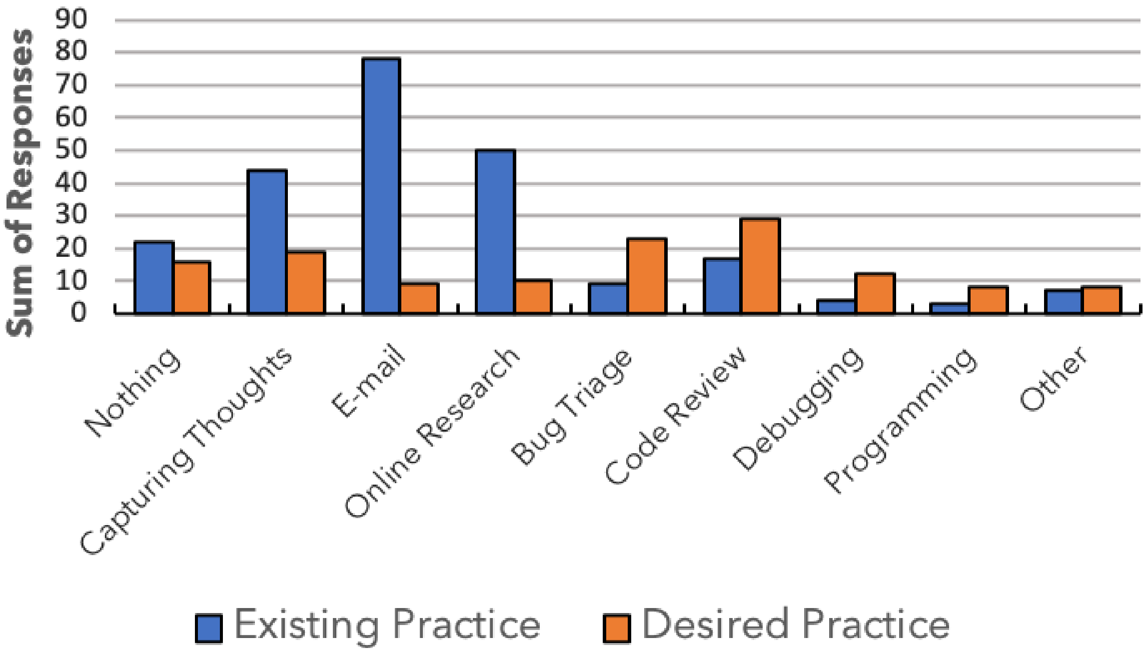

Figure 3.2: A histogram of existing and desired programmers' mobile work practices.

work practices are more grounded; 2) continuation is primarily facilitated through email by transferring captured thoughts and online research; and 3) resumption of interrupted work is facilitated with their mobile work practices.

Understanding Mobile Work Practices

We find clear separation between the practices that respondents currently employ and those they desire. Consistent with the Contextual Inquiry, the most frequently reported tasks for existing practices were Email (78), Online Research (50), and Capturing Thoughts (43). The other four task types (and "Other") were all reported far less often, with 20 respondents saying they do no mobile tasks. Existing practices are mainly *exploratory* tasks that support ideation and planning.

In contrast, participants' desired work practices are concentrated on actionable tasks that are much more *grounded* in existing artifacts. The most frequently desired tasks included code review (29) and bug triage (23). While the remaining tasks were desired by fewer than 25% of the 78 participants, 19 participants expressed a desire for capturing thoughts on-the-go as a means for enriching existing source code. Collectively, we use exploratory and grounded tasks to describe our participants' existing and desired mobile work practices. We do not consider email as its primary use was acting as an information channel between devices.

Understanding Cross-Device Continuation

Respondents' existing practices of Thought Capture and Online Research require effective mechanisms for transferring and synchronizing data to integrate the progress made while mobile back into the primary workspace. As we found in our Contextual Inquiry, email was the most commonly used mechanism for transferring information across devices. In reflecting on a recent experience, 19 of the 43 respondents who reported Capturing Thoughts (44%) indicated they used email to transfer brief notes from their mobile device to their primary workstation. 16 respondents (37%) reported using mainstream task management software (e.g., OneNote, Wunderlist) that facilitate cross-device synchronization. The remaining 8 respondents indicated that they left the information on their phone to revisit later, but did not remember to revisit it.

Similarly, 20 of the 50 respondents who conducted Online Research (40%) indicated that they used email to transfer their researched information (e.g., URLs) to themselves. 16 respondents (32%) said they retained information in their working memory (e.g., "keep it in my brain cache" (P45)). Other less common strategies included creating browser bookmarks, writing notes on paper, and sending the information to someone else. All respondents used online research to address a particular problem on their mind. All but one used a search engine for their research.

Understanding Task Resumption

Respondents reported employing mobile work practices to also counteract the effects of pausing work on their primary workstation. For example, a common theme that emerged from respondents who used email is it acts as a mechanism for maintaining and refreshing context while on-the-go and upon returning to the workstation:

> *"It keeps me updated with progress and reduces the time to catch up when I return to my desk."* (P34)

Thought capture and performing online research similarly helps maintain context which in turn supports resumption.

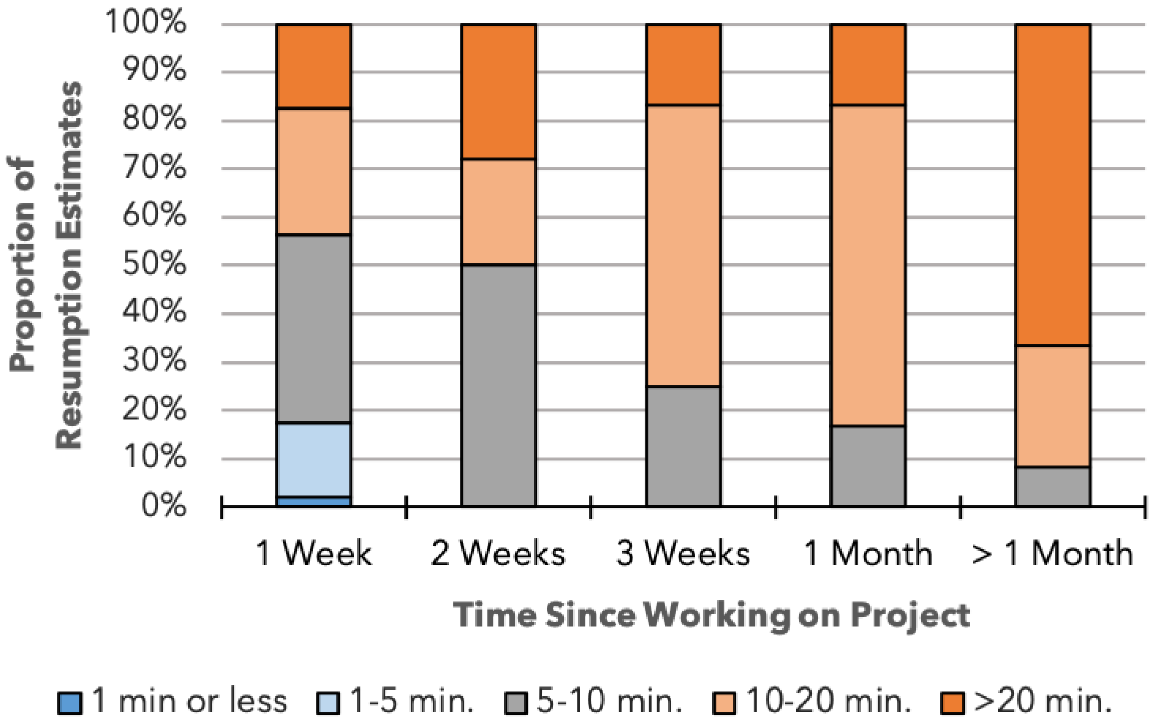

Figure 3.3: A stacked barplot of programmers' estimated length of resumption time binned by the amount of time passed since pausing a programming task.

Alongside their practices, we find that our participants recognized the amount of time needed to resume programming work. We asked them to estimate the amount of time it would take to resume a programming task that they last accessed: one week ago, two weeks ago, etc., up to more than a month ago. Figure 3.3 shows the aggregate responses. Across each time interval, participants' most frequently estimated it would take at least five minutes for them to feel prepared, and even longer for tasks paused for longer than three weeks. To that end, 69 of the 78 participants (88%) said that access to proper tooling could decrease their reported estimated resumption time, highlighting the opportunity to explore systems that help programmers resume their tasks more effectively.

Summary of Findings: Contextual Inquiry & Online Survey

Our two formative studies suggest that programmers leverage mobile devices to make progress on software development tasks, but do not write code on-the-go. Their existing mobile work practices are primarily exploratory, while their desired work practices are grounded in existing code. Email is used as the primary mechanism to continue progress across devices - where captured thoughts and online research elements are transferred from the mobile device to the workstation via email. Programmers prepare for resumption by minimizing what they need to resume and use their mobile work practices to keep context alive while away from their workstation.

3.4 Mercury, A Mobile Programming Tool

Based on our findings from our formative studies, we designed and built *Mercury*, a microproductivity system integrated with Visual Studio Code (VSCode) that automatically generates mobile-friendly, short programming-related tasks, or *microtasks* [52], to support programmers' needs and desires for continuation. When a user decides to go mobile, Mercury uses the current state of their files to generate microtasks that can be routed to the user to make meaningful progress in their work while they are away from their workstation. Users access these microtasks from their mobile device using the Mercury mobile app (see Figure 3.6) and can complete their auto-generated microtasks at their own pace and leisure. Here, we detail Mercury's architecture and its approach to generating microtasks.

3.4.1 Microtask Generation

Mercury automatically generates microtasks based on the functions in users' source code. Functions are inherently compartmentalized to separate and scope source code, making them suitable candidates to surface in attention- and resource-constrained environments. Further, the use of function-based approaches is well-supported by prior research that has demonstrated its utility in crowdsourcing scenarios [155].

Mercury introduces two, novel selfsourcing microtasks based on the paradigms of mobile work identified in our formative studies: *exploratory microtasks* and *grounded microtasks*. To design these microtasks based on functions in users' source code, we leverage "The Function Design Recipe" [76], a six-step process used for teaching function design in software engineering curricula. Specifically, our microtasks are inspired by *function templating* (step 4), and *function testing* (step 6), which correspond to preparing a function's implementation and reviewing a function's execution respectively.

Mercury's microtask generation procedure is powered by a custom source code parser that extracts each function's attributes, including location, name, parameters, body, and,

(a) Step 1 of Exploratory Microtasks ask the user to determine the relevance of a web resource for an unimplemented function.

(b) Step 2 of Exploratory Microtasks allow the user to add a note to add context to resources they find useful for a function's implementation.

Figure 3.4: Mercury's microtasking interface for exploratory microtasks.

if available, associated documentation. Importantly, the procedure relies on the presence of a function documentation string (docstring) in order to generate microtasks for a particular function. Mercury's parser was designed to specifically seek out docstrings in the JSDoc format, an industry standard already used by professional developers. We now detail the procedural aspects of generating Mercury's microtasks in depth.

Exploratory Microtasks

Exploratory microtasks (EMs) are two-step microtasks for functions with empty function bodies (e.g., function stubs). In the presence of such functions, Mercury first uses a regular expression to extract the function's description from its docstring. The description is then used as a query to Bing where the top-N web results from either a question-answering site (e.g., StackOverflow) or a documentation site (e.g., MSDN, MDN) will be converted into templated EM tasks. The first step of each EM asks users if the surfaced web resource is useful for the function's implementation. Users can tap on the resource to open the page in a modal window within Mercury's UI. Throughout this process, users have an opportunity to rate the utility of each resource (useful / not useful). Rating a resource initiates the second second step of the task, which asks users to optionally explain why the resource is useful. Upon submitting the response, the Mercury system injects the resource's URL and the user's note back into the associated function's docstring. As no convention exists for formatting URLs in source code, the resource URL was formatted to match the most commonly observed format in a recent large-scale analysis of hyperlinks in source code comments [100]. An example is shown in Figures 3.4a and 3.4b.

(a) Step 1 of Grounded Microtasks ask the user to assess the behavior of a function with a particular set of function parameters.

(b) Step 2 of Grounded Microtasks allow the user to add a note alongside the function parameters that cause the function to fail.

Figure 3.5: Mercury's microtasking interface for grounded microtasks.

Grounded Microtasks

Grounded microtasks (GMs) are two-step microtasks that are generated for functions with content. When encountering such functions, Mercury will auto-generate GMs for a function by determining the type of its parameters and their purported use within the function, as documented by the function's docstring and signature. Using this information, Mercury generates a set of parameters specifically for this function to serve as a test case. Test cases are randomly selected from a list of common edge-cases, such as empty strings and null object references, per the Function Design Recipe. In the first step of each GM, users are asked to determine if the function will execute correctly with a given set of parameters (see Figure 3.5a). If the user indicates that the function will fail execution, they proceed to the second step of the task where they are allowed to optionally explain why the test case fails (see Figure 3.5b). Upon submission, Mercury injects the test-case and the optional explanation into the associated function's docstring.

Queuing, Sequencing, and Completing Microtasks

After generating microtasks, Mercury dynamically constructs a microtask queue for the user. Mercury's strategy for ordering microtask queues is based on principles of working memory [18]. While users are actively programming on their workstation, Mercury maintains a ranked list of functions ordered by the amount of time since being edited or seen for more than 10 seconds. When transitioning to a mobile device, Mercury uses this information to route a microtask associated with the function the user was most recently working on. Beyond the first task, Mercury uses a standard round-robin algorithm to distribute

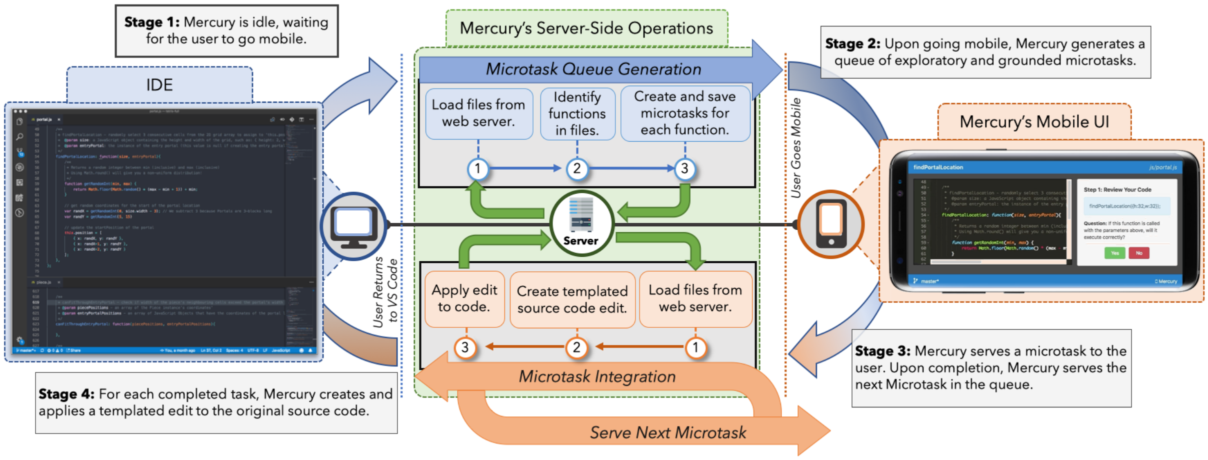

Figure 3.6: Mercury's architecture supports four stages of interaction.

attention across the functions found in the user's workspace. Importantly, Mercury allows users complete their queued microtasks at their own pace and does not require users to exhaust their queue before returning to the workstation.

3.4.2 System Architecture

Mercury is composed of two primary sub-systems: 1) a MeteorJS web application that manages all web requests, serves the front-end mobile experience, and handles information synchronization between web clients and a Mongo NoSQL database; and 2) a VSCode plugin that converts the VSCode workspace into a web client that shares workspace state with the server.

Data and Synchronization Model

Mercury's data model is file-centric and based on the principles of file-based cloud storage. Upon starting VSCode, the plugin will authenticate with the user and immediately synchronize the editor's workspace files and directories with the server. Through the plugin, changes in the VSCode editor are immediately propagated and synchronized to the server and to Mercury. Similarly, any change made through Mercury's task interface will be propagated to the server and to VSCode. Alongside files, Mercury stores and synchronizes the user's mobile tasks, their state (i.e., whether or not they are at their workstation), and any interaction they have with the system.

3.5 User Study: Methods

Following established practices for evaluating cross-device systems [41] and tools to support software engineering [143], we designed and conducted a "first-use" study [99] to understand Mercury's successes and shortcomings as a tool for supporting programmers' mobile work practices.

3.5.1 Experimental Design

We conducted a lab study that was inspired by recent research that found developers regularly experience unplanned "short breaks" throughout their workday [197]. Specifically, these types of breaks can last upward of 15 minutes, and often yield scenarios in which individuals are forced to spend time away from their workstation. To better allow our lab study to speak to Mercury's practical utility, we adopted the temporal and unexpected nature of these breaks to frame our study design. The study required participants to work on a predefined programming task on a workstation, leave the workspace for 30 minutes with a mobile device and then return to the workstation to complete the task. The study lasted approximately 1 hour and 30 minutes and was split into three 30-minute phases:

Phase I: Starting the Task

After reading the task instructions, participants were told to work toward the implementation of the study's programming task for the next 30 minutes, and were told they would be given a mobile device to use "a new mobile experience for progammers" while they were away from the workstation. Participants worked uninterrupted during this 30-minute period.

Phase II: Going Mobile with Mercury

After 30 minutes participants were interrupted and told that they would now need to leave the room. They were given a Samsung S8 smartphone that had access to Mercury and was configured with their participant identifier to ensure synchronization. At the time of interruption one researcher administratively triggered Mercury's task generation function to simulate a seamless transition between devices. Participants were instructed to use Mercury's mobile experience during the next 30 minutes from the building's atrium and asked to return to the study room to continue their implementation after the the 30 minutes had passed.

Phase III: Returning to the Task

Upon returning to the study room, participants were told to place the smartphone face-down on their desk and continue working toward the implementation of the study's programming task. After 15 minutes of continued work, they were told that the task was over; only one participant (P35) finished the task in this time. Participants were then given a post-study questionnaire and told that we would follow up within 24 hours to conduct a semi-structured post-study interview.

3.5.2 Programming Task

Participants were asked to complete a HTML5/CSS/JavaScript implementation of an enhanced version of Tetris that introduced *portals*, following prior research that has used classic arcade games as an implementation task in studies [217]. In this version, an entry portal and a corresponding exit portal automatically spawn on the Tetris game grid. When a game piece is adjacent to the entry portal, the piece's next move should transfer the adjacent pieces to the exit portal's location.

As the study task, participants were given four functions to implement in the Tetris codebase, three of which focused on portal validation and one of which focused on locating portals on the grid. All four function implementations were blank at the start of the study. If all four functions were correctly implemented, both portals would function correctly. To facilitate Mercury's integration with the codebase, all functions in the source code were documented with the JSDoc standard. Pilots of our study confirmed that the task was challenging, yet feasible. Participants were given five minutes to read through the task instructions, shown in Appendix B.2.3, before being allowed to begin the task.

Mercury was configured to create five microtasks for each of the task's four functions, totaling in a queue of 20 microtasks for each participant. The type of microtasks generated for each function were contingent on its "completeness". We used the number of lines in a function's body at the time of going mobile as a proxy. Grounded microtasks were created for functions whose body included more than five lines of code. Otherwise, Mercury recognized the function as incomplete, and would create exploratory microtasks for the function.

3.5.3 Data Collection

We collected the following data as a part of the study:

Pre-Study Questionnaire

We inquired about participants' gender, job role, and experience. We also inquired about the practices from Table 3.1. The complete questoinnaire is provided in Appendix B.1.

Instrumentation Data

We tracked participants' actions with screen capture software, and by logging low-level events within Mercury.

Post-Study Questionnaire

Before concluding the study, we administered a questionnaire that included three validated instruments: 1) the System Usability Scale (SUS) [40] to measure Mercury's usability, 2) a 5-point reattachment questionnaire for measuring participants' ability to mentally reengage with the task [255], and 3) a 5-point PANAS-inspired scale to measure how productive, engaged, and relaxed the participant felt while they were away [284] as used in Section 4.2. The complete questionnaire is provided in Appendix B.3.

Post-Study Interview

We conducted a 20-minute semi-structured post-study interview with each participant. The interview began by asking participants about the experience in general alongside the utility of each microtask, and transitioned into Mercury's effect on participants' ability to return to the task. Interviews concluded by inquiring about Mercury's practical utility.

3.5.4 Participants

20 participants (18 male / two female) were recruited by randomly sampling the same company-wide employee list of individuals with programming job roles used in both the Contextual Inquiry and the Online Survey. Job roles of those recruited include software engineer (18) and software engineering intern (2). Participants' ages included 18-24 (3), 25-34 (7), 35-44 (9), 45-55 (1), and participants' years of experience included 3-5 years (4), 5-10 years (6), and 10 or more years (10). Participants were compensated with a $50 gift card.

3.6 User Study: Findings

Overall, our user study results highlight how Mercury enhances mobile programming experiences. Participants found value in Mercury's interface and were able to make meaningful progress with little effort or attention. Mercury supported continuation of tasks across devices with seamless transfer of task progress, and interacting with Mercury's microtasks enabled participants to easily resume coding upon returning to their workstation. The utility of Mercury's tasks understandably varied between individual's and their unique contexts. We discuss themes from our user study and evaluation below.

3.6.1 Supporting Mobile Work Practices

Most participants (17 out of 20) enjoyed Mercury's microproductivity-inspired task design as it required "little attention to make progress" (P9). Participants' post-study questionnaire responses indicate that the experience allowed them to feel productive (M=3.8; SD=0.9), engaged (M=3.8; SD=0.7), and relaxed (M=4.1; SD=0.9) while mobile. The positive reception is also supported by Mercury's favorable SUS scores (M=77.5; IQR=11.8). Only two participants voiced complaints related to device constraints, stating that "the device made it difficult to read code" (P18) and that "the experience suffered from the same pitfalls as any mobile development environment" (P16). On average, participants used Mercury to complete 17 microtasks during the study. The average time per microtask was 74 seconds. No significant difference was observed between Mercury's microtask types.

Exploratory and Grounded Microtasks

The exploratory (EMs) and grounded (GMs) microtasks received positive feedback from participants, with four participants finding both to be useful, six participants liking GMs better, and seven preferring EMs instead. On average, participants identified 60% of the web resources from Exploratory Microtasks as relevant, and indicated 90% of the test-cases from Grounded Microtasks identified issues they could correct upon returning to their workspace. Only three participants found neither to be particularly helpful, yet the premise of the system was still seen as promising and beneficial:

> "*Both tasks are great ideas. They're great first-steps toward being able to mobilize myself in a new way.*" (P16)

Participants evaluated the utility of EMs on one primary characteristic: *resource relevance*. As with any online search, participants found "some references applicable and useful, but toward the end, they seemed less relevant" (P2).

Participants who found EMs useful (14 of 20) expressed sympathy for the relevance problem, highlighting that "I'd be seeing the same noise if I did my own search" (P4) and anything more accurate would "win us the Nobel prize". The noise was not always bad: four participants recounted how EMs reoriented their understanding of a problem they were stuck on, thanks to a surprising resource.

> *"One online research task made me realize the implementation was just an array intersection problem. It kept it in my head, especially when it framed the problem for me. I knew exactly what I was going to do when I got back."* (P15)

This particular participant's experience further highlights the importance of relevance for online research as it suggests surfacing the right resource may stoke individuals' resumption. In addition to accessing online resources, six participants suggested adding support for team communication channels to leverage the expertise of teammates in various scenarios.

For GMs, participants were excited about the ability to reexamine their code in a different setting. Their appreciation of GMs were centered on the task's ability to "introduce edge cases that I didn't even think of while coding" (P15). The few participants that did not find GMs useful described the automatically generated test cases as "too simple" (P14) or "repetitive after a point" (P17). However, participants' remarks were clear that the tasks would have been useful had they surfaced test cases "of the right complexity" (P9). Eighteen participants offered explicit accounts of how GMs could be situated in their current work practice within their team:

> *"The ability to pull in reviewers and use canned comments, add voice commentary, highlight code, and look at diffs on-the-go. I think that would be a huge thing." (P4)*

Participants also noted the ease of completing these tasks using Mercury. They even suggested that Mercury could improve systems that already support mobile code review in some form (e.g., Visual Studio Team Services), to be more user-friendly: "Mercury created a mobile experience that would be generally easier and more enjoyable to use in a team setting" (P3).

The three participants who found neither GMs or EMs to be useful noted that their issue was with the specific tasks they saw, but expressed interest in an experience that would have helped them "start with algorithm design" (P10), "sketch or focus on something design-related" (P13), or "refresh my mind with creative ideas" (P1).

When Mercury Would Be Used

After using Mercury, participants had no shortage of imagining how the system could fit into their daily work practice:

> *"With Mercury, I can step away from the terminal and take a break, have a coffee, go outside. I'm not tethered to the desk as much as I would be, and I can still accomplish meaningful work."* (P4)

Participants voiced excitement in using Mercury to continue their work "when you want to productive" (P14), "when you don't really need to pay attention" (P12), and "when you have nothing better to do" (P2). 18 participants noted commutes in public transport as a key setting for continuing work:

> *"I've got 45 minutes to kill on the bus each way between home and work. If I'm still thinking about some work, the end of the workday would be great if I can eke out some additional productivity on the way home."* (P16)

Discussed by 16 participants, the second most common settings cited were brief moments that involve waiting in the workplace, such as waiting for a meeting to start, waiting in line to order lunch, and even bathroom breaks. Similarly, settings that involve waiting outside of work, such as doctors' offices, were also mentioned by participants.

Participants had mixed feelings about how Mercury might affect their work-life balance. Six expressed an interest in using Mercury as a means for capturing lingering thoughts that stem from their workday.

> *"Sometimes, you come home, and you're still attached to work. Your kids (are) trying to play with you. If Mercury is easy enough to capture a thought to let me give my kids the attention they need, I'd be excited to use it then."* (P12)

The other five bolstered the need to simply capture a quick thought as a result of the right thought coming at the wrong time (e.g., "while I'm brushing my teeth" (P11)). Conversely, three participants voiced a concern of "working 24/7." (P1). We expand on this theme later, in the Discussion section.

3.6.2 Supporting Cross-Device Continuation

All 20 participants liked being able to continue their work while away from the study's workstation, and, in particular, appreciated how Mercury helped them transfer information:

> *"Getting information between devices is usually the problem. Mercury kind-of helps this by handling the synchronization."* (P16)

Participants liked having mobile access to code that had recently been written on the desktop and being able to synchronize information across devices without having to remember to do particular actions (e.g., a repository commit).

Mercury's guided nature was a thematic point of discussion for each participant. Five participants expressed satisfaction with the guided aspect of Mercury's mobile experience:

> *"It was nice because I felt like it was intuitively looking for things I probably would've looked for anyway."* (P20)

Other comments in support of a fully autonomous process described Mercury's process as one that "was nice to supply guideposts", "required little input" (P16), "gamified because you didn't know what was coming next" (P15).

Participants expressed appreciation for Mercury's guided nature and ready-made, on-the-go tasks, and provided recommendations for how these could be improved with personalization:

> *"There'd be times when I want the system to autopilot me. Other times, I'm a control freak, and I want to be able to say, 'Now is the time I do this'."* (P4)

They suggested thematic pathways that would make the mobile experience more useful for them both during the study and in practice, such as the ability to tell Mercury which function to focus on while mobile, the ability to "mark a function to view directly on Mercury" (P17), and support for task navigation (e.g., skipping and revisiting). Overall, participants found it easy to envision how Mercury could be a part of their usual work routine, and were excited to offer feedback that could help shape the system further.

3.6.3 Supporting Task Resumption

Reattachment questionnaire reports suggest Mercury positively affected participants' resumption processes (mean = 15.5; IQR = 3.4). 16 participants offered positive accounts of how Mercury helped them resume the Tetris task when they returned to the study workstation. When participants recounted their experience with Mercury in the post-study interview they said the experience "helped keep things available" (P9), "kept your mental process warm" (P14), and "felt like it greased my mind's wheels" (P11). In discussing how participants imagined the system's ability to help with resumption in unexpected scenarios, 11 participants highlighted that it would add comfort if participants needed to leave unexpectedly:

> *"Mercury would make me feel more comfortable if I need to walk away momentarily and come back. It would help bring down the ramp-up time time when I get back to my workstation, and I can just go and code right away."* (P12)

Five participants specifically stated their resumption with the Tetris task was facilitated not only by being able to continue the work on-the-go, but knowing the first step they would take when they returned to the study workstation. These statements were corroborated by their screen recordings in which we observed each participant referencing a source-code change made by Mercury upon their return and subsequently acting on it (e.g., copy-and-pasting a resource URL into their browser).

3.7 Discussion

Our study provides insight into understanding the role of mobile programming tools in practice. Prior research targets how mobile programming can be enhanced with novel touch-based interfaces for the cumbersome nature of text entry on mobile phones [271, 272], and cross-device techniques for supporting programmers across multiple mobile devices while stationary [111]. Here, we find that a mobile work experience designed around microproductivity can not only help programmers continue their work on-the-go, but also instill comfort in pausing work unexpectedly. We also see that programmers feel like they can make meaningful progress in their work with Mercury's microtasking experience in scenarios ranging from brief moments of downtime to the daily commute. Further, we observe that engaging with programming-related tasks via Mercury spurs users' ability to resume their work.

Mercury's microtask designs were driven by the mobile tasking needs and desires observed in our formative studies. An ideal microtask is contextually self-contained, requires little effort to complete, and helps people make progress [116], and Mercury's microtasks were designed with these principles in mind. However, we find the utility of Mercury's microtasks is firmly grounded in the programmer's work context. For example, a small number of users expressed a desire for design-oriented microtasks. While we explored only two types of microtasks in our exploration of microtasked programming, a framework like Mercury allows us to design and test different experiences, providing an important first step toward empowering programmers' with microproductivity in the wild.

Our research suggests that Mercury helped kindle participants' resumption processes. In our user study, we find that giving our participants the ability to mobilize their work on-demand helps them feel "not as tethered to the desk as much as they would be" (P4). Understanding how programmers' behavior changes with this newfound comfort in moving away from their workstation is an important direction of future work. Similarly, the findings from our user study establish a frontier of future research aimed at exploring the intersection of prior and current interventions (e.g., visual cues [217, 218] for cross-device experiences) in support of programmers' productivity.

Unlike our assessment of Mercury, the majority of microtask programming research has been studied in the context of teams of "transient" developers [156, 155]. Several participants in our user study noted Mercury's potential value in team settings, while others were unsure of its ecological utility for teams with diverse information needs [142]. Exploring how social experiences and larger codebases change the utility of Mercury's mobile experience is a key direction of future research.

By enabling programmers to work from their mobile devices during free micromoments, Mercury has the potential to blur the lines between work and non-work time. More than half of our user study's participants expressed an interest in using Mercury outside of the workplace. While the overarching goal of our work is to empower programmers' mobile work practices, we recognize the threat that a mobile microproductivity system like Mercury may pose on encroaching into individuals' downtime. However, we also see how participants were able to interleave Mercury tasks with other activities. As one participant notes:

> *"When I was downstairs in the atrium, I actually felt like was still making progress even though I wasn't really paying attention."* (P12)

An important area of future work should focus on how to design software tools for task continuation support that also account for programmers' need to disconnect from work.

3.7.1 Limitations

While our study provides insight into cross-device programming support, there are a number of limitations that require further study. Mercury's user study was conducted in a lab setting. Prior research reinforces lab studies as valuable approaches to study novel systems, specifically those have cross-device components that may be challenging to reliably study in-the-wild [41]. While our lab study's design was strongly grounded in observations made in the field, further studies are needed to claim that the same observations may be seen in-the-wild or consistently over time.

Our study's evaluation of Mercury was focused on understanding the success and challenges of using a microtask programming solution for on-the-go programming. Our evaluation does not compare microproductivity tools to non-microproductivity tools for on-the-go work (e.g., CodeBeat[1]), and we make no claim about how the effectiveness of these tools may differ. However, we recognize this as a valuable area of future research both for Mercury and future programming tools that incorporate elements of microproductivity.

Finally, our study's population consisted primarily of professional and experienced software engineers at a large technology corporation. Mercury may provide different experiences for individuals that program less frequently in their job roles or work at smaller companies. Mercury's mobile experience also relies on the presence of function documentation. We recognize that documentation practices may vary among professionals and that self-documenting code is not only common, but often promoted [259]. Future research is needed to understand how Mercury can be adapted to scenarios where documentation is significantly limited or unavailable entirely.

3.8 Conclusion

We presented Mercury, a system that guides programmers in making progress on-the-go with auto-generated microtasks based on their source code's current state. We detailed how the findings from our two studies – contextual inquiry and online survey – motivated Mercury's design as a microtasking system for on-the-go programming work. In studying Mercury with 20 full-time programmers, we found that mobile work experiences designed around microproductivity can help programmers continue their work on-the-go and instill comfort in pausing work unexpectedly, all the while making meaningful progress on their work tasks. Mercury's success serves as a first step in a family of future software tools that allow programmers to make progress on their work away from their primary workstation.

[1] https://codebeat.co/

Chapter 4

Supporting the Home-Work Transition with Conversational Intelligence

In this chapter, we examine how conversational systems can aid people in reorienting their attention between environments. This research focuses specifically on a transition that working people regularly make on a daily basis: the transition between home and the workplace.

We begin by motivating our problem space and providing an overview of the chapter at large. We subsequently introduce SwitchBot, a conversational bot that helps workers detach from and reattach with their work. We present a pre-study validation of of SwitchBot's underlying dialogue framework and then conduct a two-week long field study with SwitchBot deployed in a workplace. Our evaluation of SwitchBot assesses the tool's utility from the conjoined perspective of productivity and well-being.

4.1 Motivation

Adequate recovery from work is vital for replenishing resources depleted during work hours and maintaining good psychological health and well-being [303]. Among the many influential factors that promote recovery, the ability to psychologically detach from work is recognized as particularly important for its core role in facilitating mental rejuvenation and refreshment in subsequent workdays [270, 282]. Recent research has posited that rebuilding a mental connection with one's work before the start of the workday (i.e., reattaching with work) is equally as important for ensuring workplace engagement and productivity, particularly in the morning [255]. A variety of approaches, ranging from brief planning to extensive therapy, have been proposed and studied in support of these goals. The efficacy of these techniques ranges with much variation, making this an active and open area of research for novel interventions.

In this research, we study the extent to which structured dialogues, focusing on individuals' work-related tasks or emotions, can help them with the detachment and reattachment processes. Ranging from paper-based diaries to online surveys, an array of possible intervention types exists for ad-ministering such dialogues to individuals. Prior work, however, emphasizes the importance of social support that individuals may receive from others during the detachment process [94, 250]. While this constraint belies many types of technical interventions, conversational intelligence, or bots, embraces these scenarios with prior research demonstrating their ability to provide such social support through active listening and guided conversation [102, 288] as shown by systems such as ELIZA [287] and ALICE [102]. Further, conversational systems are known to offer the added benefit of inducing feelings of accountability in individuals when setting goals [31], a process that generally occurs during both the detachment process and the reattachment process.

We present and study SwitchBot, a conversational bot that helps workers detach from and reattach with their work. By identifying similarities between interruption and task resumption with detachment and reattachment, we leverage prior research to design two dialogue styles for SwitchBot, one that is task-centric and the other emotion-centric. We validated the practical value of each dialog via an online study with 108 crowd workers, and then conducted an in-situ study for 14 days where 34 information workers used SwitchBot as they began and concluded their workday. Our results show SwitchBot's dialogues were an effective intervention for supporting detachment from and reattachment with the workplace. In particular, we find that:

- Participants felt more productive and engaged during the first hour of their work when using SwitchBot;
- Participants sent fewer after hour work e-mails after detaching from their workday with SwitchBot; and
- The emotion-centric dialogue was perceived as more effective than the task-centric dialogue, but the task-centric dialogue helped participants jump right back in-to work at the start of the day.

These findings provide evidence that conversational intelligence can provide effective support for psychological detachment from and reattachment to work and suggest how they might most effectively be implemented. Further, in this work, we study the extent to which structured dialogues, focusing on individuals' work-related tasks or emotions, can help them with the detachment and reattachment processes. Collectively, the landscape of needs and challenges presented by the detachment and reattachment literatures reinforce the suitability of bots as an intervention for the problem space. These bodies of literature suggest the need for social support alongside the ability to set and manage goals, each of which have demonstrated success in conversational systems [31, 288]. We extend this prior work by designing, building, and studying a bot to mediate the detachment and reattachment processes through conversation. The interaction of the bot was designed to closely follow strategies for detaching and reattaching from work leveraging recovery theories from psychology and interruption management theories from the HCI literature.

4.2 SwitchBot

We present SwitchBot, which conversationally assists information workers in detaching from and reattaching with their work through brief conversations before the start and end of the workday. SwitchBot appears as a contact on Skype and users converse with it via Skype's chat interface.

4.2.1 Interaction Design

SwitchBot was built with the Microsoft Bot Framework and the Language Understanding and Intent Service (LUIS), services that provide a development ecosystem with support for easily integrating intelligence into bots. SwitchBot was designed specifically for the purpose of studying detachment and reattachment, and its functionally is currently limited to helping workers transition in and out of the workplace.

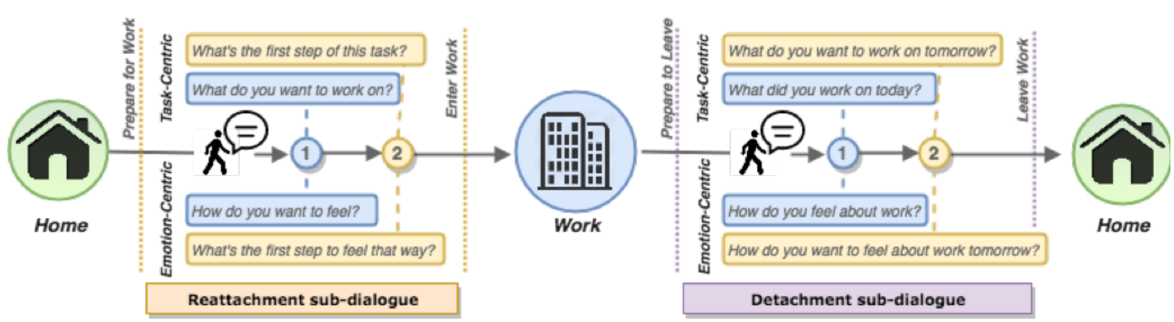

Figure 4.1: An overview of SwitchBot's reattachment and detachment dialogue structure.

Getting started with SwitchBot was designed to be quick, simple, and intuitive. New users begin by adding the bot as a contact on Skype. When receiving messages from new users, SwitchBot will introduce itself and collect the new user's name. Afterwards, it will present the user with a brief overview of the content and timing of future interactions.

SwitchBot automatically assigns a new user to one of the two dialogues of choice. After signing up, users can utilize SwitchBot to detach from and reattach with their work, as illustrated in Figure 4.1. At the end of the day users engage in a detachment sub-dialogue where they offload the day's activities and prepare to leave work. Likewise, users engage in the reattachment sub-dialogue at the start of the work day, where they prepare to return to work.

When receiving a message from a known user, SwitchBot will try to intelligently determine whether to engage the reattachment or detachment sub-dialogue based on the us-er's message content and time-of-day. If unable to do so reliably, SwitchBot will reply with a general-purpose menu that asks users to specify which sub-dialogue they would like to invoke.

SwitchBot implements a pull rather than a push model of interaction, meaning that users initiate any conversation with SwitchBot at their moments of choice. Once initiated, SwitchBot then leads the user through the conversation experience following the sub-dialogues described below.

4.2.2 Theoretical Underpinnings of SwitchBot's Sub-Dialogues

The process of detaching and reattaching between work and home can be considered analogous to the process of transitioning from one task to another, where the former task will be resumed at a later point. Task resumption research models the resumption process using two key characteristics: interruption lag (i.e., time allocated toward preparing to switch to a different task) and resumption lag (i.e., time allocated toward preparing to resume an interrupted a task) [9]. As inspiration for the structural design of our dialogues, we refer to and leverage one particular well-established framework: Altmann and Trafton's Goal Activation Model [8]. The Goal Activation Model hypothesizes that people utilize two primary cognitive techniques during their interruption lag to minimize subsequent resumption lag [36, 88, 220]:

- **Prospective goal encoding**: the action of "looking ahead" mentally to determine how to proceed.
- **Retrospective rehearsal**: the action of rehearsing what was being done.

Per Trafton et al. [274], these two conceptually translate to, "*Now what was I doing?*" and, "*What was I about to do?*", each of which can be characterized as setting goals.

Before setting goals in each detachment sub-dialogue, individuals are asked a question centered around reflection. In both dialogues, a simple form of active listening [17] is employed during the detachment sub-dialogue to allow people to continuously supply input. By doing so, we afford them the opportunity to dump their work-related thoughts as much as they would like to before leaving work.

4.2.3 Dialogue Framework

We studied two different frameworks for how SwitchBot directs the detachment and reattachment sub-dialogues: a *Task-centric* and *Emotion-centric* dialogue. These dialogues are shown in Table 4.1 and are described in greater detail below. For each question, word choices of equal sentiment were randomly selected from a large array to prevent repetition.

Task-centric Dialogue

The Task-centric dialogue framework is named after its topical emphasis on task interruption. In the model's detachment sub-dialogue, the bot asks individuals what they worked on during the day and what they want to work on the when they return to work. In the reattachment sub-dialogue, the bot reminds and confirm with individuals what they want to work on as well as ask them to specify the first actionable step toward doing the task.

The Task-centric dialogue framework heavily reflects the process of preparing a task for interruption and subsequent resumption. In support of detachment, the framework lever-ages active listening and Altman and Trafton's Goal Activation Model [273], asking the individual "*What did you work on today?*" and "*What do you want to work on tomorrow?*". Reattachment is facilitated with a task-focused goal priming cue, which motivates

Detachment Sub.	**Task-centric Dialogue**	**Emotion-centric Dialogue**
(1) Active Listening	*What did you work on today?*	*How did you feel about work today?*
(2) Goal Setting	*What do you want to work on tomorrow?*	*How do you want to feel about work tomorrow?*
Reattachment Sub.	**Task-centric Dialogue**	**Emotion-centric Dialogue**
(3) Goal Confirmation	*Do you still want to work on [...]?*	*Do you still want to feel [...]?*
(4) Goal Priming	*What's,the first step you can take toward completing this task?*	*What's,the first step you can take toward feeling this way?*

Table 4.1: Overview of the task-centric and emotion-centric dialogue frameworks.

the individual to act on the goal [8]. This framework's design is supported by research that shows the suitability of task-focused planning as an intervention for detachment and reattachment [42, 245, 273].

Emotion-centric Dialogue

The Emotion-centric dialogue framework emphasizes emotional and mood-related discussions. In the model's detachment sub-dialogue, the bot asks individuals how they feel about work today and how they want to feel about work when they return. In the model's reattachment sub-dialogue, the bot reminds and confirms with individuals how they want to feel about work and asks them to specify the first actionable step toward feeling how they want to.

The Emotion-centric dialogue's design reflects research on the psychology of mindfulness – being nonjudgmentally aware of one's emotional state in the present [110]. Each step in the dialogue draws individuals' attention to their present emotional state as a means to improve emotional awareness and set future emotion-related goals related to work [223]. The overall structure of the Emotion-centric dialogue is inspired by the task resumption model and structured behavioral therapy, which generally begins by asking people how they feel about work and the actions they want take to feel differently (i.e., better) [25]. These design concepts and their suitability toward workplace detachment and reattachment are well-supported by research in occupational health psychology and goal setting [110, 171, 220, 223].

4.3 Dialogue Validation

Before deploying and studying SwitchBot in the work-place, we conducted an experiment on Amazon Mechanical Turk to preliminarily validate the efficacy of the dialogue frameworks. We simulated the workday experience through a scenario where the workers will take a break in the middle of their workday and engage with the detachment and reattachment dialogues as part of their break. We collected user perceptions around key traits related to detachment and reattachment as a result of the interactions. Prior work has demonstrated the validity in using MTurk both for preliminary research and large-scale user studies [140]. While there are differences between MTurk and the workplace, the notion of pausing and resuming work is analogous, and findings in one context should be observable in the other.

4.3.1 Task and Procedure

We designed a HIT to simulate the detachment and reattachment process by asking workers to take a 5-minute break in the middle of their workday. Assuming that the workers had been working before engaging with the HIT, the first step of the HIT asked them to prepare for their break by engaging with the detachment dialogue, drawn from either the Task-centric or Emotion-centric dialogue framework. The HIT interface then simulated a forced break that lasted at least five minutes by preventing workers from moving to the next stage. Workers were asked to document their break (e.g., with a photo) to ensure the internal validity of our study. At the end of the break they were told that they were about to resume their workday and were subsequently given the reattachment dialogue from either the Task-centric or Emotion-centric framework, selected to match whatever they saw in the detachment dialogue. Workers were paid $2.00 for completing the HIT.

4.3.2 Measurement

Between each stage of the HIT, we measured the effectiveness of a dialogue through a set of probes based on the Positive Affect Negative Affect Scale (PANAS) [285], a common proxy for measuring detachment from work [279]. Research has shown that adequate psychological detachment or reattachment with work can be predicted with four, key emotional traits: performance [82], engagement [254], stress [252], and burnout [249]. We therefore selected 4 measures – three from PANAS (Active, Relaxed, Inspired) and one from the productivity literature [183, 182] – that correspond to a key emotional trait (Table 4.2). Our probe presented each measure in the form of a 5-point Likert scale ranging from very negative (1) to very positive (5). Before finishing the HIT, we asked workers what they did during their break and to provide feedback on the dialogue questions they were given. The probes were presented at four points in the process: 1) at the start of the HIT, before engaging in any dialogue, 2) after completing the disengagement dialogue, 3) after their break, and 4) as they returned to work after completing the reattachment dialogue.

Measure	**Statement**	**Source**
Productivity	*How productive do you feel?*	[183, 182]
Engagement	*How busy do you feel?*	PANAS [285]
Relaxation	*How relaxed do you feel?*	PANAS [285]
Inspiration	*How inspired do you feel?*	PANAS [285]

Table 4.2: The four statements used to measure psychological detachment or reattachment with work. Participants are asked if they agree with each on a 5-point Likert scale.

Measure	Effect	F	p
Productivity	*Dialogue*	*2.61*	0.11
	Stage	*5.94*	0.04*
	Dialogue x Stage	*1.87*	0.13
Engagement	Dialogue	*0.37*	0.54
	Stage	3.91	0.01*
	Dialogue x Stage	0.26	0.26
Relaxation	*Dialogue*	12.76	0.00***
	Stage	19.12	0.00***
	Dialogue x Stage	38.62	0.00***
Inspiration	*Dialogue*	3.34	0.07
	Stage	1.74	0.16
	Dialogue x Stage	1.93	0.11

Table 4.3: Results of a mixed-design ANOVA on self-reported measures from workers in the 4-stage MTurk validation study (* : $p < 0.05$, ** : $p<0.01$; *** : $p<0.001$).

To analyze the collected data, we used a mixed-design ANOVA with the worker's assigned dialogue (Task-centric, Emotion-centric) as the between-subjects factor and the HIT stage of the self-report as the within-subjects factor. Statistical significance was further examined using Bonferroni post-hoc tests. We ensured no assumptions were violated using graphical assessments to verify normality alongside a Mauchly's test of sphericity.

4.3.3 Results

We recruited 108 workers to complete the HIT; 54 were assigned to the Task-centric dialogue framework, 54 to the Emotion-centric dialogue framework. Nine workers (5 from the Emotion-centric condition and 4 from the Task-centric condition) were removed for incorrectly completing the task (i.e., spammer behavior, not taking a break as requested). Across both frameworks, workers took breaks ranging any-where from five minutes to upward of an hour. There were no statistically significant differences in task completion time between frameworks.

Table 3 shows the results from our mixed-design ANOVA. We found that the HIT stage had a significant effect on workers' self-reported productivity and engagement. The Bonferroni post-hoc test showed that that workers in both conditions felt significantly more productive ($t(99)=3.04$; $p<0.001$) and engaged ($t(99)=3.38$; $p<0.001$) with work after going through the reattachment dialogue compared to when they began the HIT.

Dialogue, stage, and the interaction of the two all had a strong effect on workers' self-reported relaxation ($p<0.001$), as shown in Table 4.3. While workers were more relaxed after the detachment dialogues, there was no difference across the different dialogue types. However, the post-hoc test showed that workers who were assigned the Emotion-centric dia-logue felt significantly more relaxed after reattaching with their work than workers who were assigned the Task-centric dialogue ($t(99)=3.41$; $p<0.05$).

Finally, we find that the assigned dialogue had a small effect on workers' self-reported inspiration. Specifically, the post-hoc test showed that workers who were assigned the Emotion-centric dialogue felt more inspired after the reattachment dialogue than Task-centric workers, but the difference was not statistically significant ($t(99)=0.59$; $p=0.08$).

In summary, these findings validate our dialogues' design. We find that the detachment dialogues helped all workers to be more relaxed afterwards. The reattachment dialogues helped all workers feel more productive and more engaged in their task following the interaction. Workers who were shown the Emotion-centric dialogue also felt more relaxed and slightly more inspired after the reattachment dialogue. These results strengthen the rationale behind studying multiple dialogues guided by distinct theory and practice.

4.4 Field Study

Given the two dialogues we developed appeared impactful and differentiated in an artificial setting, we set out to understand their impact on people's work behavior in a field study where the dialogues were used by people to actually detach from and reattach to their workday. We conducted an in-situ study of SwitchBot for 14 days with 34 information workers at a large technology corporation during the summer of 2017. Here we describe the methodology and analysis methods we employed.

4.4.1 Participant Recruitment

41 participants (M=29, F=12) were recruited by randomly sampling e-mail addresses from an organization-wide employee list. Job roles of those recruited include program manager (10), engineer (21), designer (1), analyst (1), and administrator (2). Seven participants dropped out during the study, and we therefore present data for 34 people. Participants received a $50 gift card for their participation.

4.4.2 Data Collection

We collected the following participant data via workstation logs, experience sampling probes and post study surveys. Appendix C describes the post-study survey used in detail.

Measures of Detachment

In order to measure how well participants detached from their work after the detachment dialogues, we collected the following data:

- *Detachment Questionnaire*: We modified validated self-report measures for assessing psychological detachment [251] into a 4-item measure as follows: "After interacting with the bot at the end of my workday – 1) I forgot about work, 2) I didn't think about work at all, 3) I distanced myself from work, 4) I got a break from the mental demands of work." These questions were presented to participants at the end of the study to assess their overall perception on the deattachment experience.
- *Number of Work Emails Sent During After-Hours*: In lieu of subjective measures, we use email as an objective proxy for day-level involvement in work outside of work-hours. Work-place email usage outside of work-hours was automatically monitored with Delve Analytics, an add-on built into participants' corporate e-mail, which reports time spent in both reading and sending e-mails.

Measures of Reattachment

In order to measure how well participants reattached with work after the reattachment dialogues, we collected the following data:

- *Productivity Application Logs*: To understand participants' work patterns on their workstations, we monitored and logged their application usage with AppsTracker, an open-source utility that captures all application event activity on the Windows 10 Operating System. We leverage these data to develop objective measures of productivity, including how much time participants spent on specific applications, when they switched applications, and when they were actively using their machine.

- All logged information was stored locally on participants' machines in a SQL database. An anonymization script was run across the log files to remove identifiable information and aggregate information sources for participants who actively used multiple machines during the study. We logged a total of 278,939 instances of application usage.

- *Self-reports of Reattachment and Productivity*: Using the same questions from the Turk study (Table 4.2) we collected multiple responses on participants' perceptions of their productivity, relaxation, engagement, and inspiration via experience sampling probes (ESM) throughout the day. This was done via a small pop-up window that appeared on their workstation machine. Participants were instructed to dis-miss the window if the pop-up appeared at an inconvenient time. In total, we collected 2,271 responses. All information collected from the application was written to a text file.

- *Reattachment Questionnaire* Similar to the recovery experience questionnaire, at the end of the study we presented participants with a 5-item modified Reattachment questionnaire [254] for assessing their overall reattachment perception from their experience, as follows: "After beginning my workday by interacting with the bot: 1) I mentally tuned into my work, 2) I prepared mentally for my work, 3) I reflected about/considered my upcoming workday, 4) I thought about what I wanted to achieve at work, and 5) I thought about what I will encounter at work."

Additionally, we logged all of the participants' interactions with the bot including timestamps, content, and length. Over the course of study, we recorded 1,745 messages be-tween SwitchBot and our 34 participants. Figure 4.2 shows a sample interaction. At the end of the study participants were also asked if they had an existing ritual for detaching from or reattaching with work, and for feedback on the bot's functionality.

4.4.3 Study Design

The study began on a Tuesday, and ran across a two-week period, which included 10 working days and two weekends. By including a weekend in our study timeframe, we afford-ed ourselves the opportunity to discern whether or not individuals respond differently to detaching and reattaching with a bot after a subsequent weekday versus after a subsequent weekend. The first 5 workdays of the study (Week 1) were considered a baseline week where participants went

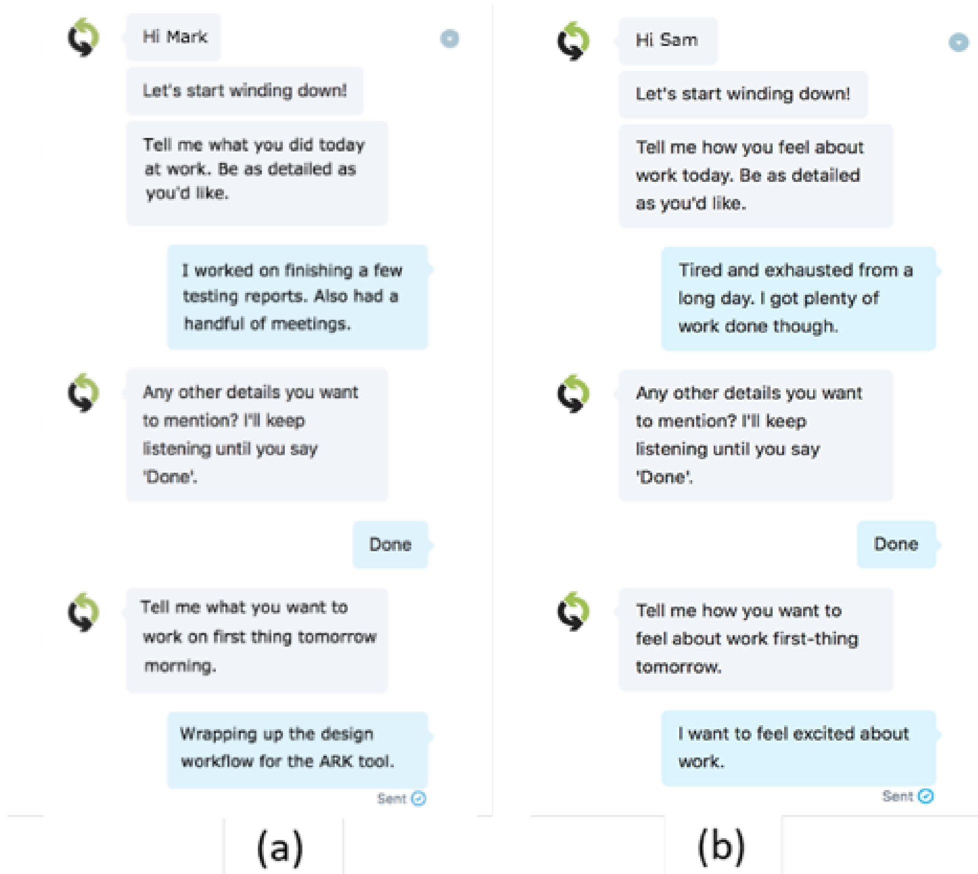

Figure 4.2: Snapshots of SwitchBot interactions in Skype: (a) Emotion-centric dialogue; (b) Task-centric dialogue.

Study Schedule

The study was managed remotely, and participants were asked to install AppsTracker and the experience sampling tool on their workstations on the morning of the first day of the study. If participants had multiple workstations, they were asked to install the software on both machines. After installing the software, participants were asked to submit a particular set of screenshots to confirm the software was both installed and that it recorded data correctly. For week 1, participants engaged in their workplace activities as usual and were asked to respond to the ESM probes as they appeared throughout the day. In week 2, additionally, they were instructed to interact with the bots at the beginning of the day before they headed into work, and at the end of the day before heading out of work. The bot was deployed to the Skype messaging service, which was actively used by participants in the workplace. At the end of Week 2, participants were given the post-questionnaire that included the detachment and the reattachment questions to assess perceptions of the bot as a tool for detachment and reattachment. Upon concluding the study, participants deposited their log files in a shared network drive.

4.4.4 Analysis Methods

We focus our analysis primarily on parts of the workday where we anticipate seeing the most change: the start and end of the workday. However, we are also interested how the effects of interacting with the bot affect overall productivity and engagement with one's work. Here, we detail our methods of analysis that we employ to study the effects of the bot at both the day-level and at specific times of the day (first-hour, last-hour).

Dependent Variables: Subjective measures of productivity, engagement, inspiration, and relaxation are used as dependent variables to understand the effects of interacting with the bot at different times during the workday. Difference in total time spent using productive software applications between Weeks 1 and 2 is used as the dependent variable to assess the bot's effect on participants' objective daytime productivity and engagement.

Independent Variables: The independent variable that we were most interested in was Dialogue (Task-centric, Emotion-centric). We also considered two other binary variables specifying whether or not the participant has an existing ritual for detaching from work (NoDetachmentRitual) or reattaching with work (NoReattachmentRitual).

Statistical Methods: We use a generalized linear mixed model (GLMM) [47] to assess each self-reported measure between weeks and between dialogues. Similarly, we use a linear mixed model to examine productive application us-age between weeks and between dialogues as a continuous variable. We specify the participant as a random effect in each GLMM. We used graphical assessments for each model to ensure that all assumptions about the model (i.e., residual distribution, constant variance) were not violated.

To assess differences between dialogues in participants' responses in Detachment and Reattachment questionnaires in the post-study survey, we employ Mann-Whitney U tests, a common procedure for comparing ordinal data [56]. Where appropriate, we employ t-tests for assessing group differences and use descriptive statistics (e.g., mean) to describe our data.

4.5 Results

Using the data, we collected from the in-situ study, we set out to answer two comprehensive research questions:

> **[RQ1]** How effective are dialogue exchanges with a bot in helping information workers detach from and reattach with work?
>
> **[RQ2]** How do individuals respond to different dialogue frameworks?

Here we present what we learned about both in detail.

4.5.1 Detaching from and Reattaching to Work

The reception of SwitchBot was generally positive. In the post-study survey, 21 of the 34 participants stated the bot complemented their everyday work life and indicated they would continue using the bot if it were available. The impact of the bot on the participants can be seen in how participants were able to detach from work in the evening, and how they were able to reattach in the morning.

Detachment

The responses on the Detachment questionnaire suggested that participants were generally neutral about SwitchBot as a tool for detachment. The average response among all participants for the adapted Detachment questionnaire in the post-study survey was exactly neutral (μ=3.0; σ=0.9). The response remains nearly the same even when limiting consideration to those without an existing detachment ritual (μ=3.1; σ=0.9). However, a paired t-test showed that participants sent less work-related email after work hours when they engaged in the detachment dialogue with SwitchBot compared to the baseline week ($t(32)=2.29$; $p=0.03$).

Reattachment

Unlike detachment, however, SwitchBot's ability as a tool for reattachment was generally seen as extremely positive (μ=4.7; σ=0.9) by participants in the Reattachment questionnaire in the post-study survey. The average response for participants with an existing reattachment ritual was only slightly lower and remained positive (μ=4.3; σ=1.4). Productivity application usage was noticeably similar between Week 1 and Week 2 as shown

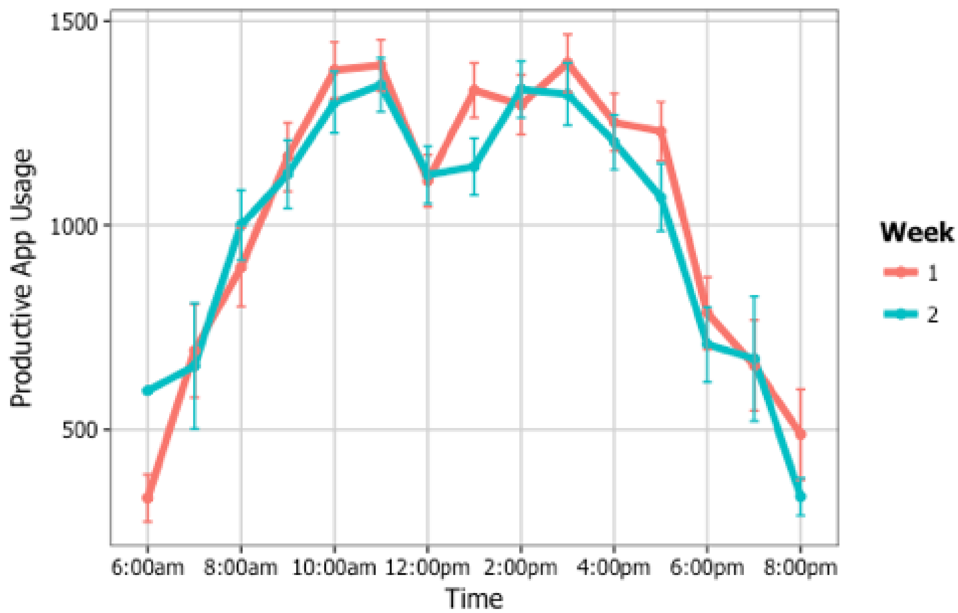

Figure 4.3: Productivity application usage over time of day between Week 1 and 2.

in Figure 4.3. In both Week 1 and Week 2, productivity application usage peaks at 11:00 am and 3:00 pm. Prior in-situ studies with information workers at larger technology corporations have seen identical peaks in productivity and focus at these same time frames, reinforcing the reliability of the logged application data [183, 182]. An analysis of application logs as an aggregate showed that there were no statistically significant differences between weeks in average productive application usage when the logs were aligned with time of day, indicating that the interaction with SwitchBot does not influence this well-established productivity curve.

However, we see a different picture when considering user self-reports collected through the ESM data. Considering all collected self-reported measures of productivity, relaxation, inspiration, and engagement collected through the ESM probes, we found that workers felt significantly more productive (β=0.11; ϵ=0.05; p=0.02), but also less relaxed (β=-0.16; ϵ=0.05; p<0.01) throughout the workday during Week 2. We are particularly interested in the first hour of the participant's work day as it immediately follows the reattachment dialogues. Limiting our GLLM's scope to the first hour of participants' workday, we found that participants felt more productive (β=-0.58; ϵ=0.09; p<0.01), more engaged (β=0.29; ϵ=0.10; p<0.01), and less relaxed (β=-0.40; ϵ=0.11; p<0.01) when starting their workday during Week 2 when using SwitchBot. While users may not overall show differences in their productivity interactions, their perceptions of productivity increase after the reattachment.

Summary of Findings for Reattachment and Detachment

In summary, we learn how SwitchBot helped participants detach from and reattach with work in the course of 10 workdays. We find that after engaging with the detachment dialogues, users send less work-emails after hours. The stronger results were seen after the reattachment dialogues – compared to the baseline week participants overall felt to have increased productivity throughout the day, but also felt less relaxed. Looking at just the first hour at work, which was right after the reattachment dialogue we observe that users report increased productivity, increased engagement but less relaxation after interacting with SwitchBot. Alongside measures of productivity and emotional state, we are also interested in perceptions of the bot's utility. Alt-hough the design of both dialogues is strongly grounded in research, participants remained neutral in their assessment of SwitchBot as an effective tool for psychologically detaching from work. However, we did find they strongly recognized SwitchBot as an effective tool for psychologically reattaching to work.

4.5.2 Responses to Different Dialogue Frameworks

Detachment

Though we found that overall participants sent less after-hour emails in Week 2, we did not see differences across the two dialogues. Comparing the detachment questionnaire responses between the two dialogues using Mann-Whitney U tests, we also see no difference, suggesting that neither dialogue was subjectively preferred more than the other. However, limiting the scope to participants who had no existing detachment ritual (19), we found that the participants who were given the Emotion-centric dialogue reported significantly higher responses on the Detachment scale than participants who were given the Task-centric dialogue ($U=16$; $Z=2.33$; $p=0.02$; $r=0.26$). Detachment ritual included driving home, exercise, turning off computers and mentally shifting to focus on home. This suggests that for people who do not have any existing practices of actively detaching from work, the Emotion-centric dialogue helps them detach through reflection and goal setting.

Reattachment

Looking at the responses on the Reattachment questionnaires, we found that workers in the Emotion-centric dialogue reported significantly higher responses on the Reattachment scale than workers who were given the Task-centric dialogue ($U=64.5$; $Z=2.77$; $p<0.01$; $r=0.47$). Surprisingly, the same observation was not statistically significant when only

Figure 4.4: Differences in productive application usage between both weeks and dialogue models for all 34 participants aligned by the start of the 8-hour workday. Difference in productive application usage is shown in seconds.

considered participants who had no existing reattachment ritual (7). Reattachment rituals typically included creating to-do lists. However, this particular observation may be due to the small sample.

Looking at the application usage, we see differences across the different dialogues. Figure 3 shows the differences in productive application usage between both weeks for each dialogue model binned by workhour. Using a GLMM to assess the difference in productive application usage, we found that workers who were given the Emotion-centric dialogue spent significantly less time using productive applications during their first hour of their work in Week 2 compared to workers who were given the Task-centric dialogue (β=-518.5; ϵ=246; df=413.2; t=-2.1; p=0.04).

On average, participants in the Task-centric dialogue had improved their productivity application usage between Weeks 1 and 2 in five of the eight workhours where workers who were given the Emotion-centric dialogue demonstrated improvements in every workhour except the first. On average, participants who were given the Task-centric dialogue showed a small improvement in the first hour of their workday, but the improvement was not consistently maintained over the course of the workday.

In terms of the self-reports on productivity and other metrics through the ESM probes we see no statistically significant differences between the two dialogues when considering the entire day. However, limiting our analysis to the first hour of participants' workday, we found that participants felt more productive (β=0.50; ϵ=0.15; p<0.01) and more inspired (β=0.27; ϵ=0.14; p=0.05) during Week 2 when they were assigned the Emotion-centric dialogue. We observed no statistically significant differences within the last hour of the work day.

Differences in Bot Interaction

We also looked at how the conversations with the bot differed across the two dialogues. We found that participants who were given the Emotion-centric dialogue sent messages significantly longer in length (t(487)=2.11; p=0.03) and sent significantly more messages both for detachment (t(4.5)=2.4; p=05) than participants who were given the Task-centric dialogue. To explain these results, we tested for a possible correlation with participants' self-reported measure of relaxation but found no significance.

Summary of Differences between Dialogues

We found that people who received the Emotion-centric questions and did not have any existing detachment ritual were able to detach better according to the detachment questionnaire, compared to those receiving the Task-centric dialogue. We did not see differences in the number of after-hour work-emails sent across the two dialogues.

In terms of reattachment, we show that the participants receiving the Emotion-centric dialogues scored higher on the Reattachment questionnaires, and they showed significant increase in their interactions with productivity applications throughout the day, except the first hour – compared to the baseline week (Figure 4.4). The participants in the Task-centric dialogues used more productivity applications in the first hour compared to the baseline week. However, this improvement in productivity was not sustained throughout the day. Interestingly, the Emotion-centric group reported feeling more productive and more inspired in the first hour compared to the Task-Centric group, even though this feeling translated into actual action only after the first hour.

The Emotion-centric dialogue is inherently more open-ended than the Task-centric dialogue, giving users the opportunity to continue conversation in arbitrary ways. We found that participants' conversations with the Emotion-centric dialogue were longer in both the detachment and reattachment sub-dialogues.

4.6 Discussion

Our study shows that bots can be effective, supplemental tools for helping information workers successfully reattach with work. We find that conversing with a bot about task-related or emotion-related goals for the workday can induce feelings of productivity and engagement at the start of the workday. We also find that priming information workers about their task-related goals can boost productivity application usage in the first hour of work but find no evidence of consistency throughout the remainder of the workday. We see positive perceptions from users about its overall effectiveness in helping people reattach with work. While SwitchBot seemed reasonably successful in helping people reattach with their work, we see less positive results in terms of detachment. There could be a few reasons for this. First, we chose not to probe people with detachment questions while they were in the detachment period as this may cause them to start thinking about work. We used a proxy of work related emails which showed a decrease when the bot was used for detachment but this may present only part of the picture. Our Turk study suggests that the detachment dialogue did make users feel more relaxed. In future studies, we intend to use more passive measures, such as physiological metrics through wearables, to get insights into relaxation and detachment.

Our research shows that a simple, but well-designed bot can have a noticeable effect on workplace engagement and productivity. One natural extension to our work is integration and extended intelligence. The success of our work indicates that bots may not only be sufficient for easing people in and out of work, but also for helping individuals transition between tasks within the workplace, too. While our work examined the efficacy of a bot with limited intelligence, future work can explore how the feasibility of bots with integration additional systems (e.g., calendar) and awareness of user preferences (e.g., learning users' mood schedules). With additional intelligence, such a bot could suggest strategic breaks throughout the workday, retrieve relevant documents for meetings, and even help find the best time of day to detach from work in their best interest.

In our study, participants detached and reattached with their work at certain times based on principles of goal setting and priming. Prior work, however, has noted that the ideal location for mentally transitioning in and out of work is during the commute [246, 254]. While there are clear challenges in interacting with a system while driving (e.g., mind wandering [101]), we see the commute to work as an important frontier for detachment and reattachment, namely in novel scenarios (e.g., self-driving cars) and hands-free interaction.

While most productivity solutions focus on supporting task management, we address the problem at the core of worker psychology – demonstrating that helping workers manage and reflect on their thoughts around productivity can also improve productivity. A small number of participants suggested additions to their bot's dialogue that existed in the dialogue they weren't assigned. For example, participants who were assigned the Task-centric dialogue suggested dialogue additions that focused on work-related reflection:

> "*(I would have liked the bot to ask me) something that I don't like about the work, what I like about the work during the day.*"
>
> – (P28, Task-centric)

Likewise, those assigned to the Emotion-centric dialogue suggested additions for task management:

> "*I would have liked the bot to have been able to keep a todo list or track things I was working on to help me pick back up in the morning.*"
>
> – (P6, Emotion-centric)

These suggestions pose an interesting direction for future work that examines dialogues models incorporating elements of interruption management and mindfulness-based therapy simultaneously.

Our study has important implications for the design of conversational systems and future interventions for facilitating psychological detachment from and reattachment to work. Future systems may not only use and extend our studied dialogues, but may also reemploy the methodology used to create them for contexts outside of detachment and reattachment. Our work's findings highlight the rich opportunity for technical interventions in the problem space, showing that simple interventions can yield powerful effects, leaving room for more complex and personalized interventions.

Limitations

Our study has several limitations. First, the findings related to our bot are grounded in the context of information workers that work at a large technology corporation. We make no claim about the efficacy of bots for workplace detachment and reattachment in smaller organizations that do not emphasize technology in their work.

Second, our study was conducted using a between-subjects design where each participant was introduced to only one of SwitchBot's dialogues. Our study's findings are unable to speak to whether there may be individual differences in the effects of the two dialogues. The key purpose of the presented work, however, was to examine the feasibility of bots as support tools for reattachment and detachment. As our findings reinforce this application, we acknowledge a within-subjects study as important future work.

Third, our study examined the effectiveness of only a single intervention. While prior work suggests that conversational systems can be superior to their non-conversational counterparts (e.g., paper) [31], we make no claim about the effectiveness of a bot as it compares to alternative interventions.

The final limitation of our study is its timeframe. The last day of our study was August 21, 2017, the day of the solar eclipse. The vast majority of our study was assessed using statistical models that detect and account for anomalies in data. While we saw no noticeable effect both in our models and by manual assessment, we feel it is important to recognize the timeframe as a potential limitation.

4.7 Conclusion

In this study, we reported findings from an in-situ study that indicate bots can be effective tools for helping information workers detach from and reattach with work. We introduced a conversational detachment-reattachment framework in which we included two, unique models of dialogue for detaching from work and reattaching with work. We presented and evaluated SwitchBot, a bot that implements the detachment-reattachment framework. We showed evidence that suggests interacting with SwitchBot before the start and end of the workday assists information workers in psychologically detaching from work and reattaching with work the next day. Future work includes studying non-information workers, examining more hybrid models of dialogue, and examining how bots can be tools for transitioning between tasks in the workplace as well as at home.

Chapter 5

Understanding Work-Related Transitions in Crowdwork

In Chapters 2 and 3, we introduced and studied two novels systems designed to help information workers managing two types of work-related transitions. Each of these systems were motivated by a wealth of prior workplace studies, which are generally absent for the majority of newer forms of distributed work, such as crowdwork.

In this chapter, we explore crowdworkers' work practices to better understand the transitions that occur in their work and the challenges that come with them. To better understand opportunities for engineering systems to help manage these transitions, we conduct our inquiry with an emphasis on characterizing the tooling that crowdworkers employ in their work.

5.1 Motivation

Over the past decade, crowdwork has risen as an established and thriving work practice for thousands of people across the globe [65]. In a 2010 survey of US-based Amazon Mechanical Turk (MTurk) workers, less than 5% of the participants identified as spending 40 hours or more on crowdwork [115]. Recent data-driven analyses of long-term worker activity on MTurk found that the population of crowdworkers on the platform is generally stable, but that "tens of thousands of new workers that arrive on the platform each year" to replace workers that abandon the profession [69, 148]. Beyond MTurk, a 2016 survey found that more than 5 million individuals in the UK are actively engaged in crowdwork [112], and 53% of a 2017 survey's respondents with crowdworkers in Switzerland reported the profession as their full-time job [113]. Spurred by the changing nature of information work today, understanding how crowdworkers accomplish their work has become an increasingly important area of research for CSCW and HCI researchers alike.

Crowdworkers, like many other professions in information work, employ a myriad of tools to support their work. Crowdwork, by design, revolves around the completion of Human Intelligence Tasks (HITs) that are posted to crowdsourcing platforms (e.g., Microsoft's UHRS [?], Figure Eight [?]) by requesters. Browser extensions and scripts, such as PandaCrazy and MTurk Suite, are frequently used to assist workers on MTurk in finding HITs to complete [131]. Online community platforms, such as MTurk Grind and TurkerNation, are not only used to aid the work-finding process, but also serve as a bastion for organizational support among workers [91, 300]. Both software tools and community platforms help workers assess prospective HITs by integrating with platforms (e.g., TurkOpticon [124]) that maintain community-driven ratings of requesters. Recent research has taken steps toward building tools that assist workers by estimating the amount of time a HIT may require [231], recommending specific HITs [96], and visualizing the HIT marketplace [96]. While prior research recognizes the importance of tooling for facilitating earnings goals [131], the broader effect of crowdworkers' *tooling practices*, i.e., how they *actually* make use of tools and how this usage impacts their quality of life and work, remains relatively unknown.

In this research, we examine the effect of crowdworkers' tooling by conducting semi-structured interviews with 21 crowdworkers who work "full-time" on Amazon Mechanical Turk. Specifically, our interview questions aimed at understanding workers' work practice and how tooling is situated within it. At a high level, we find that tooling use increases the *fragmentation* (i.e., discontinuity) that crowdworkers experience in their broader work practice. First, tooling enables task switching and multitasking behavior, thus contributing to the discontinuity of HITs. Second, we found that workers regularly employ tooling in ways that fragment their work-life boundaries, often conditioning workers into adopting a 'work-anywhere' attitude. Finally, tooling practices that stem from limited or commercial access contribute to the fragmentation of social ties within worker communities, driving workers to engage with specific communities or avoid social activity altogether.

We begin by detailing our interview's study design while clarifying the overarching goal of our work. We then report our study's findings, first describing findings related to workers' general tooling practices and second how these tooling practices drive fragmentation. We conclude by discussing our findings in the scope of future tools in crowdwork.

#	Area	Question
1	EDT	Can you walk me through how you started your workday at your primary computer?
2	EDT	What devices and tools do you use to help your work? How do they help you?
3	EDT	Have you always used your devices and tools this way? If not, how has it changed?
4	Soc.	How often do you interact with other workers through community platforms?
5	Soc.	What worker communities do you belong to? How do they help you in your work?
6	MI	Can you tell me about a time when you've multitasked on two HITs simultaneously?
7	MI	How frequently do you multitask in crowdwork? Why do you feel the need to do so?
8	MI	Can you tell me about a time when you've had to temporarily stop working on a HIT?
9	MI	How frequently do you temporarily stop working on a HIT to work on another one?
10	WLS	Can you walk me through how you end your workday when you stop working?
11	WLS	Do you feel like you ever "stop working"? Are you satisfied with your work situation?

Table 5.1: The sequence of questions used to guide the conversation during the interview. Each question represents a particular area of crowdworkers' work practices: (1) Environment, Devices, and Tooling (EDT), (2) Social Resources (Social), (3) Multitasking and Interruptions (MI), and (4) Work-Life Separation (WLS).

5.2 Interview Study

Crowdwork is comprised of short tasks, known as HITs, that can last a few seconds to multiple hours in length [97]. Given that crowdwork is growing in magnitude both in terms of numbers of people entering the field, and number of people for whom it is primarily full-time employment, what impact does full-time crowd work have on workers' cognitive load and work life boundaries? Importantly, a range of tools are available to support crowdworkers, which are relied on heavily [151]. The goal of this study is to investigate the impact that these tools have on work practice and work life boundaries for crowdworkers whose primary means of work is conducting crowdwork.

The best methodology for understanding the complex interplay of cognitive, social, and technological factors involved in crowdwork is through conducting in-depth interviews, which provide an essential opportunity to hear participants' perspectives [261]. To better understand the role of tooling more broadly, we framed our interviews around understanding the crowdworker's day-level work practice. Inspired by prior workplace studies, we focused on four key facets of work common to information work practices: (1) Environment, Devices, and Tooling (EDT), (2) Social Resources (Social), (3) Multitasking and Interruptions (MI), and (4) Work-Life Separation (WLS). To better understand how tool use affects work practices and work lives, we administered a post-study survey that included validated instruments that address topics relevant to our main research question.

5.2.1 Study Design and Protocol

Each interview was scheduled to last 30 minutes. However, many interviews exceeded the 30-minute timeframe, ranging from 27.3 minutes to 79.0 minutes (M=42.4; SD=13.2). All interviews were conducted over Skype and were scheduled during each participant's workday to more easily draw on first-hand experiences that were both recent and relevant. The researcher initiated the interview by explaining our general interest in understanding how crowdworkers "get things done". Each interview began by asking participants questions related to demographic information, including age, sex, full-time tenure, and related characteristics of work history (e.g., total number of HITs completed). We then engaged participants in a conversation that asked them to reflect about different aspects of their work that spanned the four aforementioned areas. We were careful not to instruct the participants about what they should consider tools to be, and we instead asked them to define them for us. Table 5.1 shows the sequence of questions used to guide the interviews.

Post-Study Survey

To better understand individual differences between participants, we administered a post-study survey that utilized established scales to characterize our participants' behavioral tendencies for engaging with their work. Specifically, we administered the following:

1. *Multitasking Preference Inventory (MPI)* [224]: A 14-item (5-point Likert) questionnaire to measure an individual's preferences and tendencies to engage in multitasking behavior. Prior studies have administered the MPI to crowdworkers and found that the majority of crowdworkers lean more toward multitasking than monotasking [151].

2. *Work-Life Indicator (WLI) Scale* [145]: A 17-item (5-point Likert) questionnaire to measure boundary management strategies that an individual uses to separate work and non-work. In administering the WLI instrument to crowdworkers, prior research has shown they primarily have strategies that prioritize their nonwork (i.e. family) instead of work [151].

Inspired by prior research on individual differences in crowdwork [137] and information work [180], we also administered the 8-item Neuroticism sub-scale of the Big-5 personality scale [189] and the 23-item Perseverance and Urgency sub-scales of the UPPS impulsive behavior scale [291]. However, in our analysis, we observed no differences between neurotics and non-neurotics nor impulsive and non-impulsive individuals, and we have therefore chosen to exclude them from our analysis.

All interviews were recorded with TechSmith Camtasia. During the interview, participants were encouraged to leave their camera off unless they felt more comfortable sharing their camera. Base remuneration for the 30-minute interview included a $10.00 Amazon gift card. In cases where interviews extended beyond the planned 30 minute timeframe, we added an additional $5.00 to participants' total gift card amount for every additional 15 minutes of participation.

5.2.2 Analysis

All interview recordings were transcribed and analyzed using iterative inductive content analysis [262]. During the first cycle of coding, we classified excerpts into several iteratively-refined hierarchical codes and developed a coding schema. The primary and secondary codes included:

1. **Goal**: Properties of work-related goals; goal type, goal measurability, goal feasibility.
2. **Task**: Properties of work-related tasks; task type, interestingness, deferrability, effort, polychronicity, monetary reward, reliability of requester, time constraint.
3. **Tool**: Properties of work-related tooling; improved efficiency, ease of use, significance of automation, accessibility, integration with existing practice, tool authorship and risk.
4. **Device**: Properties of work-related devices; type of computing device, purpose of computing device, screen size, interaction design, mobility, tool availability.
5. **Social**: Properties of work-related social interaction; type of social interaction, rationale for social interaction, level of engagement, perceived cost and reward of social interaction.
6. **Availability to Work**: Properties of work-related availability; social constraints, task availability, device availability, interruptability.

In the first pass analysis, statements from interview transcripts were directly coded from the interview transcripts to generate our coding scheme. This analysis revealed how tooling pervasively amplifies the fragmented nature of crowdwork. Based on recurrent themes in the coded data, the second cycle of coding identified three areas of work in which fragmentation is both apparent and influential. Our findings are organized around these three areas of fragmentation, and are grounded in a summary of general tooling practices as observed from our interviews.

5.2.3 Recruitment and Participant Overview

We used a snowball sampling approach to recruit 21 "full-time" crowdworkers who have actively worked 35 hours or more per-week on Amazon Mechanical Turk for at least six months continuously. We specifically targeted "full-time" crowdworkers to ensure we were engaging individuals who had familiarity not only with state-of-the-art tooling, but also the work practice itself. The sampling process was initiated both over e-mail and through crowdworkers' community platforms by a member of the research team who previously worked as a crowdworker.

Participants' ages ranged from 19 to 62 (M=45). Participants' tenure as full-time in experience ranged from 6 months to 7 years (M=2.2 years), and the range of total number of completed HITs ranged from 6,318 to 355,976 (M=74,821). Participants' approval rates ranged from 99.3% to 99.9%. Table 5.2 details the demographics of recruited participants alongside their post-study survey data.

Monotasksers and Multitaskers

MPI scores can range from 14 to 70 and represent individuals' preferences in engaging in multitasking behavior. A larger MPI score suggests that an individual is more preferential toward engaging in multitasking behavior. Following standard practice for calculating MPI scores [224], we find that our sample's multitasking preferences lean more toward monotasking than multitasking. Participants' MPI scores ranged from 14 to 51 (M=33; SD=11), suggesting that our sample contains monotaskers and multitaskers. We cross-examined participants' MPI scores with the number of tools used in their practice and found a weak correlation between between participants' MPI scores and the number of tools they use (Pearson's $r(19) = 0.37$, $p = 0.09$).

Work Warriors, Overwhelmed Reactors, and Family Guardians

Following standard practice [145, 151], we calculated WLI scores based on the scale's five dimensions, each of which ranges from 1 to 5. Among our participants, we find three types of WLI characterizations: (1) Work Warriors, (2) Overwhelmed Reactors, and (3) Family Guardians. Work Warriors are individuals who have high work identity (M=4.1, SD=0.9), low family identity (M=2.8, SD=1.2), and primarily allow work-related activity to interrupt nonwork time (M=4.0, SD=0.8). Overwhelmed Reactors have similar work (M=4.3, SD=0.9) and family identity (M=2.9, SD=0.6). However, they not only allow work to interrupt nonwork (M=3.1, SD=0.2), but also permit nonwork to interrupt work (M=3.2,

	Demographics						Post-Study Survey	
P#	**G**	**Age**	**Tenure**	**HITs**	**Approval**	**Tools**	**MPI**	**WLI Classification**
P1	F	18-24	3-5 years	250,000-300,000	99.5-99.9%	10	46	Work Warrior
P2	F	35-44	<1 year	10,000-25,000	99.0-99.4%	9	23	Family Guardian
P3	F	25-34	1-2 years	25,000-50,000	99.5-99.9%	2	22	Work Warrior
P4	F	45-54	<1 year	5,000-10,000	99.0-99.4%	3	30	Family Guardian
P5	M	35-44	3-5 years	50,000-75,000	99.5-99.9%	9	43	Overwhelmed Reactor
P6	F	25-34	1-2 years	100,000-150,000	99.5-99.9%	6	19	Work Warrior
P7	M	18-24	1-2 years	100,000-150,000	99.5-99.9%	7	12	Work Warrior
P8	F	45-54	1-2 years	50,000-75,000	99.5-99.9%	9	45	Work Warrior
P9	M	55-64	3-5 years	50,000-75,000	99.5-99.9%	8	27	Work Warrior
P10	F	55-64	3-5 years	50,000-75,000	99.5-99.9%	8	35	Work Warrior
P11	M	18-24	1-2 years	5,000-10,000	99.5-99.9%	2	23	Family Guardian
P12	M	25-34	1-2 years	10,000-25,000	99.5-99.9%	2	34	Work Warrior
P13	F	25-34	1-2 years	25,000-50,000	99.5-99.9%	7	29	Work Warrior
P14	F	25-34	1-2 years	150,000-250,000	99.5-99.9%	9	38	Work Warrior
P15	F	45-54	1-2 years	10,000-25,000	99.5-99.9%	2	22	Work Warrior
P16	F	55-64	3-5 years	25,000-50,000	99.5-99.9%	4	26	Overwhelmed Reactor
P17	F	25-34	1-2 years	25,000-50,000	99.0-99.4%	5	43	Overwhelmed Reactor
P18	F	25-34	5+ years	350,000+	99.5-99.9%	10	50	Work Warrior
P19	M	18-24	<1 year	5,000-10,000	99.5-99.9%	2	26	Family Guardian
P20	M	18-24	1-2 years	10,000-25,000	99.0-99.4%	2	51	Overwhelmed Reactor
P21	F	55-64	1-2 years	25,000-50,000	99.5-99.9%	9	44	Family Guardian

Table 5.2: Participant's demographic information (i.e., gender, age, tenure as a worker, total number of completed HITs, approval rate, and the number of software tools they use) and their post-study survey information.

SD=0.7). Unlike Work Warriors and Overwhelmed Reactors, Family Guardians maintain high boundary control (M=2.9, SD=0.9) and high family identity (M=4.6, SD=0.4) while simultaneously allowing nonwork to regularly interrupt work (M=3.4, SD=0.7) [145]. As Kossek et al. [145] states, our participants, on average, allow "work to puncture non-work time".

Upon visually assessing the data, we observed a trend that suggested a relationship may exist between WLI dimensions and participants work-related demographics. After confirming the data was normally distributed, we ran a multiple regression for each of the five dimensions used to calculate participants' WLI scores, using demographics as independent variables (i.e., age, sex, numbers of completed HITs, years spent working on MTurk, and number of tools). We found two statistically significant effects in analyzing these models. We first found that an effect that suggests behavior for allowing work to interrupt non-work time increases as crowdworkers employ a larger number of tools in their practice (β=0.19; SE=0.06; t(19)=3.25; p=0.006). We also found an effect that suggests that the number of years spent doing full-time crowdwork contributes to feelings of less control in separating non-work and work-time (β=-0.46; SE=0.21; t(19)=-2.22; p=0.04).

As our sample size is not large enough to make substantial claims about these findings, we extended our analysis by assigning each participant to one of the six clusters that are defined in the WLI [145]. In total, our sample includes 11 Work Warriors, 7 Overwhelmed Reactors, and 4 Family Guardians. The key distinction between Work Warriors and Overwhelmed Reactors is that the latter not only allows work to interrupt nonwork, but also permits nonwork to interrupt work. Family Guardians are notably different to these two WLI clusters, having high boundary control and high family identity while simultaneously allowing nonwork to regularly interrupt work [145].

5.3 An Overview of Tooling Practices

Our participants broadly defined "tooling" as physical or digital artifacts that "make [their] job easier while at work or otherwise" (P15). P2, for example, described her tooling (e.g. browser extensions, scripts, etc.) specifically as "the glue that makes [their work] possible". Here, we detail the tooling practices that crowdworkers employ as observed through our study. Table 5.3 summarizes the types of tools observed and the tasks they serve to support in participants' broader work practices.

5.3.1 Workstations as Tooling Platforms

Crowdworkers' workstations serve as the centerpiece to their tooling practices. All 21 participants' primary work environment was situated within their home or apartment. 15 participants stated that they use a desktop workstation as their primary work computer. The remaining six participants use a laptop as their primary work computer. Amid the many features of their machines, participants uniformly highlighted display quantity as the most productivity-defining attributes of their primary work computer. Participants' workstations included the use of only one display (6), two displays (11), and four displays (4). Only one [P9] voiced concerns against the use of multiple displays:

> "*I know there's some people that have two monitors and stuff, but more power to them. I don't know how they do it. It's too confusing for me. I want to focus on one thing at one time, and having an additional monitor won't help. It'll just make it harder to focus.*" (P9)

All multi-screen proponents shared a common strategy for "partitioning screen space" [93] toward (1) a work-finding display (i.e., in which workers primarily utilize for finding and accepting HITs) and (2) a work-doing display (i.e., in which workers primarily utilize for completing HITs). Similar techniques for mapping screen space were also commonly described by single-monitor users, e.g. "I'll split my display with a window for doing work and a window for finding work" (P20).

In general, we find that that crowdworkers employ an ecology of computing devices within their work practice to enable them to meet their work-related needs. Within the workspace, eight participants described using multiple workstations, multiple laptops, or a combination of the two to engage with her work simultaneously to "distribute CPU load" (P2) or use tooling that was "limited to a particular operating system" (P1). Beyond the primary work environment, five participants reported using their tablet device (e.g., iPad, Amazon Fire) to engage with their work to complete specific types of work while away from their primary work computer. e.g., "surveys in bed or on the couch" (P10). Each of the 15 participants voiced the challenge of engaging with work on-the-go as "most tools are designed as desktop browser extensions and don't work on mobile devices" (P14).

5.3.2 Tools for Finding and Completing HITs

HIT-finding scripts and extensions were observed as the most common and most central type of tooling used by participants. By nature, these tools attempt to assist crowdworkers' in populating their HIT queue, which can include up to 25 HITs at any one time. The two types of HIT-finding tools used by all participants were HIT scrapers and HIT catchers. HIT scrapers improve the efficiency of searching for HITs by incorporating visual information (i.e., requester reliability) to ease the decision-making process of selecting which HIT the worker should add to their queue. However, many HITs are "scooped up before you can even click the accept button" (P9):

> "*I look for HITs with good pay, and then I kind-of click through to take a peek. I tend to aggressively just grab things and return them if I don't like them. It's so competitive that, if you wait to look at what a task is before you grab it, it doesn't work. The good work will be gone before you even have a chance to decide.*" (P5)

The primary mechanism by which crowdworkers fill their queue is with HIT catchers, such as HIT Catcher and PandaCrazy, that are software tools that "catch" HITs in the case where they are returned to the HIT marketplace (i.e. relinquished by another worker).

	Description	Supported Task	Discussed Tooling	Used By
HIT-Finding	Automates finding work. Tasks include scraping MTurk to "catch" specific HITs by ID, and auto-accept HITs based on criteria.	Scraping HITs	HIT Finder*, HIT Forker	All (100%)
		Catching HITs	HIT Catcher*, Overwatch, PandaCrazy, TurkMaster	All (100%)
		Auto-Accepting HITs	Private Tools	1,3,5,7,9,21 (29%)
Cognitive	Augments cognition. Tasks include guiding focus toward particular HITs, managing and interacting with information on HIT browser windows.	Organizing and Focusing on HITs	PandaCrazy Queue Helper, Private Tools	1,3,5,7,11,13,14 16,17,18,21 (52%)
		Managing Browser Windows	AquaSnap, Window Layout, The Great Suspender, Private Tools	1,3,5,6,7,18,21 (33%)
		Interacting with Browser Windows	Private Tools	1,5 (9.5%)
Social	Facilitates community engagement. Tasks include reviewing HITs, discussing HITs in online forums, and sharing HITs with others.	Reviewing HITs	TurkerViewJS*, Turk-Opticon Extension	1,2,3,5,6,7,8,9,13,16 17,18,19,20,21 (71%)
		Discussing & Sharing HITs Publicly	TurkerView, MTurkGrind, Reddit, Facebook Groups	All, but 10,15 (90%)
		Discussing & Sharing HITs Privately	Messenger, Discord, Telegram, Email	1,5,7,8,14 16,17,18,21 (43%)
Administrative	Maintains HIT history and state. Tasks include logging completed HITs (i.e., to retain history) and documenting on-going HITs.	Logging HITs	HIT Tracker*	1,2,3,5,6,7,8,9,13,16 17,18,19,20,21 (71%)
		Documenting HITs with Physical Tools	Notebooks, Wall Calendar	4,5,8 (14%)
		Documenting HITs with Software Tools	Google Sheets, Google Docs, MS Word, Paint	1,2,3,6,7 (24%)
Mobility	Enables workers with the ability to work while on-the-go. Tasks include monitoring the HIT queue, finding HITs to complete on-the-go or save for later, and completing HITs.	Monitoring HITs	Mobile Browser, PandaCrazy, Distill	1,2,3,5,6,7,8,9,10 13,14,15,16,17 18,19,20,21 (86%)
		Finding HITs	Mobile Browser, Discord, Messenger, Private Tools	1,2,5,7,8,10,13,14 16,17,18,21 (57%)
		Completing HITs	Mobile Browser, Chrome Remote Desktop	1,2,5,7,14,21 (29%)

* *This tool is included in an aggregate tool named "MTurk Suite".*

Table 5.3: Tooling types and their supported tasks as observed from our interviews.

Importantly, HIT Catchers allow crowdworkers to specify a list of HIT IDs to seek out, which are used to make repeated and carefully timed requests directly to the MTurk API. If these tools find that a HIT has been returned to the marketplace, it will automatically add the HIT to the worker's HIT queue.

Beyond HIT Catchers, six crowdworkers utilize HIT Auto-Accepters, a script, extension, or desktop application that automates the HIT-finding process entirely by allowing workers to auto-accept HITs that meet a particular criteria (e.g., minimum reward). The key difference between HIT Auto-Accepters and HIT Catchers is that the prior requires no human intervention to perform the search process while the latter requires workers to add a HIT ID to a catcher's list of HITs to seek out. Both types of HIT-finding tools deliver notifications and alerts when new HITs are found and added to workers' HIT queue. Importantly, these notifications and alerts can be customized by the user to play certain messages or sounds (e.g. a car horn) based on the properties of newly-accepted HITs (e.g. time constraint).

More recent iterations of HIT catchers and auto-accepters have embedded support for administrative tools, specifically those that involve reviewing HITs and requesters on online platforms, such as TurkOpticon [124], but several participants noted they prefer using separated versions of the extensions. Community platforms were also mentioned explicitly by most workers as "invaluable tools", serving as a central source of work opportunities as found in prior work [91].

Complementing their HIT-finding tools, crowdworkers use cognitive tools to augment their task switching abilities. This includes visually rearranging and sorting their HIT queue (e.g. by time constraints), using saved configurations to restore and suspend their browser window arrangement, and managing visio-spatial aspects of the HITs' browser windows:

> "*[The tool] not only accepts HITs for you, but it automatically opens them in a tab. So, I can start with the first HIT in a batch, and then, as I submit it, it closes that tab and immediately opens up the next one. I love it for batch HITs. I just find it faster to still use a regular browser, but I know one of my friends relies on using the tool's feature for his workflow."*" (P1)

Two participants [P1,P5] also described that they employ private tooling to interact with browser windows to further improve their efficiency, noting its overall use is for "small optimizations" (P5).

5.3.3 Tools for Enabling Mobile Tasks

The most common mobile task performed by 18 participants was monitoring their HIT queue. 16 participants described a strategy in which they proactively configure their HIT-finding tools on their workstation to continue to seek out work, populating their HIT queue while mobile:

> "*While I'm out, I only do HITs for emergencies, because it's a lot slower to do them on my phone. I also use my phone to see what HITs PandaCrazy is finding while I'm away from my computer and whether they're worth going to a computer to do.*" (P3)

While on-the-go, most participants describe their monitoring processes as one facilitated by refreshing their HIT queue webpage with their mobile browser. One participant [P1] noted the use of a service (i.e., Distill) that monitors their HIT queue webpage, pushing alerts to their mobile device when changes are detected. HIT-monitoring was described as "frequent", particularly when participants were expecting a particular HIT to be released (e.g., a closed qualification HIT). While near their working environment (e.g. in a different room of their home), participants' monitoring strategies primarily rely on the audible alerts generated by their HIT-finding tools.

Alongside monitoring their HIT queue, 12 participants actively engage in the task of finding HITs while mobile. The most common strategies employed for finding HITs in mobile settings were those that relied on other workers. Resembling the model of friendsourcing [30], we find that our participants leverage their close social ties to support their task-finding needs while mobile:

> "*I've been in a group message on Facebook Messenger with several ladies for a while now, and we look out for each other while we're not at our computer. If one of us finds a well-paying HIT, we'll let each other know to make sure everyone can catch it.*" (P14)

Several participants described similar uses of close-knit social groups with alternative tools, namely Discord. Social scenarios aside, three participants who do not engage in socializing with workers mentioned they primarily find HITs directly because "there's no other way to do it", suggesting that social ties play a significant role in facilitating mobility. Importantly, the 12 participants who find work while mobile noted they generally do not complete found work on-the-go, but rather use it to prime their ability to work upon returning to their primary work computer.

The least common type of mobile task in our participants' practices was completing HITs. The inability to complete HITs while mobile is the result of "the terrible nature of the MTurk mobile web interface" (P11) and the inability to utilize any of their primary workstation's scripts or extensions. As P5 said, "it inherits all of problems of Mechanical Turk as a platform, is somehow even more difficult to use" (P5). The most common tool used to complete HITs while mobile was private tooling. However, two participants [P14,P21] described the use of Chrome's Remote Desktop extension:

> "*I'll just use the Chrome Remote Desktop extension to jump into my desktop. From there, I have access to all of Catchers and other scripts I need to be productive. It can be tough to do things like Copy-and-Paste, but you can make it work.*" (P14)

While these two participants are the minority, the use of their tooling highlights the ingenuity and creativity that participants' leverage in their tooling to empower their work practice with mobility.

5.3.4 Tools for Engaging with the Community

A majority of our participants actively engage in online forums, including Reddit, MTurk-Grind, and numerous groups on Facebook, to share and discuss HITs with other workers. Several participants used a new platform – *TurkerView*[1] – which they described as a "new and improved version of TurkerHub" (P7). Importantly, TurkerView was mentioned by name by every participant in our study. Participants described it as a valuable resource not only for its community aspect, but also for reviewing HITs. Like TurkOpticon [124], TurkerView offers a browser extension that allows workers to quickly and conveniently review the HITs that they've done in the past. While the extension was launched as an independent Tampermonkey script, participants noted that recent iterations of TurkerView's reviewing functionality had been built into the popular tool MTurk Suite, which most of our participants utilized in their work. Despite its growing reputation, 4 participants clarified that they avoid the platform and stopped using MTurk Suite because of TurkerView's integration.

Alongside public community platforms, private, more close-knit groups of workers have become a commonality for many crowdworkers' work practice. 10 participant described belonging to a private "team of workers" (P14). Participants noted that these groups

[1] https://www.turkerview.com

manifest themselves through messaging applications, such as Discord, Facebook Messenger, and Telegram, and serve multiple purposes "often beyond merely working" (P21). Alongside "sharing and discussing HITs" (P14) and "building and sharing tools" (P5), the opportunity for friendship was key to engagement:

> "*Some of my closest friends I've met through doing this kind of work. A lot of trying to share and work together. It's definitely not a typical line of work. As you build friendships, you kind of want to start looking out for each other because a lot of us have had different reasons for why we've chosen to stick with this kind of work. It's really cool.*" (P1)

5.3.5 Understanding How Tooling Practices Develop and Evolve

A common theme that emerged from our analysis is that crowdworkers' practices are the product of exploration, experience, and self-evaluation. Learning hurdles were apparent across all participants and included finding realistic monetary goals, finding useful software scripts and tools, understanding how tools function, understanding how to multitask work-related tasks', and understanding how to interface with worker communities. Having only worked full-time for six months, P2 said:

> *"A few weeks ago, I figured out that using multiple windows for a few things works better for me. That's why having two displays is so much better. Otherwise, I used to only have one, and I had everything stacked on top of each other and I was like 'Oh, I can't see what's going on', but now, I'd get another one if my desk was big enough."* (P2)

Senior crowdworkers who had longer periods of tenure as full-time workers voiced similar sentiments and reflections on their past "Aha! moments" (P8) of discovery. However, these individuals in particular clarified that the tooling they employ in their practice had continued to evolve as a means of reaching their daily or weekly earnings goals. As P1 stated:

> *"It's something where you have to be a self-starter, and you have to be willing to try something and experiment. A lot of the scripts that I use now – like two years ago, I was intimidated by them and I thought, "That's a lot. I'm fine with my hourly the way it is", but you just have to take a risk and see what a difference it makes. Like, 'Okay, what else can I do?'. Now, I'm just constantly trying to find a way to improve my workflow."* (P1)

Tool-Building and Private Tooling

The vast majority of tools used by our participants are publicly available for download as scripts or extensions hosted on the Chrome Extension store or the Tampermonkey website. Owing to the characterization of self-starters, we find that crowdworkers recognize and leverage tool-building as a pathway for enhancing their efficiency. Specifically, we observed an awareness of *private tooling* which one participant succinctly described as "productivity-improving tools that are engineered by a crowdworker, or team of crowdworkers, that are inaccessible to the general public" (P8). To that end, four participants described themselves as "tinkerers" (P5) who put together scripts or extensions on-the-fly as needed:

> *"I'm not a programmer, but I know some things simply because of necessity. If I can quickly throw together a script that helps me earn 20-cents per-minute instead of a 5-cents per-minute, I'll do it. Some people are so heavily into it that they'll write scripts for penny HITs to try and turn them into something worth doing. I don't have the time or the patience for that."* (P12)

Importantly, these participants noted that their authored tools are generally not shared publicly (e.g. on community forums), but instead kept to themselves or shared privately within their close-knit, social circles. Tool-builders aside, several crowdworkers corroborated the importance of tool-building experiences, noting their own usage of "invaluable" private tools (P21) that they had access to as a result of financial or social contacts as we discuss in Section 5.4.3.

In sum, we find that crowdworkers establish bespoke tooling practices. Specifically, we find that tooling practices are self-tailored to the worker themselves and the work-related goals they seek to meet. We also observe that crowdworkers recognize a need to learn and adapt themselves to "the trick of the trade" (P7). While crowdworkers have developed tooling practices that unquestionably empower their productivity, we find the tooling infrastructure comes with several costs that greatly influence the work practice at large. We now detail these costs as they relate to our broader mission of understanding how tooling practices affect crowdworkers.

5.4 How Tooling Practices Increase Fragmentation

A predominant theme among interviewees' accounts of their work practice was the overwhelming fragmentation tied to their tooling use. Here, we discuss three ways that tooling use increases fragmentation in crowdworkers' tasks, work boundaries, and the communities they engage with. Where relevant, we incorporate data from our post-study survey to strengthen our analysis.

5.4.1 HIT Fragmentation

Crowdwork is inherently *fragmented*. Crowdworkers are often tasked with completing a sequence of arbitrary and unrelated tasks. With tasks ranging from ultra-brief image tagging to longitudinal research studies, there is a persistent need to interleave and switch between HITs arbitrarily throughout the workday. Tooling, specifically HIT-finding tools such as HIT catchers and HIT auto-accepters, play a central role in crowdworkers' work practice. A key theme that emerged in our analysis was that these tools amplify the fragmentation of crowdworkers' tasks.

Tooling Use Promotes Interruptions

> "*You learn the ropes, and like everyone else, you eventually start relying HIT catchers. And from there on, you'll definitely catch HITs, but you'll be interrupted left and right.*" (P12)

Our analysis suggests that HIT Catchers / Auto-Accepters promote the fragmentation of HITs by surfacing notifications about newly-found HITs "at the wrong time" (P16). Participants recognized that the activity of these tools is reactive to the availability of work, but also regarded that "there are times to notify and times not to notify" (P18). To that end, participants often tune the notification preferences in their HIT-finding tools to match their attentional capacity for interruptions:

> "*I regularly work on a series of HITs that involve substantial reading. It's a legal case, and I need to remember who did this, who is being accused of that, the evidence provided by both parties. It's a task I absolutely refuse to put on pause.*" (P16, MPI Score = 26)

Crowdworkers are aware of the cognitive costs that stem from fragmenting HITs. Participants specifically mentioned that cognitive costs vary between different tasks, and they therefore maintain preferences toward tasks they should fragment (i.e., batch HITs) and tasks they should not fragment (e.g. HITs that resemble information work). In some cases, tooling surfaces an opportunity that cannot be turned down, i.e. because of a high reward, and a task switch is deemed "unavoidable" (P7). Some crowdworkers were able to reflect on the frequency of these scenarios and how they've come to terms with them:

> "*As you do more work, you develop ways of prioritizing your work in your head, so that you're not suffering the discord [from switching]. My notifications will still fire, and I'll still accept work, but I'll do that work in a certain order or be strategic about when I divert my attention. I guess I've created a coping method to avoid suffering that discord.*" (P5, MPI Score = 43)

In addition to surfacing notifications at inopportune times, we find that HIT-finding tools facilitate *interruption overload*, a form of distraction caused by the excessive number and inappropriate delivery of notifications or alerts [213]. When asked to reflect on their first-hand experiences, all 21 participants recounted scenarios in which their HIT-finding tools had found and accepted not one new HIT, but an excessive number of new HITS. These scenarios in particular were described as regular occurrences throughout the workday:

> "*There's times where your tools catch so many things drop at once, and you have to stop and consider 'Okay. What can my hourly be if I switch to this task?' or 'Which tasks do I enjoy more? Which one's going to be faster?'. I know that this requester typically uses bad servers, but I always make really good money from their HITs. It's like a stress-inducing game in your head where you have to decide 'What is my attention to going to?'*" (P1, MPI Score = 46)

The challenge of these scenarios is that they often force crowdworkers into "a momentary shift from my actual work to my administrative work" (P14), specifically the management of their HIT queue. Several participants explained that excessive notifications were particularly stressful as it implied that their HIT queue may have reached capacity, which would prevent their HIT Catchers and Auto-Accepters from finding "the $10 surveys that everyone wants" (P9). Participants noted that managing their HIT queue was a process that required their full attention as it involved evaluating which HITs should be kept in the queue and determining which HIT they should engage with after managing their HIT queue. Participants noted the process itself "can take several minutes" (P16) as it forces them to re-evaluate HITs in their queue, considering each HIT's time constraints, task demands, and reward. However, even after engaging with the next HIT, participants noted that the interference facilitated by these tools rarely shows signs of stopping:

"*I get stressed when I have a ton of work in my queue, and I want to do all of them. Even after managing the notifications, new HITs are still coming in like crazy, and I'm being alerted. And that is when I get stressed. When I'm doing this, I'm thinking about 'Oh my God, I gotta hurry up and finish this' because I have all these other HITs that I have to get done, too. And there's a time limit. It's constant stress.*" (P2, MPI Score = 23)

Participants unanimously described these scenarios as "overwhelming" (P3), "distracting" (P21) and "highly disruptive" (P4), as the scenario requires them to temporarily stop working and devote their attention to evaluating "the path of greatest reward" (P9).

Despite these negative effects, the consensus among participants was that HIT-finding tools are irreplaceable in their work practice. Participants expressed an awareness of the distractions that come with these tools, noting that "crowdworkers just have to deal with them" [P1]:

"*Notifications from these tools always come at the wrong time, but there isn't a 'good time' for them to come either. You're trying to make as much money as possible, and it's hectic – but hectic means that I'm have more money lined up and stuff to do.*" (P12, MPI Score = 34)

Owing to the inadequacies of notification timing, P14 described their HIT catcher as "nothing more than a terrible manager that's unaware of your already insurmountable to-do list", suggesting that its major drawbacks are its lack of awareness of crowdworkers' current state of mind and workload.

Tooling Use Promotes Multitasking

A common criticism of HIT-finding tools voiced both by monotaskers and multitaskers was that these tools "make it so easy to multitask when you shouldn't" (P21). While the decision to engage in multitasking behavior ultimately made by the worker, 12 participants specifically explained their multitasking behavior as a practice enabled not only by their desire to reach their earnings more quickly, but also by the availability of secondary work in their HIT queue:

"*When you're forced to wait for a minute, you have to evaluate whether you want to decide what you value your more – your attention or your money. Catchers make it easy because the work is already in your queue, just waiting for you.*" (P19, MPI Score = 29)

Although we saw no significant differences in impulsivity as measured with the UPPS scale, participants who were measured to have high impulsivity generally voiced similar sentiments, stating they would "probably be more focused if I wasn't even aware of the other work I could do" (P3). Conversely, low-impulsivity particants describing pending work as something "that can wait on me to get there" (P7). While participants were willing to avoid multitasking if the pay was high enough, they also described their own personal aversions to multitasking despite regularly engaging in it. Participants described multitasking as "stressful" (P6), "confusing and costly" (P2), and most frequently "harmful to my overall work quality" (P4):

> "*I want to do my best, and I want a high approval rate. If I'm dividing my attention between 3 tasks, I can't pay attention enough to do a good job.*" (P8, MPI Score = 26)

Resembling task multiplexing techniques from prior work [228], participants commonly described a strategy in which they fill their primary task's downtime with a secondary HIT that requires little attention. Surveys and batch HITs were explicitly mentioned as secondary HITs for their brevity and minimal context, both of which "make it easy to put down and pick back up". Participants with higher MPI scores also noted technical downtime as a driver to their multitasking behavior:

> "*I usually can do three or four batch image-tagging HITs simultaneously. I open four different browser windows because it takes time to load the image each time I submit a HIT, which takes time away from me, from making money. [Requesters] understand that there's loading time for the photos and that takes another three seconds or four seconds sometimes when you could be doing another HIT, so they allow it.*" (P3, MPI Score = 36)

Participants also noted that their multitasking behavior is driven by the nature of the work they're currently engaged in. Collaborative or interactive HITs that have forced waiting periods or periods of inactivity were specifically mentioned by more than 18 of the 21 participants:

> "*I frequently do HITs where I'm asked to chat with other crowdworkers. Most of the time, your partners are really slow. So, you have a lot of lag time in between when you reply and when they reply back. If there's a quick batch HIT, like a penny HIT, in my queue, I'll open two windows, and I'll go back and forth between both of them.*" (P8, MPI Score = 30)

Tooling Use Promotes Beneficial Interruptions

Despite the stress-inducing scenarios that accompany their use, we find that HIT-finding tools play a central role in fragmenting HITs beneficially. Tools can serendipitously improve engagement by surfacing opportunities to task switch in moments where participants needed to "mentally refresh themselves" [P9] from mononotous work:

> "*I switch all the time. I have no attention span. I'll work on one HIT for a while, and after some time, I'll constantly be looking through the HIT Catchers and Finders to see if anything else is coming up with a short timer on it that I can use to clear my brain.*" (P8, MPI Score - 45)

Participants said that switching to a different task "fires different neurons, you know, and just engages me differently" (P5), "improves the quality of my ability to work" (P7), and "generally makes the work more enjoyable" (P9). However, mental strain from monotonous work does not always guarantee that a task switch will occur. In fact, many crowdworkers leverage the moments to temporarily step away from work entirely:

> "*Sometimes, I'll get mentally exhausted. I'll switch into a different window and check Twitter or Tumblr or something like that. Maybe I'll go like make a cup of tea, or I'll try to do some chores for a little bit and come back to the work I paused after I feel better.*" (P6, MPI Score = 16)

Importantly, crowdworkers' work practices are driven by earnings goals, and we find earnings opportunities can often overpower the need to "mentally refresh" for proficient toolers:

> "*If I wanted to put myself through Hell, I could. If I wanted to do the monotonous, garbage, $12-per-hour grunt work, I could put myself through that. I don't choose to, I don't need to. However, when you pay enough, nothing is monotonous - I can promise you that.*" (P7, MPI Score = 12)

Despite its generally negative effect on the work-related engagement, crowdworkers acknowledge that a time and place exists for monotonous work that can help you "zone out" (P10). In general, the negative sentiment surrounding task monotony is driven by the notion that HIT-finding tools fail to account for diversity in crowdworkers' workflows in any capacity.

In summary, we find that tooling use promotes interruptions with unprincipled notifications and alerts that disrupt crowdworkers in excessive quantities or at inopportune times. We also find that tooling use encourages multitasking behavior by making passive work easily accessible. We finally find that workers rely on their tooling to fragment their work beneficially by utilizing it to diversify their HIT workflows, specifically in large streams of monotonous work.

5.4.2 Work-Life Boundary Fragmentation

A common theme in our analysis was that work "sometimes doesn't end" (P1) after it's been set aside. All 21 participants described their work practice as one they "tried to follow a routine work schedule" (P12). However, participants' work schedules varied heavily between one another, and ranged from "the standard 9-to-5" (P11) to "working sun-up to sun-down" (P18). We find that tooling plays a significant role in increasing their on-demand availability during nonwork time as well as their mental attachment to their work.

Tooling Use Increases On-Demand Availability

> "*I wake up, and it's always time to work because it just never ends on MTurk and you never know when it's gonna get busy and when it's not.*" (P12, *Work Warrior*)

Crowdworkers leverage tooling to make themselves available when and wherever possible. Many participants mentioned strategies for configuring their tooling to run, but never knowing when it may trigger an interruption during their nonwork time. However, we find differences among our participants in the extent to which they go about making themselves available. To that end, we find similarities within the WLI clusters, i.e. Work Warriors, Overwhelmed Reactors, and Family Guardians, and the strategies they employ in practice for increasing their availability.

Among our participants, all four Family Guardians employed strategies that were focused on making themselves as inaccessible as possible during nonwork hours. Participants described strategies for firmly separating themselves from their work by leaving the room for the rest of the night, committing to social plans, and simply focusing on nonwork matters:

> "*In the evening, I'm busy with other things. I've got other things that need my attention, but I might leave my catchers running to check in periodically*" (P4, Family Guardian)

These participants described little interest in working with devices while away from their computer with the one exception being closed qualification HITs that have extremely limited time constraints.

Conversely, Overwhelmed Reactors and Work Warriors described strategies that center around "micromoments" – small gaps in time for getting things done [266]. These participants described a diverse set of work-on-the-go scenarios, "while sitting in in the living room" (P9), "while watching my kids outside" (P18), "in the line at the grocery store" (P3), and even "while I'm sitting at a red light" (P16). Tooling plays a key role in allowing people make use of these moments:

> "*[The tools] keep me occupied if I'm riding in the car or if I'm walking to my office at the University. University parking kind-of sucks, and I might as well use the 10-minute walk from my car to my office to be a little bit productive.*" (P13, *Work Warrior*)

While these scenarios vary between individuals, we find that Work Warriors specifically maintain a desire to make productive use of every moment possible, even if an opportunity arises at an inconvenient time. In several instances, participants described such scenarios that demonstrated making use of every moment possible meant sacrificing their engagement toward something else:

> "*If you're at a boring dinner or something, and you get an alert – 'Oh, this batch pays well'. Yeah, sure. I'll just mindlessly tap this under at the table, and no one will know.*" (P1, Work Warrior)

> "*I recently woke up at 2:00am to go to the bathroom, and like any tech-minded individual today, I checked my phone. I saw an alert on my private tool from a requester about an opportunity for a $20 survey. I finished the survey in 15 minutes and went back to bed.*" (P20, Work Warrior)

Several workers, primarily Work Warriors, have their entire work practice centered around perpetual availability:

> "*I can carry it with me, and the work never leaves. In that case, it's important because when you're so involved in crowdwork, you could sit and work for 14 hours straight without a break very easily because the HITs are flowing. You have to regulate yourself and if you don't do that, you'll become a workaholic.*" (P10, *Work Warrior*)

The desire to continue work is primarily driven by money. Our participants' earnings goals were often limited to the day or the week as more long-term goals could not be set to "account for the ups-and-downs of the market" [P20]. Participants generally described using their earnings goals as a form of finish line to mark the end of their day. Overwhelmed Reactors or Family Guardians demonstrated an ability to set work aside after their goals had been made. Work Warriors, however, described an affinity toward continuing work if the opportunity exists:

> "*I have a different philosophy on goals because it can be so tough to put down. If you made $30, you can make $33. If you made $33, you can definitely make $37. It goes on and on.*" (P8, *Work Warrior*)

The sentiment voiced by P8 was specifically echoed by participants who have worked on MTurk for more than a year — goals become become more like "guidelines rather than finish lines" (P18), which may explain the relationship we find between WLI scores and demographics in Section 5.2.3.

Tooling Use Facilitates a Mental Attachment to Work

Across all three classifications of boundary management strategies observed in our study, we find it common practice for crowdworkers to actively leave their HIT-finding tools running during their nonwork time, allowing them to remain passively engaged with their work. We find that this behavior largely contributes to a sustained feeling of being "mentally connected" (P1) to their work regardless of whether they actually engage with their work during their nonwork periods.

Crowdworkers noted that they are motivated to remain"on call" (P5) in part because of the feeling of serendipity of discovering unanticipated HITs, especially after hours. As one participant said, "[you] never know when something valuable will show-up" (P13). Several participants referred to their HIT-finding tools as a technology that "plays on the fears of missing out" (P19):

> "*Even when the catchers aren't running and I've shut it all down, sometimes the thoughts creep back in. What am I missing? What's on the market?*" (P21, *Family Guardian*)

To our participants, "escaping work is fairly impossible sometimes" (P12). For example, work-related communication, such as e-mails from requesters, often need to be addressed as soon as possible, and leaving it unaddressed runs the risk of losing money for work that a worker had already done earlier in the day or week. Several participants described these communications as “forcing them to come back to work mode” (P7) even when they choose not to attend to them.

For a small number of crowdworkers, an attachment to work is not always regarded as negative. While Family Guardians and Overwhelmed Reactors expressed a desire to be less focused on work than they already are, Work Warriors sees their sustained connection to work is one of enjoyment:

> “*I do feel that [I'm always attached], I really do. I mean, I actually like this work because I have autonomy. I can make my own hours. I'm my own boss. And I actually enjoy most of this work. I really like it.*” (P10, *Work Warrior*)

When asked to clarify if their connection to work is rooted in the nature of the work or the tools they use, participants expressed conflicting sentiments. On one hand, participants were quick to suggest their tooling was at fault, but often backtracked, recognizing the decision to continue using their tooling is ultimately their own to make:

> “*I want to blame the tool's because they're designed to work this way, but it's my fault, too. I mean, come on. I'm in control. It's just when the HITs are flowing and the opportunity to make good money is there, the tools make it easy to jump back in.*” (P9, *Work Warrior*)

During the interview, participants commonly followed these remarks with a stated desire to change their tooling in such a way that would allow them to devote more attention to things unrelated to work during nonwork time. When this occurred, we continued the discussion by asking participants to imagine and describe the type of tooling that could help them do so:

> “*We have catchers and auto-accepters, sure. But we just don't have the right tools to help us avoid these problems. We just do our best to not have those days occur.*” (P2, Family Guardian)

One participant (P21) was interested in seeing a tool that “could help [them] forget about work entirely” at the end of the workday, but was unable to characterize exactly what they meant. More commonly, several participants described that “the current model of catching

HITs" was too central to crowdwork for an alternative approach to exist, speaking to the sociotechnical limitations of crowdsourcing platforms as touch-and-go systems for work.

In summary, we find that crowdworkers affiliate their sustained mental attachment to their work as one intermixed between the work itself and the tools they use in their practice. By maintaining this attachment to work, they fragment their boundary between work and nonwork, engaging with work-related tasks at the whim of a notification or alert. The significance of their attachment is that it is often sustained despite workers being aware of the adverse consequences that may follow.

5.4.3 Community Fragmentation

Social ties are an important facet to crowdworkers' broader work practices. We find that tooling use is a central point of social tension that often had led to a fracture within their communities. Specifically, employing tools in support of productivity is a universal effort, but a gap exists between those who have access to the appropriate tooling and those that do not.

Limited-Access and Commercial Tooling

Throughout our analysis, we observe that several crowdworkers have access to private tools that enable them to work more efficiently, both while at their primary work computer and while away from it. We find that limited accessibility of these private tools play a significant role creating social fractures within the MTurk community.

As topics of discussion, TurkerView and private tooling were often interlinked. Participants who employed private tooling toward the task of auto-accepting HITs often avoided identifying the tooling source, instead stating that these tools "come from a private place from a person willing to offer that to me or to anybody else" (P5). While some participants find their tooling elsewhere, e.g. P5, many perceive the platform as a hub for such tooling:

> "*Last summer, [someone on TurkerView] was trying to create some more tools that were just a little bit more intensive than a browser script. He was charging a subscription for that because it was taking a lot of time out of out of his workday to maintain it.*" (P13)

P13 is a crowdworker who chooses not to engage in TurkerView in any capacity and, like many others, has heard of TurkerView's rumors on other forums or social channels. The platform's association to the development of private tools was described by 16 of our 21 participants, 3 of which explicitly said that they pay for private HIT auto-accepters sourced from the platform. Participants also noted the platform's adopted a new subscription model for its popular reviewing extension, which runs separately from the private tools that our 3 participants stated they pay for.

While the platform serves as a valuable point of access to the broader crowdwork community, several crowdworkers perceive TurkerView's decision to commercialize their reviewing extension as a shift in "what's best for the community" (P10). While the majority of tools are pubilcly available, the notion of private tools is not necesarily new [131]. The key distinction between TurkerView and its private tooling predecessors (e.g., Turkinator) is its centrality to crowdworkers' work flow:

> "*Kaduchi, who makes MTurk Suite, makes Turkinator that you can pay $10 a month for. It's not as efficient as using the other ones because of the way it searches. But with TurkerView, it's not like you can't use it. You need to be able to see the reviews.*" (P17)

We find that TurkerView's relationship to private tooling has shaped crowdworkers' perception of community platforms significantly. Participants who actively use the platform described the TurkerView community as one that is generally "more experienced than most Turkers you'll find elsewhere" (P7). While the perception of productivity is generally true for TurkerView's userbase, the commercialization of their software has lead people to question its motives:

> "*TurkerView has a monopoly on the community. There are suspicions that [the TurkerView extension] hides HITs from people who aren't paying for the full version. That's the main reason why I uninstalled it. I've also found TurkOpticon's reviews to be more accurate than those on TurkerView, which makes me think that they're gaming reviews, too.*" (P14)

In lieu of participating in TurkerView, P14 frequently participates in a Facebook group of more than 2,000 active crowdworkers Unlike P14, many participants cite the open tooling practice as a significant deterrent for engaging with communities altogether:

> "*I've browsed TurkerView, and the things that people bicker over is insane. You'll see peoples say things like 'I made $85 today!'. It's just clear this person is bragging about their earnings and we know you just have the right tools. It's just – it's frustrating, and it's everywhere.*" (P20)

Even in scenarios where tooling is accessible, crowdworkers may not choose to utilize it in their work. We find that ambiguity in MTurk Policy Agreement[2] plays a significant role not only in crowdworkers' decision to utilize a particular tool in their work, but also how they perceive the fairness of their practice. Participants noted that over-automating components of their work too excessively can result in "a temporary suspension" (P7) or "a complete ban of your account" (P1). As a collective, participants engaging in private work highlighted the discrepancies in the policy that drive their decisions to engage in a potentially terminating tool practice:

> "*The terms tell us not to have scripts that needlessly pull data from MTurk. In order to catch any HITs, you have to do that. It's against the Terms of Service technically, but you're not gonna get anything done if you don't. It's 'Damned if you do. damned if you don't'.*" (P13)

Participants who shared P13's perspective were also those who belonged to more personal, close-knit groups that emphasize building scripts and extensions "as newer opportunities to optimize the workflow" (P1) arise. In contrast, we find that participants that did not belong to these communities expressing more ethically-minded remarks about the fairness of private tooling:

> "*The private tools I know of are just automatically accepting by the dollar value, and I know that I don't use them, but God, I'm sure it would be great, and I'm sure I'd make much more money. But it's just isn't particularly ethical to everyone else on the platform.*" (P3)

Tooling availability, in sum, strongly contributes to the fragmentation of social ties within and between crowdworkers' communities. Crowdwork is centered on the pursuit of work opportunities in which each worker has a fair chance of finding work. Private tooling practices are a significant barrier in preventing this premise from becoming reality by facilitating unequal access to work opportunities between workers. Motivated by mixed perceptions of unfairness in tooling practices, crowdworkers splinter their social ties between communities that continue to empower "the upper echelon" (P11) and those that instead strengthen the broader crowdworker community at large.

[2]https://www.mturk.com/worker/participation-agreement

5.5 Discussion

Engaging a diverse set of full-time crowdworkers in discussions of their broader work practices allows us to understand how their tools affect the way they work. We found that crowdworkers regularly experience cues that facilitate interruptions and multitasking and cause attentional fragmentation while working. We have also found that crowdworkers maintain fragmented work boundaries between their work and nonwork spheres, passively engaging with their work during micromoments of availability or more broadly whenever they are called upon. Finally, we have found that notions of tooling fairness strain social ties within the broader crowdworker community, driving crowdworkers toward private communities or away from social engagements altogether. We now discuss the implications of these findings as they relate to the future of tooling.

5.5.1 Understanding Crowdworkers' Tool Ecologies

Prior studies of tool ecologies have introduced characterizations of tools in more traditional information work settings that bear similarity to our own characterization presented in Table 5.3. Gonzales et al. [86], for example, introduce four unique software roles that tools can play among teams engaged in solving a collaborative, complex task. Our work complements, blends, and expands on these software roles by introducing a more comprehensive assessment of software roles specific to the full-time crowdworker on Mechanical Turk. Similarly, Turner et al. [275] noted the value in leveraging multiple communication tools in the workplace, detailing that each tool offered a unique social value to the individual. Speaking to Section 5.3.4's findings on engaging in both public and private communities, we share Turner et al.'s conclusion in that workers similarly engage with these communication tools, whether they be public or private, for a range of reasons and that each tool's sustained use is driven by workers' social needs more than others (e.g. functional needs).

Our study suggests that workers' tooling, in its current state, is designed to optimize for productivity. Beyond the scope of crowdwork, building tools in support of productivity and efficiency is often criticized for enabling a practice of Taylorism, a theory of management that prioritizes productivity (i.e., output) often at the expense of the individual [169, 298]. HIT-finding tools specifically are no exception to this criticism as they optimize for earnings without regard for other facets of crowdworkers' work and nonwork lives. Our study highlights the reality of these expenses by demonstrating the fragmentation workers experience both in their work and beyond it.

5.5.2 Reimagining the Crowdworker's Toolbox

Combatting the fragmentation that crowdworkers experience requires a reimagination of the tools they employ to find work. Here, we argue that this reimagination should be an independent venture, but a collaborative one. We describe several key considerations for designing and engineering tools in support of crowdworkers' work and non-work lives.

Empowering Workers' Tooling Practices with End-User Development

We find that crowdworkers' tooling practices are generally composed of software developed by people (i.e. workers) within the crowdwork community. Importantly, crowdworkers rely heavily on other individuals to build and maintain these tools that make their work practice possible. Further, within our study, we identified four "tinkerers" that already self-engineer tools that allow them to improve their efficiency as needed. Importantly, these "tinkerers" have a tooling practice that serves as a form of end-user development (EUD) [144, 165]. Studies of EUD have demonstrated that enabling the end-user to engage in the software development process can take shape in a variety of ways (e.g., allowing end-users and developers to co-develop software [11]) and can yield a plethora of reusable resources that allow others to learn and adopt the EUD process in their own workflows [114, 163]. However, a central question here is understanding how researchers can introduce new systems and infrastructures that make the personalization of tooling workflows more accessible. Similar goals have been undertaken in other contexts with success, such as Microsoft's MakeCode initiative that enables students of any age to engage in programming [21]. From participatory design studies to co-developed systems, a key direction of future research is understanding how CSCW researchers can build high-value infrastructures that enable workers with the ability to craft a work practice that suits themselves.

Designing Tools for Productivity and Well-Being

Our study suggests that HIT-finding is at the core of productivity support tools. Prior research has taken first steps toward supporting crowdworkers' decision-making processes by building and evaluating tools that help workers make more informed decisions about the work pursuit[96], work acceptance [231], and work completion [247], signalling next steps toward task recommendation systems that handle work far more strategically than the HIT-finding tools that crowdworkers currently rely on. Our findings speak directly to the importance of the systems' ability to surface the right type of work and the right amount of work at the right time – all of which have been studied in prior information work settings [19, 121, 134, 296]. Per our findings, the most fruitful avenue of impact is enabling workers to further customize the cueing mechanisms (i.e., alerts and notifications) that enable them to sustain their engagement with work. Tools and systems used in practice should account for the worker's context both in and out of work, maintaining an awareness of their attentional preferences, their attentional capabilities, and their desire to engage with work-related tasks at a particular time. Importantly, these same tools and systems should also prioritize the protection of their users' privacy, employing techniques to ensure that user-generated data is both secure and managable.

While the design of HIT-finding tools is situated at the forefront of the problem space, we recognize that how people decide to use their tools ties into the work-related fragmentation they experience. Studies of organizational interventions of workaholism speak to the importance of "*managerial influence*" [103, 265] in the workplace, citing that change can stem from leading by example [13]. This is particularly true for psychologically detaching from work [256]. As crowdworkers often recognize their HIT-finding tools as managerial complements to their work, one possible solution is to innovate new systems and tools that make it more difficult to engage with work [180] or facilitate detachment from work with a tool, such as SwitchBot [295]. However, solving such a problem where there are external pressures to work (e.g., failing to meet an earnings goal) overlooks the larger problem of what is causing the pressure to work in the first place. In such a scenario, there is a strong presumption that technology can solve it, when we may need to look beyond the scope of technological innovations. We therefore recognize that the reimagination of the crowdworker's toolbox is a tool design problem that should be approached from an interdisciplinary lens, involving teams of many disciplines (i.e., computer science, sociology, occupational health, cognitive science) rather than being grounded in one particular area of research.

The Future of Fair Tooling: Ethics and Community

Prior research has recognized that the design of crowdwork platforms thrives on an inherent imbalance of power between workers and requesters [185, 193, 125]. We find that the private tooling practices that crowdworkers self-create and engage in serves as a form of power redistribution not between requesters and workers, but instead among the workers themselves. A lack of clarity and oversight on Amazon's behalf plays a central role in the inability to concretely define and understand fairness in the context of tooling. Should workers be allowed to self-engineer tools for themselves? Is tool-sharing permissible? What level of automation mandates a policy violation? Most importantly, who is qualified to address these questions? Off-loading the onus of answering these questions onto crowdworkers has enabled the current state of private tooling practices, driving mixed perceptions of fairness and accountability.

We argue that designing and promoting fairness can and should be a collective effort between workers and the research community – a process employed by a number of platforms that come before us, such TurkOpticon [124, 125] and Daemo [84]. However, collective action systems in crowdwork are particularly contentious as researchers and crowdworkers often have distinct goals, and if tool-building is to become an effort shared between workers and researchers, both parties should be incentivized appropriately. As prototype systems continue to be built and studied by academics, researchers can play an active role in promoting tool fairness by open-sourcing the tools they study. In line with EUD [144], workers and researchers could co-maintain a citeable web listing of prototype tools that have been studied, the type of workers they've been studied with, and a reference to the tool's source code repository. The web-listing could not only allow workers to share their code, but also allow them to receive donations for a particular script. Recent work, for example, has demonstrated that many feel comfortable using their labor as a form of donation (e.g. donating the competition of a HIT instead of a monetary donation) [135]. A similar model could be adopted to incentivize tool-sharing within the broader community to allow workers to more easily show appreciation to one another for their efforts as seen in open-source software [147].

5.5.3 Beyond Tooling: The Nature of Crowdwork Platforms

A key consideration in evaluating and investing in future tooling research is recognizing that this study's findings are grounded in the nature of crowdwork. Research has long recognized the many shortcomings of platform design in crowdwork [277]. Crowdsourcing platforms and marketplaces, for example, do not regulate or oversee that HITs have appropriate task constraints (e.g., allotted time), nor do they oversee that monetary rewards are commensurate for the amount of effort given toward a particular task [95]. Several efforts (e.g., Stanford's Fair Work initiative[3]) have taken steps toward building tools aimed at overcoming the constraints of these platforms in such a way that advises requesters to pay more fairly, should they need to. While these tools and systems are unquestionably well-aligned with the mission of reducing fragmentation, the demand for fair pay has continued as a central point of discussion both in and beyond academic literature [241].

The penultimate solution for combating fragmentation is one that drives change not only within tooling practices, but more broadly within the work practice itself. Agency,

[3]https://fairwork.stanford.edu/

flexibility, and learning opportunities are valued aspects of crowdwork that extend to the broader gig economy [90, 161, 176, 301]. Recognizing that corporate interests often drive the design of these platforms, we encourage these crowdwork corporations – namely Amazon – to pursue and prioritize partnerships with research collectives of both academics and crowdworkers with the goal of exploring pathways for guiding the future of work. For example, to combat the fragmentation between work and nonwork, MTurk could provide workers with the ability to limit their work hours to an 8-hour window during the day. How would such a system ultimately influence work-life fragmentation? Could such a system nudge requesters to pay more fairly? Inspired by prior work-related studies, other platform-level changes could include suggestions for scheduling when *not* to work [173], limiting access to distracting websites while working [180], and managing the viewership of HITs from workers to promote engagement [159]. Such possibilities are largely subject to platform-level changes and rely on Amazon, among other corporations, to recognize the need for change. Until then, tool research will remain the most fruitful pathway for empowering workers both at their workstation and beyond it.

5.5.4 Limitations

Our study was conducted with crowdworkers who regularly work a minimum of 35 hours per week on Amazon Mechanical Turk. Our study makes no claims about the broader work practices (e.g. device usage, tool usage, etc.) of people who work less than 35 hours per week or work on alternative platforms, such as Microsoft's UHRS [4], Figure Eight [1], and LeadGenius [2]. We recognize the need to understand how tool definition, tool use, and tool effect varies across these platforms as a key direction for future research.

5.6 Conclusion

In this chapter, we reported findings from an interview study aimed at exploring the tooling practices employed in full-time crowdwork. Our findings suggest that the tooling utilized by crowdworkers (1) strongly contributes to the fragmentation of microwork by enabling task switching and multitasking behavior; (2) promotes the fragmentation of crowdworkers' work-life boundaries by relying on tooling that encourages a 'work-anywhere' attitude; and (3) aids the fragmentation of social ties within worker communities through limited tooling access. We concluded this chapter by discussing the implications of our findings in the context of engineering and studying tools that meaningfully impact the productivity and well-being of the crowdworker community.

Chapter 6

Conclusion

Based on the research presented in this dissertation, we can make the following conclusions about systems that help information workers manage their work-related transitions across tasks, devices, and environments. We find that such systems can enable information workers, specifically programmers, with the ability to continue their work while on-the-go can mitigate the resumption cost that traditionally stems from interrupted work. We also find evidence that suggests that systems designed to aid people in discontinuing their work can support peoples' productivity and well-being, especially if they no existing practice in place. Finally, we find that newer forms of work function in such a way that threatens the viability of these system approaches for the broad spectrum of information work.

In the next section, we restate and outline the contributions made in this dissertation.

6.1 Contributions and Impact

In this dissertation, we make the following research contributions:

1. We argue that the challenges stemming from transitions are motivated by an inability to effectively continue or discontinue one's work. We argue that designing systems for continuing or discontinuing work hinges on understanding these challenges.

2. Based on a contextual inquiry with 10 participants, we provide evidence that suggests transitioning between the desktop and mobile context is a significant challenge for programmers who have a desire to continue or access desktop work on-the-go.

3. We extend our contextual inquiry with an online survey in order to characterize programmers' existing and desired mobile practices. We provide insight to the nature of these practices and their support of programmers' work-related transitions.

4. We present Mercury, a mobile programming tool that mitigates transitional overhead by enabling programmers with the ability to continue their work on-the-go with microtasks that require little attention, effort, and context to complete.

   a. We present evidence from a laboratory study that demonstrates how Mercury allows programmers to engage with work can mitigate the costs that stem from interrupted work, particularly in scenarios of brief interruption.

   b. We contribute a novel discussion on the ethics of introducing systems, like Mercury, that allow people to work anywhere, noting their potential for negative impacting peoples' work and personal spheres despite being well-intentioned.

5. We present SwitchBot, a text-based conversational agent that aids people in psychologically detaching from their work at the end of the workday and psychologically reattaching with their work upon returning to the workplace.

   a. Based on joint findings from a crowdsourced study and a field study, we present evidence that suggests using SwitchBot's dialogue paradigm was successful as a tool for aiding people in their transitions, though this varied heavily bsaed on participants' existing practices.

6. Based on an interview study with 21 crowdworkers, we provide a thorough analysis of the work-related transitions that crowdworkers experience through the lens of tooling. We find that crowdworkers' current tools amplify the cognitive impact of work-related transitions, contributing to the "fragmentation" of their work practice.

7. We coalesce the findings from our studies to highlight directions and opportunities for future research.

In the next section, we discuss the frontier of open research problems that stem from the research presented in this dissertation. We use these open problems as a lens for opportunities for future work aligned to the goal of designing, engineering, and understanding systems for managing work-related transitions across tasks, devices, and environents.

6.2 Opportunities for Future Work

We concluded the previous three chapters with independent discussions of each study's design implications and important pathways for future research related to scope of the project. In this section, we widen this scope and describe additional directions of future work, framed by the collective findings of the previous three chapters.

6.2.1 Managing Transitions in the Future of Work

Our findings about crowdworkers' work practices raise a number of questions about the generalizability of systems for managing work-related transitions across forms of information work that are distributed or remote. Here, we highlight several key directions of future work within the purview of crowdwork.

Observational Studies of Work Practice and Transitions in Crowdwork

Our inquiry of crowdworkers' work-related transitions highlights a significant distinction between the interruptions that occur in traditional information work settings and those that occur in contemporary information work (i.e., crowdwork). Observational studies have historically played an important role in understanding both the frequency and effect of interruptions in information workers' work practice [178, 182]. A key takeaway from Chapter 5 is that, in comparison to traditional information work settings, there are several characteristics that challenge the accuracy of observational studies aimed at understanding crowdworkers' work practice. For example, we found that crowdworkers frequently utilize a range of devices to engage with and accomplish their work. We also found that several workers leverage tools that allow them to control other devices during periods of inaccessibility (e.g., Chrome Remote Desktop). These two facets of work practice challenge the assumption that work will be accomplished on a single computer, which is often made in studies of interruptions and transitions in the workplace.

One fruitful direction for reliably conducting observational studies is utilizing the rich space of existing tools within crowdworkers' work practice. Consider, for example, the TurkerViewJS extension, a tool that many participants in Chapter 5 described as central to their workflow. As shown in Figure 6.1, the extension auto-populates information about a recently completed HIT and asks crowdworkers to rate the HIT's payment and communication. Crowdworkers are also given an opportunity to quickly report the pros and cons of the HIT as well as provide feedback to the requester.

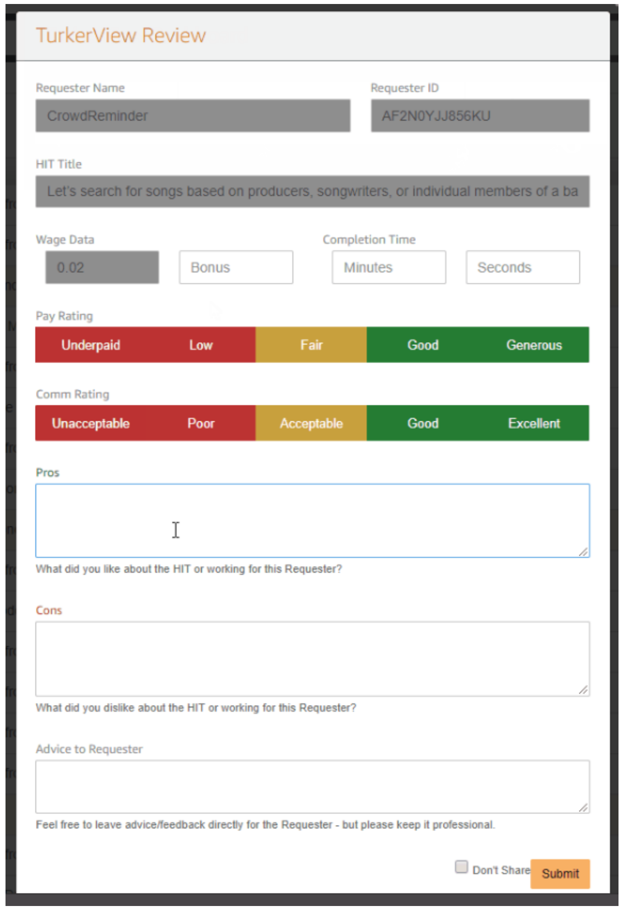

Figure 6.1: A snapshot of the TurkerViewJS extension's interface.

A key direction of future work is using HIT-reviewing tools as probes for experimentation and observation. Tools for reviewing HITs and their associated requesters, like the TurkerViewJS extension, are among the most commonly used tools within crowdworkers' work practice. Further, these tools are browser extensions, which allows their client-side behavior to be modified for broad experimentation. Mirroring prior studies of information work [181], the TurkerViewJS extension can be used to document and record the how crowdworkers begin, switch between, and complete HITs while simultaneously capturing relevant HIT information (e.g., title, reward, etc). With several additional input fields, the TurkerViewJS extension's interface can also be used to replicate more comprehensive studies of task switching in information work (e.g., Mark et al.'s study of attentional states [182]). The primary goal of these studies is better characterizing the differences in interruptions between traditional and more contemporary information work settings.

Supporting Micro-Transitions between Work and Non-Work Environments

A central direction of future research is understanding pathways for aiding crowdworkers in separating their work and non-work lives. Our research draws attention to HIT-finding tools as systems that continuously motivate crowdworkers in re-engaging with work opportunities that arise at often inopportune times. An important caveat of these systems is that, like the systems proposed in this dissertation research, they are ultimately designed to prioritize user autonomy. Though these existing tools undoubtedly amplify the temptation to engage with fleeting work opportunities, the decision to re-engage with work is ultimately in the hands of the crowdworker.

The nature of the crowdworkers' work-related transitions between work and non-work introduce new criticisms for the Mercury and SwitchBot systems which were previously introduced and evaluated in Chapters 3 and 4 respectively. SwitchBot, for example, was designed to augment the transition between home and workplace, which generally occurs bidirectionally only once per day in more traditional work settings. Our observations about crowdworkers' intermittent work engagement motivate an enhanced version of the system that support peoples' *micro-transitions* that allow them to quickly switch between their work and non-work environments with minimal cost. Several new research questions arise in understanding how systems can be designed to support these micro-transitions. For instance, it remains unclear if conversational systems are appropriate for supporting the transition, or if a graphical interface are sufficient. The design of such a tool can be motiviated through a series of formative studies that range from observation to generalization as was done in designing Mercury in Chapter 3.

An important consideration for future systems research is that work-nonwork separation practices are generally well-studied in older forms of distributed information work. Studies of telework and remote work, for example, have found evidence that shows people may devote certain rooms to their work while others may sufficiently divide their environment based on the time of day or day of the week [79]. Our study of crowdworkers' work-related transitions inquired about our participants' preferences for separating work and non-work, but we did not explicitly inquire about their practices for reinforcing their preferences (e.g., limiting work-related activity to a room or place). A valuable pathway for designing and studying systems that support more fine-grained transitions is better understanding these practices that crowdworkers' utilize in separating their work and non-work.

6.2.2 Longitudinal Studies of Work-Related Transitions

The foundation of this dissertation research introduced two systems – Mercury and SwitchBot – that sought to support information workers' ability to manage their work-related transitions in two unique settings. Both Mercury and SwitchBot enables new digital experiences that had not previously existed in peoples' work practices, and we therefore designed fixed-term evaluations to address the immediate research questions for each system.

The findings both from Mercury's evaluation and from SwitchBot's evaluation introduce a number of questions regarding how they influence long-term user behavior. A key goal for future research with Mercury is understanding how the system promotes and instills work-related habits that are harmful to an individual's well-being. The design philosophy of microproductivity systems is built on the promise of making work more accessible. The influence of these systems on information workers' broader work practices is relatively unknown because they have only recently made their way into practice [116]. Understanding how these systems affect information work professions in the long term will not only improve our understanding of these systems as behavior change tools, but also determine other factors that may have influenced Mercury's evaluation (e.g., novelty bias).

Engineering effective systems for managing work-related transitions hinges on a continued and sustained understanding of the transitions that occur within peoples' work practice. Our study of crowdworkers' work-related transitions serves as a blueprint for replication in crowdwork and in newer forms of on-demand work. An important direction of future research is aimed specifically at designing new studies, inspired by our findings in Chapter 5, that explore how information workers generally adapt to the transitions they experience in their work. In the scope of crowdwork, one particular research goal, for example, is understanding how HIT-finding tools can condition crowdworkers to better anticipate transitions. Aligned with Mackay and Fayard's triangulation of methods [174], addressing this goal could not only introduce new systems for supporting crowdworkers in adapting to their work, but also motivate new theories of cognitive resource management.

To understand how our proposed systems support people in managing their work-related transitions, we evaluated SwitchBot and Mercury using a combination of subjective metrics (i.e., self-reported feelings, perceived reattachment, and perceived detachment) and objective metrics (i.e., e-mail usage during after-hours, productivity application usage) that were relevant to information workers at large. Future studies of systems in the vein of research may benefit from utilizing additional metrics that capture more nuanced aspects of work life. For example, one possible proxy for measuring an individual's detachment from work might be asking a third-party (e.g., a spouse) to evaluate detachment on behalf of the individual.

Depending on the individual's profession, an objective metric may look beyond e-mail usage and focus specifically on communication application usage more broadly. Instant messaging applications for teams, such as Slack and Microsoft Teams, have become primary channel of communication for many companies engaged in technical or digital work. Mirroring our findings around HIT-finding tools in Chapter 5, these types of communication applications allow people to freely communicate at any time during the day and can yield unruly notifications if configured inappropriately. The scope of psychological detachment metrics could focus specifically on telemetry data collected through these tools, ranging from how frequently someone opens the application to the number of messages they send during non-work hours. From the longitudinal perspective of behavior change, the ideal intervention for psychologically detaching from work is one that the user eventually dismisses as a result of having adopted the behavior as habit.

The notion of behavior change introduces a significant question: Are psychologically detachment and reattachment to types of problems that demand technical solutions? Research has both theorized and demonstrated that the ability to psychologically detach from work hinges on individuals' ability to self-regulate their attention as it relates to their task-related goals [162, 245]. SwitchBot embodied these overarching ideals, but the necessity of using a technical system, in contrast to a human being, remains significantly unclear. An important vein of research can focus on better understanding the social aspects of psychological detachment and detachment alongside the social role that the system plays.

6.2.3 Context-Aware Approaches for Managing Transitions

The systems introduced in this research are centered around user autonomy, and are designed to act reactively to the user's initiation. As systems for supporting work-related transitions across tasks, devices, or environments, the successes and shortcomings of Mercury and SwitchBot motivate further inquiry and study to determine how inferring and leveraging the user's context can change the nature and effectiveness of their interactions.

Work-Related Transitions in Traditional Information Work

As described in Chapter 2.3.2, significant attention has been given to engineering systems that autonomously act based on a user's inferred context (e.g., location, place, attentional resources). A wealth of prior techniques exist in the literature on context-aware computing and attention management systems that can augment the systems described in Chapters 3 and 4 significantly. For instance, Mercury was designed to enable programmers to make meaningful progress while on-the-go. One pathway for expanding Mercury's approach to mobile productivity is identifying and recommending opportune times to transition between environments, or *environmental breakpoints*. As with many context-aware systems, this research goal relies on an ability to model the user's context effectively. Incorporating such recommendations into future versions of Mercury introduce a number of new questions regarding how users' context should be modeled, how users trust the system, and how inferred context can influence the microtasks routed to the user while mobile.

Our findings regarding SwitchBot suggest that recommendations can play a significant role in helping information workers manage the transition between home and the workplace. One specific direction for augmenting SwitchBot's interaction design focuses on incorporating and understanding the effect of proactive interaction that takes place upon arriving at their workplace or upon leaving their workplace. Prior research has described proactivity in conversational systems as a continuous point of tension that relies substantially on being used in the right context [164]. A future inquiry could focus specifically examine how the needs and desires for proactivity in these systems changes with the user's context. For example, an individual running late to work may have different preferences for proactivity in comparison to an individual who arrived to work on-time.

An important characteristic of future research could also widen our scope of devices. Newer automobiles are becoming increasingly embedded with context-aware sensors, such as embedded GPS navigation and hands-free interaction via voice. These attributes promote the automobile as a compartmentalized context-aware environment with rich opportunities for studying both proactive engagement and multi-modal interaction. These possibilities motivate new research questions about how user context can be modeled between two environments simultaneously (i.e., home and the workplace), how conversational systems can adapt the conversation to the user's context (i.e., percentage of commute completed), and how systems can help navigate the unanticipated need to switch between environments more frequently.

Our work highlights the practical differences between traditional information work that takes place in office spaces and newer, emergent forms of information work that takes place on a global, more distributed scale. On-demand work is, by design, fragmented with moments where people rapidly switch between tasks of varying complexity, effort, and scale. Our study of crowdworkers demonstrates that this switching behavior motivates transitions between work and nonwork, often at inconvenient and unexpected times. The extent to which similar aspects of fragmentation are increasing in traditional information work settings. However, microproductivity systems, such as Mercury, can be used to serve as the foundation for future systems that can transform traditional information work contexts into similarly fragmented practices. Ensuring these future systems are used ethically is a responsibility that should be shared by researchers and practitioners at large.

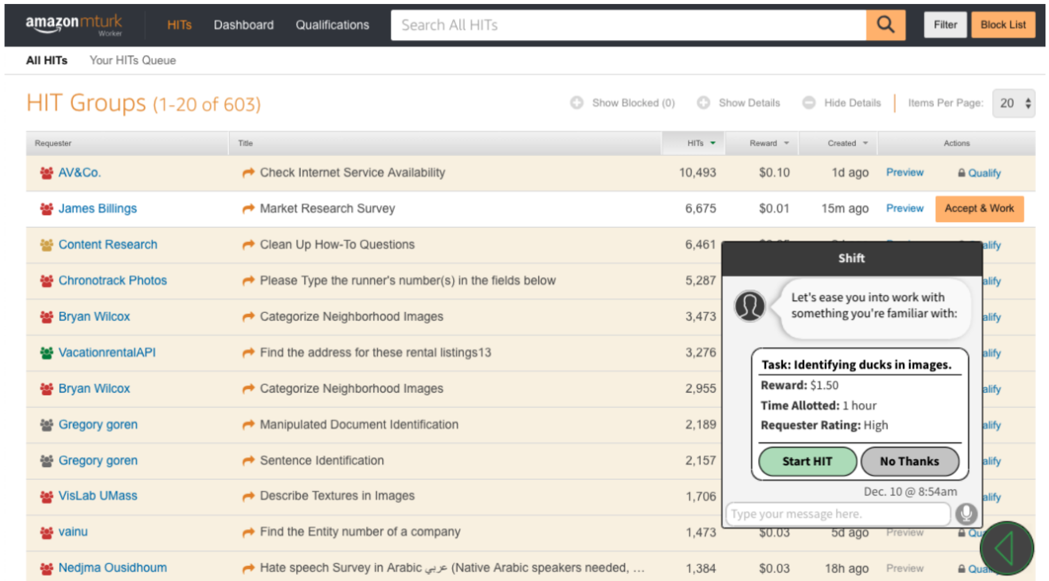

Figure 6.2: A mock-up of Shift, a protoype system for finding HITs via conversation.

Context-Aware Tooling in Crowdwork

The on-demand nature of crowdwork introduces a series of new and interesting challenges to supporting users with modeling and sensing techniques. For example, our study of crowdworkers' work-related transitions reinforces the notion that tasks (i.e., HITs) often arise unexpectedly and on-the-fly, making it challenging to model information about a worker's tasks like has previously been done in other settings [290]. There are, however, opportunities for modeling crowdworkers' context about their broader work context, such as their normal working hours, the characteristics of their workstation, and their preferences and aversions to certain types of tasks that commonly arise on crowdwork platforms.

Through these simple attributes of context, new systems and interactions can be engineered that center around supporting the transitions that people experience in their work. Figure 6.2 shows a mock-up of Shift, a prototype system designed to accomplish the task of HIT-finding in conversation. The conversational nature of the system could allow the system to proactively ask the user for their context to better identify work opportunities that suit the user's current needs (e.g. "Do you want to work on something different soon?"). Shift serves as one of many possibilities in the space of tool design and development for re-imagining how work opportunities can be both discovered and managed. Other studies, for example, could explore alternatives to conversational interfaces or examine the effect of approaches that simply let users statitically configure these systems at depth.

A promising direction for impact is understanding how context can help crowdworkers in managing their notifications and alerts from work-related opportunities. Mitigating the effects of inopportune notifications and alerts has been a central goal for much research in studies of attention management systems [119]. A key distinction between prior studies' contexts and the current setting of on-demand crowdwork is that notifications are the primary pathway in which crowdworkers accumulate their work. Therefore, any system that algorithmically determines how a notification from a work opportunity should be surfaced to a crowdworker may be implicitly deciding to forego and relinquish the opportunity. Understanding how people navigate the tension between user autonomy and system distraction is valuable both within and beyond the scope of supporting work-related transitions.

6.3 Summary

In this chapter, we outlined the contributions of this thesis, and described several directions of future work following this dissertation research, including:

- Conducting observational studies to further understand work practice and work-related transitions in crowdwork with existing tools.
- Conducting formative studies to better understand pathways for designing systems that support transitions across tasks, devices, and environments at the micro level.
- Investigating the effect of systems for managing work-related transitions longitudinally with the goal of understanding how motivate behavior change.
- Complementing our proposed systems with modeling and sensing techniques from the rich space of context-aware systems to explore proactive system interactions.
- Applying lessons learned from our study of crowdworkers' work-related transitions to motivate new strategies for leveraging users' context in tooling.

In summary, the research presented in this dissertation serves as a foundation for future research aimed at designing, engineering, and understanding systems for managing work-related transitions across tasks, devices, and environments. We believe and hope that these highlighted directions will be useful for guiding future research in this space.

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APPENDICES

Appendix A

Mobile Work Practices in Programming Survey

This appendix includes the full survey that was used in Section 3.3. The survey included six unique sections:

1. Survey Criteria
2. Demographics
3. Understanding Interruptions and Resumption
4. Understanding Mobile Device Presence
5. Understanding Current Mobile Work Practices
6. Understanding Desired Mobile Work Practices

Answers were constrained to be one of the following, depending on the type of question:

- Open-ended questions: text field
- Choose from a list: radio buttons constrained to a single choice
- Choose multiples from a list: checkboxes that allow multiple choices
- 5-point Likert scale

A.1 Survey Criteria

1. Do you own and regularly use a mobile device, i.e. smartphone?
    - Yes
    - No

A.2 Demographics

1. What is your age in years?
    - 18-24
    - 25-34
    - 35-44
    - 45-54
    - 55-64
    - 65+
2. To which gender identity do you most identify?
    - Male
    - Female
    - Non-Binary
    - Other
3. What is the highest level of education you have completed, or the highest degree you have received?
    - Less than high school
    - High school degree or equivalent (e.g., GED)
    - Trade/Technical School
    - Some college, no degree
    - Associate degree
    - Bachelor's degree

- Advanced degree (Master's, Ph.D., M.D., etc.)
- Prefer not to answer
- (Other (please specify:)

4. Since graduating and/or entering the workforce, how many years of experience do you have as a software developer?
   - 0 Years (e.g., I am a student intern)
   - 1-2 Years
   - 3-5 Years
   - 5-10 Years
   - 10+ Years

5. Which of the following best describes your job role?
   - Intern (Product Group)
   - Intern (Research)
   - Software Developer (SDE)
   - Research Software Developer (RSDE)
   - Program Manager (PM)
   - Researcher
   - Data Scientist
   - Designer
   - Other: (Please specify)

6. What percentage of your workday is spent programming?
   - 0% – 20%
   - 20% – 40%
   - 40% – 60%
   - 60% – 80%
   - 80% – 100%

7. Please indicate the type of software development work that most closely aligns with what you currently do:

- ○ Back-end development
- ○ Full-stack development
- ○ Front-end development
- ○ Mobile development
- ○ Desktop or enterprise applications development
- ○ Embedded applications or devices development
- ○ Other: (Please specify)

8. Please indicate the primary development environment that you use in your work:
   - ○ Visual Studio
   - ○ Visual Studio Code
   - ○ Android Studio
   - ○ Apple XCode
   - ○ Vim / EMacs
   - ○ Netbeans
   - ○ Eclipse
   - ○ Komodo
   - ○ Jetbrains IntelliJ
   - ○ Sublime Text
   - ○ Other: (Please specify)

A.3 Understanding Interruptions and Resumption

In this section, we are interested in understanding the underlying challenges related to resuming a programming task.

1. Think of the last time you started working on a programming project that you hadn't worked on for more than a week.
   a. When was the last time you worked on the project?
      - ○ About a week ago

- About two weeks ago
- About three weeks ago
- About a month ago
- More than a month ago

b. What resources did you refer to while you were getting back up to speed or mentally preparing yourself to begin working on the project again?

- I reviewed personal notes that I took before I left
- I reviewed project resources, i.e., project planning documents
- I reviewed source control history, i.e. git commits
- Other: (Please specify)
  –OR–
- I didn't review anything when I was getting back up to speed.

c. To the best of your ability, indicate how long it took for you to feel prepared to start making progress on your project when picking it back up:

- 1 minute or less
- 1-5 minutes
- 5-10 minutes
- 10-20 minutes
- More than 20 minutes

d. Do you believe that software, applications, or tools can help decrease the time needed to feel prepared to start making progress on your work?

- Yes
- No

e. Do you believe that software, applications, or tools can help decrease the time needed to feel prepared to start making progress on your work?

- Yes
- No

f. On a scale from 1 to 5 where 1 is Strongly Disagree and 5 is Strongly Agree, state your agreement with the following statement:

"I believe I currently have access to the necessary software, applications, or tools to decrease the time needed to mentally prepare for my work."

- Strongly Disagree

- ○ Disagree
- ○ Neutral
- ○ Agree
- ○ Strongly Agree

g. Indicate the physical objects you currently use to help you manage your tasks:

- ○ A Notebook / Notepad
- ○ Post-It Notes
- ○ A physical paper calendar
- ○ A dedicated section on your whiteboard
- ○ Other: (Please specify)

h. Indicate the software you currently use to help you manage your tasks:

- ○ E-mail (i.e. Outlook, Gmail, etc.)
- ○ Task Management Tools (i.e. Wunderlist, Trello, etc.)
- ○ Source Control Tools (i.e. VSTS, GitHub, etc.)
- ○ Other: (Please specify)

i. Describe how these tools could be improved to help you feel better prepared to start making progress on your work after time away from the project:

____

A.4 Understanding Mobile Device Presence

In this section, we now ask you to reflect on when you choose to take your mobile device with you when leaving your primary work location.

1. When I know I'm leaving my office only for a few minutes, I ________ take my mobile device with me.

- ○ Never
- ○ Rarely
- ○ Sometimes
- ○ Often
- ○ Always

2. When I know I'm leaving my office for more than 15 minutes, I ________ take my mobile device with me.

    - ○ Never
    - ○ Rarely
    - ○ Sometimes
    - ○ Often
    - ○ Always

3. When I know I'm leaving my office for more than an hour, I ________ take my mobile device with me.

    - ○ Never
    - ○ Rarely
    - ○ Sometimes
    - ○ Often
    - ○ Always

A.5 Understanding Current Mobile Work Practices

In this section, we ask that you reflect on your current use of your mobile device throughout your workday.

1. Please indicate, if any, which of the following types of work you currently do on your mobile device while you're away from your office to make progress toward programming-related tasks.
   - **Capturing Thoughts and Ideas**: Write down or record (e.g., taking pictures of) general thoughts and ideas related to programming tasks.
   - **E-mail**: Reading, sending, and organizing e-mail for a programming-related task (including sending e-mail to yourself).
   - **Online Research**: Searching and browsing the Internet for information related to a programming-related task.
   - **Code Review**: Reviewing and commenting on my / others' code
   - **Bug Tracking and Triage**: Documenting and reporting on bugs.
   - **Debugging & Testing**: Fixing existing source code.
   - **Programming**: Creating and writing source code.
   - **Other**: (Please specify)

The following sections of the survey were given to participants based on their responses to the prior question.

A.5.1 Capturing Thoughts and Ideas

1. Think of the last time you documented or recorded thoughts or ideas for a programming-related task on your mobile device while you were away from your primary work location.
   a. What was the purpose of documenting or recording the information?
      - I didn't want to forget the information.
      - Other: (Please specify)

   b. How did you document or record the information?

- I wrote myself a note.
- I made an audio recording of myself.
- I took a photo.
- Other: (Please specify)

c. What did you do with the documented / recorded thoughts or ideas?

- I wrote myself a note.
- I made an audio recording of myself.
- I took a photo.
- Other: (Please specify)

d. To the best of your ability, indicate when this occurred:

- In the last 24 hours.
- In the past few days.
- In the last week.
- In the last month.
- Beyond the last month.

A.5.2 E-mail

1. How do you make progress on programming-related tasks when using your mobile device in the context of e-mail?

   - ☐ I read emails relevant to my task.
   - ☐ I send emails relevant to my task.
   - ☐ I organize e-mails relevant to my task.

The following subsections of the survey were given to participants based on their responses to the prior question.

Reading E-mail

1. Think of the last time you read e-mail on your mobile device to make progress toward a programming-related task while you were away from your primary work location.

   a. What was the purpose of the e-mail?

b. How did reading the e-mail help you make progress?

c. To the best of your ability, indicate when this occurred:
   - In the last 24 hours.
   - In the past few days.
   - In the last week.
   - In the last month.
   - Beyond the last month.

Sending E-mail

1. Think of the last time you sent e-mail on your mobile device to make progress toward a programming-related task while you were away from your primary work location.

   a. How did sending the e-mail help you make progress?

   b. To the best of your ability, indicate when this occurred:
      - In the last 24 hours.
      - In the past few days.
      - In the last week.
      - In the last month.
      - Beyond the last month.

Organizing E-mail

1. Think of the last time you organized e-mail on your mobile device to make progress toward a programming-related task while you were away from your primary work location.

   a. How did organizing the e-mail help you make progress?

b. To the best of your ability, indicate when this occurred:
   - ○ In the last 24 hours.
   - ○ In the past few days.
   - ○ In the last week.
   - ○ In the last month.
   - ○ Beyond the last month.

A.5.3 Online Research

1. Think of the last time you were searching or browsing the web to find programming-related information on your mobile device while you were away from your primary work location.

   a. What information were you trying to find?
      - ○ I was looking for ________________________.

        – OR –
      - ○ I wasn't searching for anything in particular.

   b. What did you do with the information (e.g., a URL) you found?
      - ○ I wrote it down on paper.
      - ○ I emailed the information to myself.
      - ○ I bookmarked it in my browser.
      - ○ I did nothing.
      - ○ Other: (Please specify)

   c. To the best of your ability, indicate when this occurred:
      - ○ In the last 24 hours.
      - ○ In the past few days.
      - ○ In the last week.
      - ○ In the last month.
      - ○ Beyond the last month.

   d. To the best of your ability, indicate how long it took you to find information relevant to your search:
      - ○ Less than a minute.
      - ○ Less than 5 minutes.

- Less than 10 minutes.
- Less than 30 minutes.
- More than 30 minutes.

A.5.4 Code Review

1. Think of the last time you performed a code review, in any capacity, on your mobile device while you were away from your primary work location.

   a. What tools / applications did you use to perform the code review?
      - I used ________________________________.

A.5.5 Bug Tracking and Triage

1. Think of the last time you tracked or reported on bug-related information from your mobile device while you were away from your primary work location.

   a. What tools / applications did you use to track or report on bug-related information?
      - I used ________________________________.

A.5.6 Debugging and Testing

1. Think of the last time you performed debugging or testing from your mobile device while you were away from your primary work location.

   a. What tools / applications did you use to debug and test source code?
      - I used ________________________________.

A.5.7 Programming

1. Think of the last time you wrote source code from your mobile device while you were away from your primary work location.

a. What tools / applications did you use to write your source code?
   ○ I used ________________________________.

A.6 Understanding Desired Mobile Work Practices

1. Please indicate, if any, which of the following types of work you want to be able to do on your mobile device while away from your office to make progress toward programming-related tasks.

   ☐ **Capturing Thoughts and Ideas**: Write down or record (e.g., taking pictures of) general thoughts and ideas related to programming tasks.

   ☐ **E-mail**: Reading, sending, and organizing e-mail for a programming-related task (including sending e-mail to yourself).

   ☐ **Online Research**: Searching and browsing the Internet for information related to a programming-related task.

   ☐ **Code Review**: Reviewing and commenting on my / others' code

   ☐ **Bug Tracking and Triage**: Documenting and reporting on bugs.

   ☐ **Debugging & Testing**: Fixing existing source code.

   ☐ **Programming**: Creating and writing source code.

   ☐ **Other**: (Please specify)
   – **OR** –

   ☐ **N/A**; I already do each of these on my mobile device.

2. Imagine that your mobile device is capable of helping you make meaningful progress on your work in such a way that complements your existing development practice (e.g. integrates with your IDE, etc.) and doesn't require to write code to make progress.
   On a scale from 1 to 5 where 1 is Strongly Disagree and 5 is Strongly Agree, state your agreement with the following statements:

   a. Using this functionality would enable me to accomplish tasks more quickly.
      ○ Strongly Disagree
      ○ Disagree

- Neutral
- Agree
- Strongly Agree

b. Using this functionality would improve my job performance.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

c. Using this functionality would increase my productivity.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

d. Using this functionality would enhance my effectiveness on the job.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

e. I would find this functionality useful in my job.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

3. Can you think of anything else you do on your mobile device in support of your work when you're away from your primary work location?

____

Appendix B

Mercury: User Study Materials

In this appendix, we describe three types of materials used in conducting our user study with Mercury:

1. Pre-Study Questionnaire
2. Participant Study Information
3. Post-Study Questionnaire

B.1 Pre-Study Questionnaire

This section includes the questionnaire given to participants before beginning Mercury's user study. Answers were constrained to be one of the following, depending on the type of question:

- Open-ended questions: text field
- Choose from a list: radio buttons constrained to a single choice
- Choose multiples from a list: checkboxes that allow multiple choices
- 5-point Likert scale

B.1.1 Demographics

1. What is your age in years?
   - ○ 18-24
   - ○ 25-34
   - ○ 35-44
   - ○ 45-54
   - ○ 55-64
   - ○ 65+
2. To which gender identity do you most identify?
   - ○ Male
   - ○ Female
   - ○ Non-Binary
   - ○ Other
3. What is the highest level of education you have completed, or the highest degree you have received?
   - ○ Less than high school
   - ○ High school degree or equivalent (e.g., GED)
   - ○ Trade/Technical School
   - ○ Some college, no degree
   - ○ Associate degree
   - ○ Bachelor's degree
   - ○ Advanced degree (Master's, Ph.D., M.D., etc.)
   - ○ Prefer not to answer
   - ○ (Other (please specify:)
4. Since graduating and/or entering the workforce, how many years of experience do you have as a software developer?
   - ○ 0 Years (e.g., I am a student intern)

- 1-2 Years
- 3-5 Years
- 5-10 Years
- 10+ Years

5. Which of the following best describes your job role?
   - Intern (Product Group)
   - Intern (Research)
   - Software Developer (SDE)
   - Research Software Developer (RSDE)
   - Program Manager (PM)
   - Researcher
   - Data Scientist
   - Designer
   - Other: (Please specify)
6. What percentage of your workday is spent programming?
   - 0% – 20%
   - 20% – 40%
   - 40% – 60%
   - 60% – 80%
   - 80% – 100%
7. Please indicate the type of software development work that most closely aligns with what you currently do:
   - Back-end development
   - Full-stack development
   - Front-end development
   - Mobile development
   - Desktop or enterprise applications development
   - Embedded applications or devices development
   - Other: (Please specify)

B.1.2 Understanding Current and Desired Mobile Work Practices

1. Please indicate, if any, which of the following types of work you **currently do** on your mobile device while away from your office to make progress toward programming-related tasks.

   - ☐ **Capturing Thoughts and Ideas**: Write down or record (e.g., taking pictures of) general thoughts and ideas related to programming tasks.
   - ☐ **E-mail**: Reading, sending, and organizing e-mail for a programming-related task (including sending e-mail to yourself).
   - ☐ **Online Research**: Searching and browsing the Internet for information related to a programming-related task.
   - ☐ **Code Review**: Reviewing and commenting on my / others' code
   - ☐ **Bug Tracking and Triage**: Documenting and reporting on bugs.
   - ☐ **Debugging & Testing**: Fixing existing source code.
   - ☐ **Programming**: Creating and writing source code.
   - ☐ **Other**: (Please specify)

2. Please indicate, if any, which of the following types of work you **want to be able to do more effectively** on your mobile device while away from your office to make progress toward programming-related tasks.

   - ☐ **Capturing Thoughts and Ideas**: Write down or record (e.g., taking pictures of) general thoughts and ideas related to programming tasks.
   - ☐ **E-mail**: Reading, sending, and organizing e-mail for a programming-related task (including sending e-mail to yourself).
   - ☐ **Online Research**: Searching and browsing the Internet for information related to a programming-related task.
   - ☐ **Code Review**: Reviewing and commenting on my / others' code
   - ☐ **Bug Tracking and Triage**: Documenting and reporting on bugs.
   - ☐ **Debugging & Testing**: Fixing existing source code.
   - ☐ **Programming**: Creating and writing source code.
   - ☐ **Other**: (Please specify)

B.2 Participant Study Information

In this section, we describe the printed document that participants were given after completing the pre-study questionnaire. The document was organized as follows:

B.2.1 Study Overview

In this study, you will be asked to complete the HTML5 / JavaScript / CSS implementation of an enhanced version of Tetris. The study is split into 3 phases and will last a total of 1 hour and 30 minutes. During the first phase of the study, you will be asked to work toward your implementation. During the second phase of the study, you will be given a mobile phone and asked to leave the study's computer workspace for 30 minutes. You will be asked to use a web application on your mobile device while you are away from the study's computer workstation. During the third phase, you will return to your computer workstation and continue your implementation. You will be given post-questionnaires before the first phase and after the third phase.

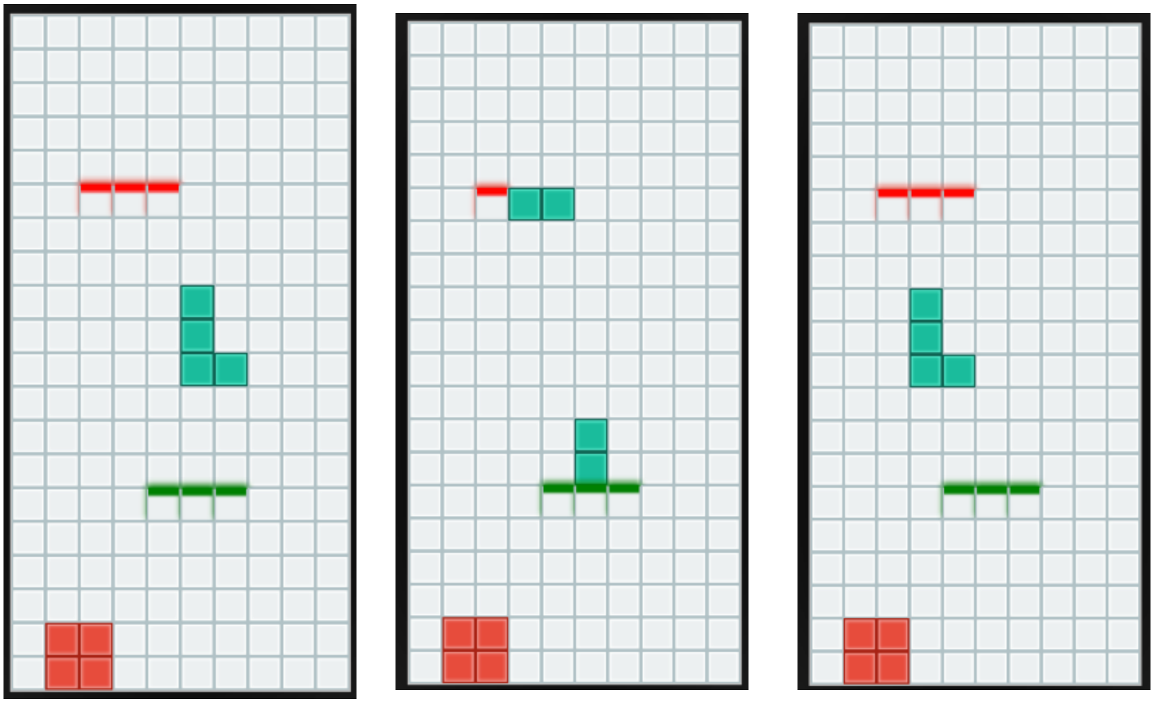
B.2.2 Tetris: Enhanced

Your task is to complete the implementation of an enhanced version of the classic arcade game Tetris. In this implementation, the Tetris game grid has been extended with Portals. Before Tetris begins, the game implementation will automatically generate (1) an entry portal and (2) an exit portal on the game grid. Tetris pieces can move through the entry portal to progress through the exit portal. The implementation is written in HTML5, CSS, and JavaScript

B.2.3 Task Instructions

Missing Functionality: Portals are not functional in the current implementation. However, there are a few problems. (We recommend opening index.html and seeing for yourself.)

1. **Problem #1**: *Portal locations are static when they should be dynamic.*
   When a game starts, portals are always placed in the same place on the Tetris game grid. However, the desired experience of Tetris we seek to build is one of surprise and engagement. Portal locations should be dynamically chosen when a new game begins.



(a) Approaching entry portal. (b) Passing through. (c) Leaving the exit portal.

Figure B.1: Tetris: Enhanced with functional behavior.

2. **Problem #2**: *Tetris game pieces are not validated before moving into a portal.*
   In order for a Tetris game piece to be able to move through the entry portal, the Tetris piece must meet the following criteria:

   - **Entry Fit**: In the piece's current orientation, the Tetris piece's width cannot be greater than the width of the entry portal.
   - **Entry Alignment**: In the piece's current orientation, the Tetris piece must not overlap with an edge of the entry portal.
   - **Exit Collision**: In the piece's current orientation, the Tetris piece must be capable of leaving the exit portal without colliding with another existing piece.

   What happens if the Tetris piece fails to meet this criteria?
   If a Tetris game piece fails to meet any of these criteria, the piece's next move on the grid should progress as if the portal is not there at all.

Completing Function Implementations: Your goal is to complete the implementation of 4 specific functions that exist in the current implementation's source code, but

	Function Name	**Description**	**Location**
1	*findPortalLocation*	Gives a Portal instance a random location on the Tetris game grid. The location must be between rows 5 and 15 of the game grid.	js/piece.js
2	*isAlignedWithEntryPortal*	Returns true if a piece's cells share alignment with the portal's cells.	js/piece.js
3	*canFitThroughEntryPortal*	Returns true if the width of a piece's cells exceed the portal's width.	js/piece.js
4	*canAvoidCollisionThroughExitPortal*	,Returns true if a piece's cells will overlap with existing pieces if the piece moves through the exit portal.	js/piece.js

Table B.1: Functions that require implementation in Mercury's user study.

have yet to be implemented. (They are missing function bodies.) The functions, their description, and their location are shown in Table B.1:

Understanding Functional Portals in Tetris: Enhanced

If you'd like to see what a functional portal looks like, you can forcefully set the body of each portal validation function (i.e., isAlignedWithEntryPortal, canFitThroughEntryPortal, and canAvoidCollisionThroughExitPortal) to true. Exact details of how to accomplish this are shown in Figure B.2.

Study Requirements

There are several requirements for completing the task in our study:

1. You cannot use 3rd party libraries (e.g. jQuery) in your implementation.
    - This means that you must write your code in "raw" JavaScript.
2. You must complete all of your work in Visual Studio Code.

```
    /**
     * isAlignedWithEntryPortal - check if the piece's cells are aligned with same
grid cell columns as the portal
     * @param piecePositions - an array of the Piece instance's coordinates'
     * @param exitPortalPositions - an array of JavaScript Objects that have the
coordinates of the portal location, e.g. [{x: 1, y: 2}, {x: 2, y: 2}, {x: 3, y: 2}]
     */
    isAlignedWithEntryPortal: function(piecePositions, entryPortalPositions){
       return true;
    },

    /**
     * canFitThroughEntryPortal - check if width of the piece's neighbouring cells
exceed the portal's width
     * @param piecePositions - an array of the Piece instance's coordinates'
     * @param entryPortalPositions - an array of JavaScript Objects that have the
coordinates of the portal location, e.g. [{x: 1, y: 2}, {x: 2, y: 2}, {x: 3, y: 2}]
     */
    canFitThroughEntryPortal: function(piecePositions, entryPortalPositions){
        return true;
    },

    /**
     * canAvoidCollisionThroughExitPortal - check if the piece's cells will overlap
with existing pieces in the grid array if it moves through the portal
     * @param piecePositions - an array of the Piece instance's coordinates'
     * @param exitPortalPositions - an array of JavaScript Objects that have the
coordinates of the portal location, e.g. [{x: 1, y: 2}, {x: 2, y: 2}, {x: 3, y: 2}]
     */
    canAvoidCollisionThroughExitPortal: function(piecePositions, exitPortalPositions){
        return true;
    },
```

Figure B.2: Source changes for demonstrating functional behavior in Tetris: Enhanced.

- You must not close the Visual Studio Code window.

3. You must use the Google Chrome browser.
   - You must not close the Chrome window.

Tetris: Enhanced - Game Controls

There are four usable buttons in the game:

- **Left Arrow Key**: Move Piece Left
- **Right Arrow Key**: Move Piece Right
- **Down Arrow Key**: Move Piece Down
- **Space Bar**: Rotate current piece

B.3 Post-Study Questionnaire

This section includes the questionnaire administered after Mercury's user study had concluded. Answers were constrained to be one of the following, depending on the type of question:

- Open-ended questions: text field
- 5-point Likert scale

B.3.1 System Usability Scale

1. On a scale from 1 to 5 where 1 is Strongly Disagree and 5 is Strongly Agree, state your agreement with the following statement:

    a. I think that I would like to use this system frequently.

    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree

    b. I found the system unnecessarily complex.

    - Strongly Disagree
    - Disagree
    - Neutral
    - Agree
    - Strongly Agree

c. I thought the system was easy to use.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree
d. I think that I would need the support of a technical person to be able to use this system.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree
e. I found the variation functions in this system were well-integrated.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree
f. I thought there was too much inconsistency in the system.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree
g. I would imagine that most people would learn to use this system very quickly.
   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree
h. I found the system very cumbersome to use.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

i. I felt very confident using the system.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

j. I needed to learn a lot of things before I could get going with this system.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

B.3.2 Reattachment Scale

1. On a scale from 1 to 5 where 1 is Strongly Disagree and 5 is Strongly Agree, state your agreement with the following statement:

   a. Before returning to the computer, I reflected about the Tetris task.

   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

   b. Before returning to the computer, I prepared mentally for the Tetris task.

   - Strongly Disagree
   - Disagree
   - Neutral

- Agree
- Strongly Agree

c. Before returning to the computer, I thought about what I would encounter in the Tetris task.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

d. Before returning to the computer, I thought about what I wanted to achieve next in the Tetris task.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

B.3.3 4-Item Productivity Scale

1. On a scale from 1 to 5 where 1 is Strongly Disagree and 5 is Strongly Agree, state your agreement with the following statement:

   a. While I was away from the computer, I felt productive.

   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree
   - Strongly Agree

   b. While I was away from the computer, I felt engaged.

   - Strongly Disagree
   - Disagree
   - Neutral
   - Agree

- ○ Strongly Agree

c. While I was away from the computer, I felt relaxed.
   - ○ Strongly Disagree
   - ○ Disagree
   - ○ Neutral
   - ○ Agree
   - ○ Strongly Agree

d. While I was away from the computer, I did exactly what I wanted to do.
   - ○ Strongly Disagree
   - ○ Disagree
   - ○ Neutral
   - ○ Agree
   - ○ Strongly Agree

B.3.4 Mobile Experience Perceptions

1. What are your overall impressions of Mercury as a tool for supporting your work on-the-go?

   ____

2. In what ways do you believe that Mercury's mobile experience could be improved?

   ____

Appendix C

SwitchBot: Post-Study Survey

In this appendix, we describe the post-study survey described in Section 4. The survey included four sections:

1. Assessing Psychological Disengagement from Work
2. Assessing Psychological Re-engagement with Work
3. Understanding Perceptions of SwitchBot
4. Reporting E-mail Usage

Answers were constrained to be one of the following, depending on the type of question:

- Open-ended questions: text field
- 5-point Likert scale

C.1 Assessing Psychological Disengagement from Work

1. On a scale from 1 to 5 where 1 is Strongly Disagree and 5 is Strongly Agree, state your agreement with the following statement:
    a. After interacting with the bot at the end of my day, I forgot about work.
        - Strongly Disagree

- Disagree
- Neutral
- Agree
- Strongly Agree

b. After interacting with the bot at the end of my day, I didn't think about work at all.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

c. After interacting with the bot at the end of my day, I distanced myself from work.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

d. After interacting with the bot at the end of my day, I got a break from the demands of work.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

C.2 Assessing Psychological Reattachment with Work

1. On a scale from 1 to 5 where 1 is Strongly Disagree and 5 is Strongly Agree, state your agreement with the following statement:

   a. After interacting with the bot at the start of my day, I mentally tuned into my work.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

b. After interacting with the bot at the start of my day, I prepared mentally for my work.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

c. After interacting with the bot at the start of my day, I reflected about/considered my upcoming workday.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

d. After interacting with the bot at the start of my day, I thought about what I wanted to achieve at work.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

e. After interacting with the bot at the start of my day, I thought about what I will encounter at work.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

C.3 Understanding Perceptions of SwitchBot

1. Would you continue using the bot if it was openly available? Why or why not?

   ___

2. What did you like about the bot?

   ___

3. What did you not like about the bot?

   ___

4. If you have anything else that you'd like to tell us about the bot, please mention it here. Otherwise, leave this response empty.

   ___

C.4 Reporting E-mail Usage

Please login to Delve Analytics and address the following questions:

1. Please calculate and report the number of "After hours" emails sent from 8/8/2017 - 8/14/2017:

   ___

2. Please report the number of "After hours" emails sent from 8/15/2017 - 8/21/2017:

   ___