MENTAL CONTEXT REINSTATEMENT IN DIGITALLY REPRESENTED WORK

THROUGH COMPUTATIONALLY AUGMENTED PHYSICAL ARTIFACTS

A Dissertation

by

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Submitted to the Graduate and Professional School of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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December 2024

Major Subject: Architecture

ABSTRACT

Knowledge workers (KWs) are individuals whose work primarily revolves around the consumption and production of project-centric information. A common trait among KWs is their ability to understand their information resources within a conceptual framework that integrates goals, tools, deadlines, constraints, and collaborators. Another shared characteristic is the management of multiple projects simultaneously. Each project is distinguished by how it is understood and acted upon within a specific situational or working context. To manage these working contexts, KWs must be able to pause progress on one project to focus on another, preventing any single project from being completed at the expense of others. KWs switch between different working contexts either by personal choice or in response to external demands.

Critical to the progress of knowledge workers (KWs) are the tools that remind them of their goals, progress, and future actions within their working contexts. KWs strategically use artifacts associated with these contexts, spanning both physical and digital media, to help prioritize tasks and maintain focus when resuming work. In managing digital information, the desktop metaphor has long been employed in personal computing to represent digital information relationships through organizational and representational schemes. While this metaphor has supported KWs' practices across various industries and roles, its current design presents challenges to those same practices. Considering how knowledge workers (KWs) use physical artifacts to support switching between working contexts, this dissertation aims to explore how re-representing digital working context information through physical proxies can better support KWs' digital context-switching strategies. To study both digital and tangible work context management, this research employs a

mix of iterative design, prototyping, and deployment phases, conducted in both experimental and in-the-wild settings.

DEDICATION

I dedicate this work to two key individuals in my life. First, I'd like to thank God for bringing me to this moment, getting me through the hurdles I've experienced, building me up to be more than what I had thought possible. I would not be able to do this if not for HIM. Second, I'd like to dedicate this to my mom. She has been a constant source of support in my life and had always believed in me, even when I didn't believe myself. She was always there for me for encouragement, and was always my biggest supporter in this long journey that was graduate school. Third I'd like to dedicate this work to my chair, Dr.Stephen Caffey. He was also another source of support and always had my best interest in mind, always looking for opportunities to build me up. Stephen pulled me out of a difficult situation during my PhD and I will always be grateful for what he did and the opportunities that arose from it. Finally, I'd like to dedicate this to work to my life coach Jamie Manning, who was responsible for helping to overcome my own insecurities and to understand my self-more.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr.Caffey, and my committee members, Dr.Ferris, Dr.Seo, and Dr.Liew for their guidance and support in this work. Thanks also goes to my friends and colleagues within the TEILab, HCIED lab, and Department of Architecture. Finally, I want to thank my mother, father, sister, and brother for their patience and encouragement.

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supervised by a thesis (or) dissertation committee consisting of Professor Stephen Caffey of the Department of Architecture and Professor Thomas Ferris of the Department of Industrial and Systems Engineering, Professor Jinsil Hwaryoung Seo of the Department of Visualization, and Professor Jeff Lieu of the Department of Educational Psychology.

All work conducted for the dissertation was completed by the student independently.

Funding Sources

Graduate study was supported by a research assistantship from Texas A&M University under the TEILab's awarded National Science Foundation grants:

- *"Broadening Participation for Remote Communities: Situated Distance Telepresence Mentoring through Embodied Communications"*,National Science Foundation, Cyberlearning-1917950, August 1, 2019 – July 31, 2022, $750,000.
- *"Making to Micro-Manufacture: Re-imagining Work Beyond Mass Production",* National Science Foundation, September 1, 2017 – August 31, 2019
- *"EAGER: Making in The Colonias: Motivating STEM Participation through a Making as Micro-Manufacturing Model",* National Science Foundation, in response to Dear Colleague Letter on Making in Education (DCL-Making). DRL- 1623543, $285,000.
- *"II-EN: Device and Display Ecologies",* National Science Foundation, August 1, 2010 – July 31, 2017, CNS-1059398/ CNS-1439614, $600,000.

This work in this dissertation was also supported via the TEXAS A&M INSTITUTE OF TECHNOLOGY-INFUSED LEARNING**.**

NOMENCLATURE

HCI	Human Computer Interaction
WCM	Work Context Management
EPM	Episodic Memory
DCog	Distributed Cognition

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CHAPTER I INTRODUCTION

I.1. Research Situation in Time and Space

Knowledge workers (KWs) are individuals whose work primarily revolves around project-centric information consumption and production activities (Drucker, 1974; Kidd, 1994). With the advent of personal computing in day-to-day life, knowledge work has become common across industries and roles *(e.g., clerical workers, designers, engineers, scientists, and executives)* (González & Mark, 2004). Common to most KWs, their information resources are understood within a conceptual framework that connects goals, tools, deadlines, constraints, and collaborators involved (Czerwinski & Horvitz, 2002; González & Mark, 2004, 2005; Okundaye, Quek, Sargunam, Suhail, & Das, 2017). Through this conceptual framework, KWs often describe their activities with a high-level descriptive label *(e.g., a graduate student talks about his activities as the "CSCE-629" projects)* (Czerwinski & Horvitz, 2002; Czerwinski, Horvitz, & Wilhite, 2004).

Another commonality among KWs is their management of multiple projects in tandem (Bannon, Cypher, Greenspan, & Monty, 1983; Czerwinski & Horvitz, 2002; Czerwinski et al., 2004). Each of these projects can be distinguished from one another by how they are understood and acted upon situationally, or within a given *"working context"*. In managing these working contexts, by necessity, KWs must be able to stop progress within a given project to attend to other, out-of-focus working contexts (Czerwinski & Horvitz, 2002; Czerwinski et al., 2004), lest one be completed at the expense of others. KWs switch across their different working contexts either by choice (e.g., adhering to a schedule) or by demand from the environment *(e.g., an officemate asks for information pertaining to a work context out of current focus)* (Adamczyk & Bailey, 2004; Czerwinski & Horvitz, 2002; Czerwinski et al., 2004; González & Mark, 2004, 2005).

Critical to KWs' progress are the means to be reminded of their goals, progress, and future actions in their working contexts (Bergman, Beyth-Marom, & Nachmias, 2006; Monsell, 2003; Sellen et al., 2007; Sellen & Harper, 2003). KWs strategically use working-context associated artifacts across physical *(e.g., notepads, sticky notes, calendars, agendas)* and digital *(e.g., windows, desktop directory, email)* media to aid in the prioritization and maintenance of attention when resuming working contexts (González & Mark, 2004, 2005; Rule, 2015; Rule & Hollan, 2016; Rule, Tabard, & Hollan, 2017). Generally, these practices work by overcoming working memory overheads by offloading references to working contexts into the environment (Kirsh, 2013; Starcic, Cotic, & Zajc, 2013). By offloading references to the environment, KWs gain support for the re-finding of information sources for a given working context, as well as reminding themselves to return focus to a previously out-of-focus working context (Kidd, 1994; Malone, 1983).

Critical to KWs' capability to offload to digital information, the desktop metaphor has been used in personal computing to represent digital information relationships through representational (*e.g., word document and word processing application*) (Rule, 2015; Rule & Hollan, 2016; Rule et al., 2017) and organizational schemes (*e.g., hierarchies of file directories and associated folders and documents*) (Malone, 1983). While the desktop metaphor has been conducive to KWs' practices across industries and roles, there are issues in its current design that challenge these same practices. First, personal computing systems assume a data model that supports individual tasks like word processing but not the integration across tasks for a given work context (Mark, Gonzalez, & Harris, 2005; Mark, Gudith, & Klocke, 2008). Second, documents related to a working context are often distributed across physical *(e.g., a notecard)* and digital media *(e.g., a spreadsheet),* making it challenging to keep them together without converting them into another medium (Bondarenko & Janssen, 2005). Together, these issues make it difficult for KWs to maintain the cohesion of their working context-associated information collections. The consequence of KWs' work practice is additional effort to locate relevant resources for a working context, contributing to an overall sense of information overload evidenced by *"a higher workload, more stress, higher frustration, more time pressure, and effort"* (Cowan, 2010; Malone, 1983).

In the space of Human-Computer Interaction (HCI), there have been a multitude of approaches that have sought to alleviate the representation and organizational issues that come with digital work context management. Such solutions can be characterized as either '*window*' (e.g., *"Task Gallery"* (Robertson et al., 2000), *"Rooms"* (Henderson Jr & Card, 1986) , and *"Scalable Fabric"* (Robertson et al., 2004)) or '*model*' centric approaches (e.g., *"Desktop History Tool"* [6] or *"Task Tracer"* (Dragunov et al., 2005)). However, there is a complication in contemporary computing that challenges the efficacy of these approaches. With the advent of cloud computing and increased storage capability, we are able to maintain larger and larger collections of digital information (Farrell, Buchmann, Campbell, & Maglio, 2002). To complicate things further, we are also able to interact with this data on a variety of different devices and locations. At present, KWs use emergent ad-hoc strategies that are glued together by our cognition (memory) to manage their digital working contexts, potentially overtaxing our embodied capabilities.

In the face of these present issues in digital work context management, there have been different tracks of research that emphasize how to design systems to support human cognitive mechanisms towards work context management. One track of research considers the use of visual histories—the display of captured images, video, and audio of prior activity—as a means of work context resumption, acting as a cue for autobiographical memory for work context resumption

(Czerwinski & Horvitz, 2002; Ishii & Ullmer, 1997; M. G. Lamming & Newman, 1992; Parnin & DeLine, 2010; Rule et al., 2017; Safer & Murphy, 2007; Sellen et al., 2007). A second track, *Tangible User Interfaces (TUIs)*, considers interaction beyond graphical user interfaces (*GUIs*) (Ishii & Ullmer, 1997) by coupling digital information with physical structures or perceptible phenomena to support activities such as representing work state (Ahmed, Chambers, Frontz, & Voida, 2014; Yuzawa & Mark, 2010) or guiding attention across different activities (Mugellini, Rubegni, Gerardi, & Khaled, 2007; Zuckerman, Gal-Oz, Tamir, & Kopelman-Rubin, 2015).

Taking into consideration how KWs use physical artifacts to support switching across working contexts, this dissertation seeks to understand how the re-representation of digital working context information through physical proxies can better support the digital work context switching strategies of KWs. The mechanisms for supporting work context management *(information aggregation, access, traversal, and resumption)* rely upon our embodied capabilities of offloading cognition to the environment and using the environment in turn to guide attenuation across working contexts. In the interest of studying digital and tangible working context management, it is necessary for the study to make use of a mix of iterative design, prototyping, and deployment phases in both experimental and in-the-wild settings. Below are the set of research questions (Table 1) that will be posed for the dissertation based on the theoretical frameworks described in Section III.1, "*Theoretical Foundations*".

I.2. Framing in Disciplinary Contexts

The dissertation is situated across the disciplines of HCI, psychology, and architecture. Primarily, the research is based in HCI, concerned with how digital information is represented in personal computing devices and how it can be interacted with and understood. Concerning psychology, the dissertation seeks to understand the ways in which digital information representation and recognition support the reduction of memory overheads in work context management. Finally, concerning architecture, work context management is an emergent phenomenon across physical and digital media, requiring an understanding of how space and place in the built environment can support digital work context management.

Table 1 Set of research questions (RQ) for proposal on Work Context Management.

Sign Mediation Theory and Material Carrier (SMT-MC)-1: How are conceptions of working contexts represented via physical and digital media?
Episodic memory (EPM)-1: What features of digital and physical media aid in cuing episodic memory of digital working contexts?
Distributed Cognition (DCog)-1: How is traversal of working contexts distributed across media?

I.3. Dissertation Formatting Approach

The dissertation used a three-article formatting option, conducting a series of experimental studies of how KWs engage in digital work context management and how a research-through-design intervention can support day-to-day digital work context management practices. The articles were either published or submitted to major HCI conference venues (e.g., Association of Computer Machinery (ACM) Computer Human Interaction (CHI), Tangible Embedded/Embodied Interaction (TEI), and Computer Supported Collaborative Work (CSCW)) and journals (e.g., ACM Transactions on Computer Human Interaction (TOCHI) and ACM Computing Surveys (CSUR)).

CHAPTER II RELEVANT BACKGROUND

The following section will provide an overview of the relevant literature that informs the areas of relevant work that supports the dissertation document. Each sub-section describes the space of the identified literature and how it is relevant to the aim of the dissertation.

II.1. Working Context Overview

Knowledge workers (KWs) are a kind of office worker whose activities revolve around information consumption and production activities (Drucker, 1974; Kidd, 1994). KWs' activities are open-ended in their structure, necessitating self-generated solutions as their own understanding of the problem changes. KWs perceive their work problems as a kind of mental workspace, organizing associated goals, resources, and individuals within it (Czerwinski & Horvitz, 2002; Czerwinski et al., 2004; González & Mark, 2004, 2005; Mark et al., 2005; Mark et al., 2008; Okundaye et al., 2017). This mental workspace acts as a unifying cognitive construct to support efficiency in mental workload when resuming a specific work problem. KWs can give a high-level label to their workspaces, acting as a pre-linguistic structure to support metacognition (i.e., creation, exploration, and modification of activities) (Kidd, 1994).

Building on the idea of mental workspaces, the working *context* refers to the unique constellation of tools and data that are required by an individual to function within a given mental workspace. Working contexts emphasize the way in which a KW maintains a vector of cognitive engagement in a specific domain of work (e.g., a specific project for a class).

II.2. Maintaining and Resuming Attention Across Working Contexts

KWs are exposed to a steady information stream across physical and digital information spaces, which may be variably related to a KW's present working context (González & Mark, 2004, 2005). At times, this information stream can demand a response from the KW, which the

KW could address the interruption, defer and set aside for a later time, or even ignore. While KWs prefer to maintain continuous attention to their present working contexts, they will need to use an interleaving workflow, suspending a given working context to address a different one. Because of KWs' interleaving, progress in working contexts can be characterized as segmented, sequential episodes instead of a continuous stretch.

Interruptions are managed by directing attention to different activities (i.e., working contexts). How exactly attention is allocated to said activities is guided by how they are dynamically prioritized and situated with one another (Woods, 1995). Sarter (N. Sarter, 2013) describes interruption management as serving three purposes: 1) Timely detection of interrupting activities; 2) Providing knowledge workers the ability to properly assess the nature of an interrupting activity (i.e., Does the activity warrant a response or can it be deferred?); 3) If the activity is to be addressed, how might it be integrated into the knowledge workers' ongoing activity? Wickens and McCarley describe interruption management in the form of a multi-step, contingent process. In summary, the model describes how an individual can engage in interruption management and different potential actions to address it (C Wickens & McCarley, 2008). First, Wickens and McCarley point out how the individual could miss the interruption's signal (e.g., *an individual receives a text notification on their phone but they don't acknowledge it because the phone was set face down on their desk and was on silent mode*). Next, should the individual be aware of the signal, they could either choose to acknowledge it or ignore it. If the individual chooses to acknowledge, they could do one of the following: 1) The individual could decide to attenuate to the interruption and eventually return to their ongoing task (e.g., *stopping progress on editing an article when a lab mate asks an urgent question by text*); 2) The individual might address the interruption by working on it in parallel with their ongoing task (e.g., *answering a phone call* *while highlighting a paper*); 3) The individual defers the interrupting task to a point after they complete their ongoing tasks (e.g., *after completing the edits for a section of a paper, an individual responds to a text they received during the task*).

Interruptions in a working context are not inherently detrimental to KWs, as interruptions can support the prospective memory of remembering what one needs to do, which is necessary for managing multiple working contexts. However, interruptions do incur a cost to the KW in the form of cognitive effort in coordinating the re-access of relevant thought and information structures, either physical or digital, associated with a given interrupting working context (Mark et al., 2008). If interruptions arrive at an inopportune time for the KW, the KW could experience increased stress, frustration, workload, effort, and pressure, ultimately affecting productivity and the potential for distraction (Adamczyk & Bailey, 2004; Czerwinski & Horvitz, 2002; Czerwinski et al., 2004; Dabbish, Mark, & González, 2011; González & Mark, 2004; Iqbal & Horvitz, 2007; Mark et al., 2008; Rule, 2015; Rule & Hollan, 2016; Rule et al., 2017).

The deleterious effects of an interruption can be variable depending on the individual and environmental factors of the KW. Individually, a KW's perception of disruptiveness can be influenced if enough time is given to the KW to find a stopping point and create a means to return to their working context *(e.g., leaving a note)* (Monsell, 2003) , personality traits of the extent the KW is open to experiences (Mark et al., 2008), KWs' perception of the interruption's respect for their main working context (Adamczyk & Bailey, 2004), or how the interruption may or be interrelated to their present working context (Czerwinski et al., 2004; González & Mark, 2004, 2005; Mark et al., 2005; Monsell, 2003; Rule et al., 2017). The environment of the KW can influence how interruptions can arise or be handled; the office layout, office culture for information seeking, or expectation of interruption from the environment could also influence how KWs can tolerate or anticipate interruptions (Mark et al., 2005; Mark et al., 2008).

II.3. Personal Information Management (PIM) and Working Contexts

KWs' working contexts are based on information resolution and creation activities (Rule, 2015; Rule & Hollan, 2016; Rule et al., 2017) and PIM can support these activities by considering the role of how information resources such as paper and digital documents, alongside their associated supportive structures like desktops and filing cabinets, can support their work contexts *(Bergman et al., 2006; Bergman, Boardman, Gwizdka, & Jones, 2004; W. P. Jones & Teevan, 2007; Teevan, Jones, & Bederson, 2006)*. PIM points to how paper affords markability, which supports annotation for various activities in knowledge work (Kidd, 1994; Sellen & Harper, 2003). Paper, by way of its physicality, supports social mechanisms in office work by supporting discussion through concurrent viewing and can have added meaning through tangibility.

PIM identifies the role that desktops play in KW's information-retrieval and reminder needs through the way the desktop acts as a spatial holding pattern for inputs and ideas. In this role, the desktop supports two kinds of organizational schemes for information relationships. (Czerwinski et al., 2004; González & Mark, 2004, 2005; Kidd, 1994; Malone, 1983; Miah & Alty, 2000). First, files represent a major organizational element, where they are explicitly titled and arranged in accordance with a systematic order (alphabetical or chronological). Second, piles refers to how individual elements are not expectedly titled and are often not arranged in any particular order. Piles arise from the dynamics of haphazard, inverse chronological order due to either systematic or intentional arrangement.

II.4. PIM and Electronic Resources

PIM supports KWs access to digital working contexts by representing information in a fast and complete fashion across devices, applications, and operating system interfaces (González & Mark, 2004, 2005; Teevan et al., 2006). PIM supports interleaving practices through the two related approaches. First, hierarchical classifications work by using a piece of digital information's own metadata, whether it be its name, date of access, date of retrieval, or data type (Rule, 2015). Second, visual metaphors extend hierarchies by representing digital information in terms of windows, files, desktops, directories, and applications as a means of describing units and collections of information (Malone, 1983).

KWs have information sets situated in parallel to one another, a result of having larger connections of variably connected information (Iqbal & Horvitz, 2007). At a given time, only a subset of information may require users' attention at a time. Owing to the ways that digital information is represented and organized, there is added effort in their collective organization, with multiple consequences. First is KWs' added effort in managing different information hierarchies in parallel or in tandem with one another (Bergman et al., 2006). Second, KWs need to create bridging strategies to interconnect multiple applications for joint use; this is attributed to inconsistent user interaction and data models (Boardman, Spence, & Sasse, 2003; W. Jones, Munat, Bruce, & Foxley, 2005). Third, KWs need to actively store and retrieve information items across information hierarchy locations and lack a structural connection between them (Bergman, Beyth-Marom, & Nachmias, 2003; Boardman et al., 2003; W. Jones, Phuwanartnurak, Gill, & Bruce, 2005).

Work context resumption is guided by motivations, justifications, and strategies to guide KWs in continuing previous or new activities to situate them towards short- and long-term goals

(Rule, 2015; Rule & Hollan, 2016; Rule et al., 2017). Two different types of cues to aid in their resumption of computer-based activities. Explicit cues refer to notes that users would leave for themselves to remember where they were doing their task. Implicit cues are cues that arise as a byproduct of the activities themselves.

II.5. Supporting PIM Practices in Personal Computing

Restoration of digital working contexts works by supporting the re-finding of previously accessed information and the recreation of digital desktops. Window-based approaches support work context management by preserving the relative window location of information as a means of work context organization (Card & Henderson Jr, 1986; Miah & Alty, 2000; Robertson et al., 2004; Robertson et al., 2000; Tashman, 2006). Model-based approaches support work context management by modeling linkages between users' information to represent specific working contexts for resumption. Visual histories are an approach that emphasizes mental context restoration for digital work context management (Dragunov et al., 2005; Kelly & Davis, 2003; Kersten & Murphy, 2015). Visual histories work by displaying captured images, video, and audio of prior activity to cue autobiographical memory of the to-be-resumed working context (Czerwinski & Horvitz, 2002; M. Lamming & Flynn, 1994; M. G. Lamming & Newman, 1992; Safer & Murphy, 2007).

Multimodal interfaces are another perspective that can support effective interruption management, specifically on how information associated between ongoing tasks (i.e., present working context) and interrupting tasks (i.e., out-of-focus interrupting working context) can be distributed across the vision, audition, and touch sensory channels (Oviatt, 2003; N. B. Sarter, 2002). Through multi-sensory channels, multimodal interfaces support users by shifting the primary burden of attentional awareness away from the visual channel. In using other sensory channels, multi modal interfaces enable individuals to attenuate between ongoing work and incoming interruptions in parallel by presenting interruptions in different sensory modalities. In addition, multi modal interfaces use the unique properties of each sensory channel to maximize its signal salience for different interruption contingencies.

Based on Wickens and McCarley's model, Sarter points to how human machine interfaces can be designed to exploit multimodal sensory capabilities of individuals to support interruption management.

II.5.1. Noticing an Interruption Signal

First, Sarter points to how the modality of an interruption can influence how the knowledge worker engages both their ongoing and interrupting tasks (S. Lu et al., 2012; S. A. Lu, Wickens, Sarter, & Sebok, 2011; Christopher Wickens, Prinet, Hutchins, Sarter, & Sebok, 2011). Generally, representing an interruption by combining visual and auditory information has demonstrated more accurate performance of the interrupting task over unimodal approaches while also achieving a comparable response time to unimodal approaches as well. However, it was also reported that performance was lower when multimodal approaches were used when returning to the original ongoing task. Based on this reported performance, Sarter suggests that for multimodal design, using auditory and visual information in a redundant fashion in cases where: 1) The knowledge worker's communication tasks are under high workload; 2) When the need for alerting and tracking tasks are in low workload; 3) In cases where the knowledge workers' immediate visual angle is small, limiting the available field of vision for attenuation.

II.5.2. Judging the Importance and Feasibility of Handling an Interruption

Sarter points to two multimodal approaches from Grandhi and Jones' (Grandhi & Jones, 2010) work on how to support knowledge workers' initial assessment of an interruption and immediate action. First *concerns notification modification*. This refers to how the interrupting signal can be modified regarding its level of disruptiveness and salience. Through notification modification, the interrupting signal is switched across different modality mediums (e.g., *"Instant messages could be set to notify a new message by a minimized flashing window rather than as a fully open window"*). Second, involves interruption previews, the way in which an interruption provides information regarding the interruption before its full context is made apparent; the purpose behind this approach is to help give some clues to the knowledge worker about its immediacy (e.g., *"emails are designed to allow for more information on what the interruption is about such as subject and priority"*).

Through the different modalities and their individual properties, affordances, and weaknesses, Sanderson (P. Sanderson, 2006) describes how visual, auditory, and haptic modalities can inform interruption handling. Visually perceptible information is characterized as having high information resolution owing to how visual information can be made persistent, is localized with respect to the viewer, and can be made socially inclusive and when in view by other collocated individuals. Auditory information has a moderate information resolution and is more transient in nature and largely cannot be ignored without some hearing aid. Similar to visual information, it can be socially inclusive if audibly perceptible to other collocated individuals. Finally, tactile information has the lowest information resolution. However, it can be highly personal given the haptic experience, cannot be ignored, and is not a socially inclusive event. Altogether, Sarter suggests that the different sensory channels can be used as a resource to inform appropriate involuntary cueing regarding its salience and implementation to an interruption, all the while considering the urgency and importance of the interruption (McFarlane & Latorella, 2002).

II.5.3. Concurrent Performance of Ongoing and Interrupting Tasks

Owing to how different sensory modalities tax different processing resources of individuals, multiple resource theory (MRT) (N. B. Sarter, 2007) suggests how it is possible for tasks to be performed in parallel if different, unrelated tasks are presented across different modalities. Regarding modalities, MRT suggests that task performance can see a decline if tasks (i.e., ongoing and interrupting) are competing for the same attentional resources (e.g., a pilot acknowledging an auditory interruption notification when receiving instructions by radio from flight control) (Latorella, 1998).

In Latorella's study on airline pilot's enactment of air traffic control instructions on a simulated flight deck, she studied how pilots' performance varied depending on the modality of the task and its interruption medium. Latorella's key findings were that depending upon the interruption and ongoing task's modalities, there are interaction effects with respect to quantifiable errors (e.g., keystrokes and sequence of procedural tasks) and response times (e.g., acknowledgement and initiation of tasks). The study reports reduced performance when cross-modalities were used for interruptions as opposed to unimodal approaches, while Sarter comments that it is likely that performance lags may be attributed to "differences in salience rather than modality per se".

Timing and location of cue presentation can affect the awareness of and response to multimodal signals if their relative salience is not controlled for (Ferris & Sarter, 2011; N. B. Sarter, 2002). For example, there are examples of phenomena where there are unintended interactions between modalities when presented together, create misperceptions between the ongoing and interrupting task by way of merging or confusing signals. First, is the *McGurk effect*, referring to when two stimuli in different modalities result in a perception that is qualitatively different from either stimulus in isolation (e.g., *"For example, when auditory /pa is dubbed onto visual lip movements of /na, perceivers often report hearing "ta.""* (Sekiyama, 1997)). A second identified effect is *Ventriloquism,* how the perceived location of an auditory cue is shifted toward a concurrent visual cue. One example case of ventriloquism is in Irvantchi's work in *Digital Ventriloquism,* where smart speakers are embedded into everyday objects, creating the effect as if they were speaking, interactive entities through the use of a pan-tilt ultrasonic array to *"emit sound that is inaudible "in flight" and demodulates to audible frequencies when impacting a surface through acoustic parametric interaction"* (Sekiyama, 1997).

II.5.4. Switching to a Postponed Interrupting Task and Resuming an Interrupted Task

When knowledge workers need to return to their postponed task, there is a challenge in remembering what they need to do next; this could be frustrated further the more time is spent away from the postponed task. Ratwani et al. demonstrates how the modality of an interruption can influence how an individual is able to return to their original task (Ratwani, Andrews, Sousk, & Trafton, 2008). In their study, when an interruption has a perceptible link to the postponed task, this associative link allows for faster resumption of the postponed task in comparison to the conditions where no such link was established. Specifically, they reported how capturing eye movement in an auditory interruption for a visual task saw participants maintaining a fixed gaze towards the environmental context of the original task, likely to maintain awareness of it. In application to human computer interaction, Ratwani et al. suggest that in designing for interruptions, there should be consideration to how perceptible links to a postponed task are represented, whether the ongoing task can remain within visual view or if an auditory link is associated with cuing back to it.

II.6. Tangible User Interfaces (TUIs) and Supporting Memory

TUIs generally work by embedding computation into physical objects and linking them to digital information (Ishii & Ullmer, 1997; Shaer & Hornecker, 2010). In TUI design, I/O devices are designed to emphasize the coupling of physical and digital media TUIs leverages physical touch as a sensory element alongside the visual and aural senses. By including touch, users can use their embodied knowledge and skills to interact with digital information. TUIs support work context management by offloading mental representations across physical and digital information representations and providing a perceivable link across the physical/digital barrier (Ahmed et al., 2014; Mugellini et al., 2007; Yuzawa & Mark, 2010; Zuckerman et al., 2015). Essentially, the TUI acts as a multi-media junction. Following from the research prototypes in the TUI literature, TUIs can support work context management in one of two ways. First, by creating a tangible representation of the KWs' own working state, and second, by guiding attention during activity.

CHAPTER III METHODOLOGY

III.1. Theoretical Foundation

III.1.1. Design and Analysis Considerations of MC and SMT to Work Context Management:

Vygotsky's Sign Mediation Theory (SMT) frames language as a psychological tool to mediate internal thoughts (Lev S Vygotsky, 2012; Lev Semenovich Vygotsky & Cole, 1978). In this framework, language and thought are two distinct phenomena where they are bridged through words, a kind of sign, made possible as thought is bound to words and words in kind are communicated out into the world. The material carrier (MC) is a related concept concerned with how SMT is represented for the self and others in perceptible reality (Lev S Vygotsky, 2012; Lev Semenovich Vygotsky & Cole, 1978). The concept represented by a sign can be attached to perceptible phenomena, acting as a carrier for the sign. Examples of phenomena that a sign can be attached to include gestures, physical locations, or perceptible objects themselves.

For the purposes of analysis for digital working context management, SMT and MCs can provide a theoretical framework that explains the relationship between units of thought (e.g., conceptions of working contexts) and physical artifacts associated with working contexts. SMT is the means by which office workers can arbitrarily unite sets of information collections, people, places, goals, and time frameworks to create a thought object to organize a working sphere. The material carrier concept is relevant to supporting work context management, where the concept of a working context is made manifest through physical objects, locations, or gestures. Of relevance to HCI, how can these ways we regard work contexts be linked to computational and physical representation to support perceived cohesion for the individual?

III.1.2. Distributed Cognition

Distributed cognition (DCog) (Hollan, Hutchins, & Kirsh, 2000; Nardi, 1996) refers to how cognition extends beyond an individual's own mind, conceiving cognition as a networked phenomenon distributed across people, resources, and materials embedded in the perceptible environment. In identifying instances of cognition, one needs to examine how an individual's own thinking is interconnected with others and resources. DCog necessitates the observation of interactions between individuals and resources used in cognition. Through DCog, there is consideration of how external processes, individuals, objects, and the environment at large are interconnected to represent the sum of an individual's own cognitive process.

For analysis, DCog can inform: 1) attention to how information takes form through various forms of interaction across a system; 2) how interactions coordinate across internal and external mental representations of information; and 3) how the surrounding environment serves to support the coordination of all elements for cognitive activity.

III.1.3. Context Dependent Memory

Memories can be context-dependent when they are reinstated due to a surrounding environment that is close or exact to the conditions under which the memory was initially experienced. The effect, known as context reinstatement, is dependent upon how the memory was encoded initially and retrieved at a later point in time. For encoding, depending on the extent to which activities are bound to surrounding contexts, it is more likely that those experiences can be associated with that given environmental context (e.g., listening to a song repeatedly during a cross-country car drive). For retrieval, if one were to return to the same environmental context after encoding (e.g., listening to a song repeatedly during a cross-country car drive) , it is likely they would be able to reinstate associated memories of the past event.

In the domain of work context management, the context reinstatement effect can be seen when, for example, the spatial arrangement of papers on one's desk after a break in work reminds one of events and behaviors before the break. Further, the cue-overload effect suggests that keeping all of one's projects in a single place, such as a folder or a desktop, makes them confusable with each other, which in turn makes one's memory of the projects unclear as well.

III.1.4. Encoding Specificity and Neural Reinstatement

According to the theory of encoding specificity, context is encoded spatio temporally with focal information present. If an individual's environmental context contains the same focal information or is close enough to the original encoding, the individual's environment can be used as a retrieval cue when engaging in context reinstatement (Isarida, Isarida, & Okamoto, 2005). While environmental contexts reinstatement has considered cases such as natural landmarks (e.g., land and water (Godden & Baddeley, 1975)) or the built environment (e.g., room size (Bjork & Richardson-Klavehn, 1989; Eich, 1995), rooms with different features and objects (S. M. Smith, 2013; S. M. Smith, Glenberg, & Bjork, 1978)), this consideration can be extended to the virtual, computational environments such as foreground color, background color, and item (Murnane & Phelps, 1994, 1995; Murnane, Phelps, & Malmberg, 1999) encountered in personal computing graphical user interfaces (GUIs).

In recognition of using computational GUI elements as memory cues, there has been work within the space of computer-human interaction that emphasizes the use of visual histories, the display of captured images, video of prior digital desktop based activities (Czerwinski & Horvitz, 2002; Hu & Lee, 2020; M. G. Lamming & Newman, 1992; Parnin & DeLine, 2010; Rule et al., 2017; Safer & Murphy, 2007; Sellen et al., 2007). Supporting work context resumption in this manner works generally by reconstructing prior working contexts (M. Lamming & Flynn, 1994) through the use of visual cues displayed in a chronological sequence. Work context resumption by visual history has been used in the support of activities such as web browsing history (M. Lamming & Flynn, 1994), identifying task boundaries in programming work environments (Safer & Murphy, 2007), or recalling memory for daily computer-supported events (Czerwinski & Horvitz, 2002; M. G. Lamming & Newman, 1992).

Neural reinstatement is the act of reactivating specific neural patterns during memory retrieval that are like how it was originally experienced during encoding (i.e., learning) of memory (Johnson, McDuff, Rugg, & Norman, 2009; Polyn, Natu, Cohen, & Norman, 2005; Ritchey, Wing, LaBar, & Cabeza, 2013; Staresina, Alink, Kriegeskorte, & Henson, 2013; Tambini, Ketz, & Davachi, 2010). When an event is taking place, the brain forms specific patterns of neural activity, acting as a kind of record of the event. Said neural "record" of the event could be distributed across different regions of the brain. When one attempts intentionally (e.g., trying to remember what one ate for dinner last Monday) or unintentionally (e.g., you see a photo of your family from your brother's 3rd birthday), the brain automatically reactivates the regions of the brain that were associated with the original encoding event, enabling the individual to recall the event.

In relating neural reinstatement with encoding specificity, the latter points to how the retrieval of memories is dependent upon how the brain responds to perceptible cues and how neural activity matches neural activity associated with the memory at encoding (Staudigl & Hanslmayr, 2019; Xiao et al., 2017). When one experiences an event of is learning some concept, there is neural activity taking place in the brain, acting as a kind of signature of the event, this referred to as a memory trace. Neural reinstatement in conjunction with encoding specificity highlights how when one attempts to recall an event via a memory trace, either the same or similar neural activity takes place, reinstating the memory. Moreso, through perceptible cues, the extent to which they match or are close to the encoding cues, influences the likelihood that the associated memory would be retrieved.

III.1.5. Task Switching Processes

Individuals change their attention to different tasks or working contexts through a process of cognitive reconfiguration (Monsell, 2003), also known as task-set reconfiguration (TSR). Monsell characterizes TSR as a kind of mental '*gear changing'* that is undertaken before appropriate task sets can be called forth. TSR arises in cases where attention is shifting across different stimuli or conceptual criteria, and the goal is to retrieve the exact goal and rule set into procedural working memory. In shifting attention, TSR brings a switch-cost to performance, which is characterized by a slower response time to the present working context and a higher chance of errors. TSR-associated switch costs cannot be removed entirely. However, its effects can be lessened when a KW is given the opportunity to prepare (*i.e., to be reminded*) (Monsell, 2003). Switch cost can be attributed to the transient and long-term carryover of the 'task set' and inhibition mechanisms present in the task-set reconfiguration process.

III.2. Overview of Methodology for Two-Phase Research Study

The studies were conducted through a two-phase process using both experimental and qualitative (i.e., "*in-the-wild*" anthropological observations) studies (Figure 1). For *Phase-I,* existing supportive technologies for digital work context management were studied to better understand how KWs are supported and challenged by existing personal computer systems. For *Phase-II,* using the data and findings from Phase-I, a research-through-design approach (Chu, Quek, Wang, & Hartson, 2013; Fallman, 2003, 2007; Zimmerman, Forlizzi, & Evenson, 2007) were used to create a research prototype, covered in 0 and Chapter VIII. Through the prototype, the dissertation serves as a testbed to investigate the interaction design of tangible and embodied digital working context management.

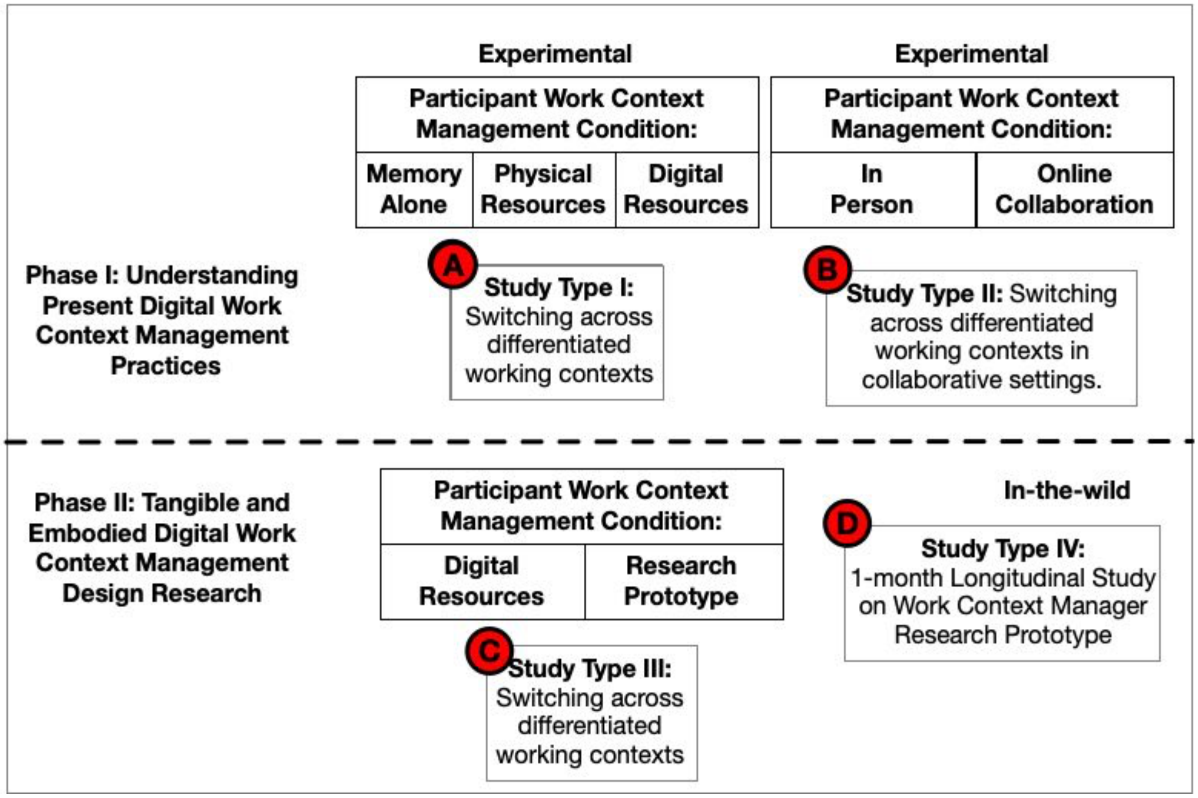


Figure 1 Overview of studies to be conducted for two phase research agenda.

III.2.1. Experimental

The dissertation conducted a series of experimental studies that investigate how work context management can be influenced by the similarity of working context activities and the artifacts used to reinstate them.

III.2.1.1. Independent Variables (IVs)

The IV focused on work context management methods (IV) (see “participant work context management condition” in Figure 1 Study A Type I). Methods for study type I (covered in Chapter V) will include 'Memory Alone’ (i.e., participants will reengage work context without the aid of physical and digital artifacts present when resuming), 'Physical Resources' (i.e., using sticky notes, paper, and planners), ‘Digital Resources' (i.e., digital documents will be present during resumption), and 'Research Prototype' (i.e., resuming work context using the developed research prototype system). In Chapter VI, this study is modified where we compare groups of participants working together in collaborative contexts, between in-person and online representations (Figure 1 Study B Type II). The last experimental study, Study C Type III, compared the performance in work context resumption between existing approaches (i.e., existing personal computer system) and the research prototype.

III.2.1.2. Dependent Variables (DVs)

TSR – Resumption Lag and Subjective Workload:

The first DV, *Resumption Lag (DV-1)*, refers to the time interval between the end of a secondary task (i.e., the interrupting working context) and the KW’s first intentional action upon returning to their original working context. By using resumption lag as a metric, the time interval separating working contexts can illustrate the extent of disruptiveness that an interruption has on a working context.

For the second DV, the dissertation used the *NASA-TLX (DV-2)* (Hart, 2006), a subjective, multidimensional survey that examines how individuals perceive workload for a given task as mediated by a system. The index has six subjective sub-scales based on 21 gradations from very low to very high. For the dissertation, the sub-scales were adapted to focus primarily on how features of KW's digital and physical artifacts support work context management (See).

III.2.1.3. Experimental Study Design

The study investigated how different approaches to computer-based work context management vary across management strategies (IV). Participants worked across three thematically different projects, following a set of demands and a budget to work under (Figure 2).

There were three types of studies. The first study type focused on switching across differentiated work contexts (see A of Figure 1) whereas the second study type focused on switching across similar working contexts (see B of Figure 1); effectively, these studies are based on IV.

Tasks and scenario: Common across experimental studies are an information foraging task that is used to encourage participants to create different working contexts and manage the them as they traverse between them as the study demands. Participants completed a series of information consumption and production tasks situated across three individual working contexts, each of which were completed over two individual sessions within the study (Figure 2). The tasks were designed to be sufficiently complex and in-depth that they would be difficult to complete within a single session. In supporting their working contexts, participants used the set of applications, documents, and web pages that were supplied based on the work context management condition they are assigned to (IV).

To simulate the conditions KWs experience in multiple working contexts in their day-to-day work, the participant were asked to act out the role of an overloaded office worker in a small travel agency. In their role, the participant were charged with the responsibility of completing three working contexts, which include: 1) creating a travel package for a client; 2) a large office technology purchase for the office; and 3) an end-of-quarter party plan. Each working context task involved the creation of a budget report and the recommendation of action from the tasks listed. The scenario informs the design of the tasks, where there is the potential for the participant to experience greater resumption lag, reduced context reinstatement performance, and greater subjective workload when switching attention across working contexts.

II.2.2. In-the-wild Studies

A second grouping of studies examined how KWs can support their digital working contexts in individual and collaborative settings (see D of Figure 1). The studies used an in-the-wild longitudinal study approach similar to that used by Voida et al. (Voida & Mynatt, 2009) and Rule et al. (Rule et al., 2017). The study recruited individuals that work in work-context-centric settings such as research labs, academic offices, or small businesses. The studies were designed to better understand a participant engages in work context management and what kinds of strengths, weaknesses, and emergent strategies arise in supporting their practices.

CHAPTER IV ANALYSIS METHODOLOGY

IV.1. Experimental Studies

The experimental studies were designed with an interest in identifying differences between work context management methodologies (IV) and their influence on resumption lag (DV-1), and subjective workload (DV-2). A between-subjects quantitative analysis was used to analyze differences using descriptive and inferential statistics.

In analyzing the data, qualitative analysis method was utilized to uncover how work context management is supported using the theoretical lenses of SMT, MC, and DCog. Across the studies, a grounded theoretical approach was used to analyze subject's interview transcripts. The process went as follows: (1) open coding to determine core categories and focal points of analysis; (2) focus or axial coding employing the categories and focal points to derive more refined themes and observations; and (3) selective coding, where new themes and observations are applied to further refine the analysis and the coding is done subservient to the core categories [94, 95].

Concerning the lenses of DCog and SMT-MC, an extension to the above analysis was used. A major point of the dissertation is to understand how cognition takes place in digital work context management. In support of this, an analysis approach used by Chu et al. was designed to understand how the thinking process arises in the display and device ecosystems (DDE) (Chu & Quek, 2013). In Chu et al., they established an analysis framework, the digital object path analysis, to best understand how users think through and interpret their actions in their personal computing system. The digital object path analysis examines transcripts generated from interviews and diaries to identify how thinking arises through digital media and is made manifest through its supportive physical artifacts. The approach first identifies thinking episodes, and coders perform a first-round analysis to identify thinking episodes. Chu et al. define a thinking episode as *"" a coherent run of* *[thinking] in which the constituent [processes] have a constant direction, a purpose""*, with the caveat that thinking as an emergent phenomenon has no clear end-point and not necessarily a clear outcome. A few examples of thinking episodes that Chu et al. describe include "filtering out important keywords', 'searching for information', and 'annotating papers". Once a thinking episode is identified, said episode is broken down into subcomponents to identify thinking objects (TOs), digital-objects (DOs), manifest-objects (MOs), and what technology is associated with them. Chu et al. describe their unit of analysis for the thinking episodes through specific digital documents, such as Google Docs, Evernote notes, and PDFs.

CHAPTER V INVESTIGATION OF THE WORK CONTEXT MANAGEMENT STRATEGIES OF KNOWLEDGE WORKERS

V.1. Introduction

The mechanisms supporting the resumption of work contexts rely on our ability to externalize cognition to the environment and use it to guide attention across different working contexts. This is evidenced by how KWs engage in information aggregation, access, traversal, and resumption activities. This chapter examines how KWs utilize digital and physical artifacts to facilitate switching between working spheres and how they use associated artifacts to enter into a *working context.* We aim to understand how digital working contexts are represented and perceived through their associated on-screen elements. By exploring how KWs resume their computer-represented working contexts, we seek to identify which features of the digital desktop serve as cognitive aids for work context resumption strategies.

To support our inquiry, we compared three groups of KWs, varied by the extent of computational support that is given to them when resuming a computationally represented working context, these including *Digital Support* (i.e., *maintaining on-screen resources over time*), *Physical Support* (i.e., *physical resources are used to support resumption*), and *No-Support (i.e., participants rely on conscious, self-guided memory to support resumption*). These comparisons are chosen as they reflect the various ways that KWs can resume a working context whether or not their information collections are preserved across stretches of time (e.g., *How would resumption compare between a maintained desktop or a fresh desktop after a system crash?).*

V.1.1. Research Questions

We argue that cues for computational work context management comes from an artifacts' cueing affordance. First by how artifacts can help KWs reduce resumption lag when they switch attention between working contexts. Second, how artifacts associated with working contexts can help KWs to recall of prior episodic, cognitive states of work. We pose the following research questions:

- **RQ-1:** Are there any differences in mental workload in KWs when they are variably given support for computational work context resumption?
- **RQ-2:** Are there any differences in resumption lag in KWs when they are variably given support for computational work context resumption?

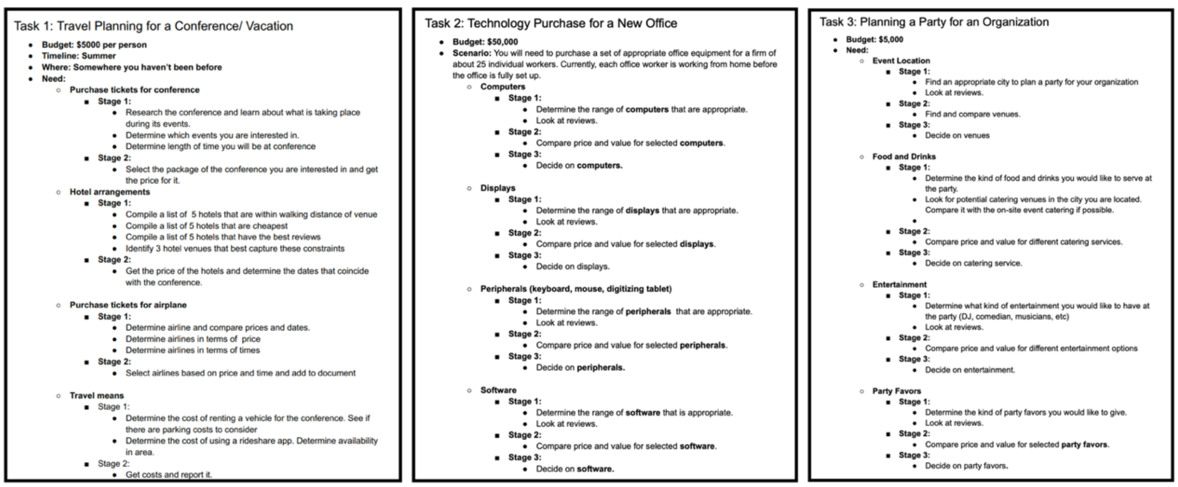
Our work presents empirical findings on how knowledge workers resume their computationally represented working contexts. We identify the challenges KWs face when resuming prior work states, the variations in their resumption strategies, and the compensatory strategies employed when cues (i.e., sets of windows, applications, and tabs accumulated over time) are unavailable. We found statistically significant differences across the various resumption conditions in our study, highlighting the challenges users encounter and the ad-hoc approaches they use to address these issues. We discuss these approaches in terms of their implications for the design and implementation of computationally represented working contexts.

V.2. Study Methodology

V.2.1. Study Overview

Our study employed an experimental laboratory design to investigate how managing computer-represented work contexts can be influenced by the availability of environmental cues across both physical and digital media to support project resumption. In our experiment, participants assumed the role of an overworked travel agent in a small travel agency. They were tasked with completing a recommendation report for three distinct projects, each representing its own working context: planning travel accommodations for guests, preparing a technology purchase for the office, and organizing a social event for co-workers (Figure 2).

Each project was characterized by a set of intentionally open-ended constraints and tasks designed to necessitate active information seeking and aggregation (Figure 2 and Appendix). Participants worked on these projects according to a predetermined schedule, with activities interrupted for short breaks, followed by a shift to the next project in sequence. Upon returning to the interrupted projects, we examined the strategies participants used to resume their work.


Task 1: Travel Planning for a Conference/ Vacation

- **Budget: $5000 per person**
- **Timeline: Summer**
- **Where: Somewhere you haven't been before**
- **Need:**
  - **Purchase tickets for conference**
    - **Stage 1:**
      - Research the conference and learn about what is taking place during its events.
      - Determine which events you are interested in.
      - Determine length of time you will be at conference
    - **Stage 2:**
      - Select the package of the conference you are interested in and get the price for it.
  - **Hotel arrangements**
    - **Stage 1:**
      - Compile a list of 5 hotels that are within walking distance of venue
      - Compile a list of 5 hotels that are cheapest
      - Compile a list of 5 hotels that have the best reviews
      - Identify 3 hotel venues that best capture these constraints
    - **Stage 2:**
      - Get the price of the hotels and determine the dates that coincide with the conference.
  - **Purchase tickets for airplane**
    - **Stage 1:**
      - Determine airline and compare prices and dates.
      - Determine airlines in terms of price
      - Determine airlines in terms of times
    - **Stage 2:**
      - Select airlines based on price and time and add to document
  - **Travel means**
    - Stage 1:
      - Determine the cost of renting a vehicle for the conference. See if there are parking costs to consider
      - Determine the cost of using a rideshare app. Determine availability in area.
    - Stage 2:
      - Get costs and report it.

Task 2: Technology Purchase for a New Office

- **Budget: $50,000**
- **Scenario:** You will need to purchase a set of appropriate office equipment for a firm of about 25 individual workers. Currently, each office worker is working from home before the office is fully set up.
  - **Computers**
    - **Stage 1:**
      - Determine the range of **computers** that are appropriate.
      - Look at reviews.
    - **Stage 2:**
      - Compare price and value for selected **computers**.
    - **Stage 3:**
      - Decide on **computers.**
  - **Displays**
    - **Stage 1:**
      - Determine the range of **displays** that are appropriate.
      - Look at reviews.
    - **Stage 2:**
      - Compare price and value for selected **displays**.
    - **Stage 3:**
      - Decide on displays.
  - **Peripherals (keyboard, mouse, digitizing tablet)**
    - **Stage 1:**
      - Determine the range of **peripherals** that are appropriate.
      - Look at reviews.
    - **Stage 2:**
      - Compare price and value for selected **peripherals**.
    - **Stage 3:**
      - Decide on **peripherals.**
  - **Software**
    - **Stage 1:**
      - Determine the range of **software** that is appropriate.
      - Look at reviews.
    - **Stage 2:**
      - Compare price and value for selected **software**.
    - **Stage 3:**
      - Decide on **software.**

Task 3: Planning a Party for an Organization

- **Budget: $5,000**
- **Need:**
  - **Event Location**
    - **Stage 1:**
      - Find an appropriate city to plan a party for your organization
      - Look at reviews.
    - **Stage 2:**
      - Find and compare venues.
    - **Stage 3:**
      - Decide on venues
  - **Food and Drinks**
    - **Stage 1:**
      - Determine the kind of food and drinks you would like to serve at the party.
      - Look for potential catering venues in the city you are located. Compare it with the on-site event catering if possible.
    - **Stage 2:**
      - Compare price and value for different catering services.
    - **Stage 3:**
      - Decide on catering service.
  - **Entertainment**
    - **Stage 1:**
      - Determine what kind of entertainment you would like to have at the party (DJ, comedian, musicians, etc)
      - Look at reviews.
    - **Stage 2:**
      - Compare price and value for different entertainment options
    - **Stage 3:**
      - Decide on entertainment.
  - **Party Favors**
    - **Stage 1:**
      - Determine the kind of party favors you would like to give.
      - Look at reviews.
    - **Stage 2:**
      - Compare price and value for selected **party favors**.
    - **Stage 3:**
      - Decide on party favors.

Figure 2 Task description sheets for the three individual tasks. Left: Task 1 sheet for travel planning for a conference/vacation. Middle: Task 2 sheet for technology purchase for new office. Right: Task 3 sheet for planning a party for an organization.

V.3. Variables

V.3.1. Independent Variables

Our independent variable (IV) focuses on work context management resumption methods, as illustrated by the *"participant work context management condition"* in Figure 3 Experimental study design schematic. We controlled the approach participants used to resume their computer-represented projects through three different methods:

- **1) Digital Support:** This involved maintaining the state of the desktop applications and internet browsers, including their arrangement, between scheduled interruptions.
- **2) Physical Support:** In this approach, the desktop was cleared of all open windows, requiring participants to rely on supplied notebooks, pens, and sticky notes for resumption support.
- **3) No Support:** Similar to the *"Physical Support"* approach, the desktop was cleared, but participants had to consciously recall and guide their activities upon resumption.

A common feature across these approaches is the use of a supplied paper task sheet listing all tasks specified for each project.

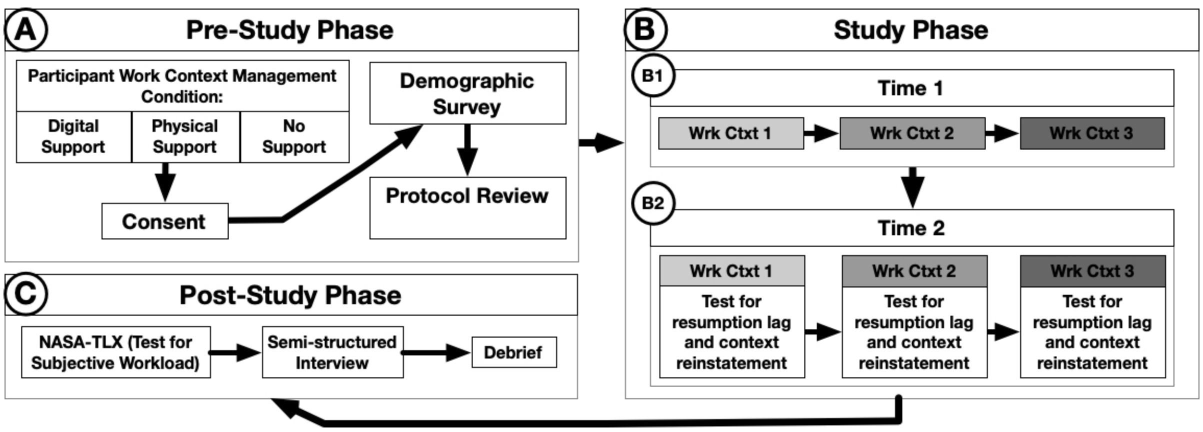


Figure 3 Experimental study design schematic.

V.3.2. Dependent Variables

We have two dependent variables (DVs) in our study. The first DV (DV-1), *Mental Workload* (MWL), refers to the cognitive demands experienced by workers. It is defined by the worker's task demand/performance, skill level, and the extent to which the environment contributes to the worker's performance. Young and Stanton provide an operationalized definition of MWL that reflects "*The level of attentional resources required to meet both objective and subjective* *performance criteria, which may be mediated by task demands, external support, and past experience." (Young & Stanton, 2004)*.

The second DV (DV-2), *Resumption Lag*, measures the time interval between the start of an interrupted task or project and the participant's first intentional action upon returning to their original working context. We define *"first intentional action"* as any activity that does not involve reorganization or retrieval of previous project-related media but rather any activity suggesting active progress towards completing the recommendation report (e.g., typing a finding in a Word document, pasting a link, filling out a web form, or writing in a notebook). Using resumption lag as a metric, as referenced by Trafton et al. (Altmann & Trafton, 2004), allows us to quantify the time spent on work preparation after an interruption, indicating the extent of disruptiveness.

V.4. Measures

V.4.1. Eye tracking and Screen Recording Video Collection (for DV-1 and DV-2)

Eye tracking is a technique used to measure and record eye movements, gaze patterns, and pupil dilation activity. Through eye-tracking, researchers can closely examine human attention, perception, and cognitive processes (Hansen & Holmqvist, 2021). A key benefit of eye-tracking is the insight it provides into user behavior and usability issues, thereby informing improvements in interface design, advertising, and user experience optimization. In our study, eye tracking allows us to observe when and where resumption lag occurs during resumption activity. Specifically, we examine changes in pupil diameter (measured in millimeters) to indicate activity.

Pupil responses are known to reflect brain processes related to perception, attention, decision-making, and reactions to external stimuli or activities Mitre-Hernandez, 2021}. Pupil dilation has been empirically tested to indicate higher-order human activities, such as sex-specific fixation on particular visual stimuli (Hess & Polt, 1960), prediction of the timing of decisions and choice of visual stimuli (Einhauser, Koch, & Carter, 2010; Einhäuser, Stout, Koch, & Carter, 2008), task difficulty (Beatty, 1982; Gavas, Tripathy, Chatterjee, & Sinha, 2018; Hess & Polt, 1960; Kahneman & Beatty, 1966), and as a biomarker for cognitive load. For our study, we use the dilation effect, Psychosensory Pupil Response (PPR), that is associated with increased cognitive activity due to heightened arousal or mental effort (Mathôt, 2018).

For eye-tracking, we utilize Pupil Core, an open-source software and hardware platform (Kassner, Patera, & Bulling, 2014). The Pupil headset features a front-facing scene camera (world camera) and two infrared (IR) cameras positioned to detect users' dark pupils. These cameras connect via a high-speed USB 2.0 connection to stream video to connected devices such as laptops, desktops, or mobile devices. The camera streams are processed by Pupil Capture software, which supports real-time pupil detection, gaze-mapping calibration and validation, recording, and surface tracking. After recording, Pupil Player is used for playback and visualization of eye-tracking data, including blink detection, fixation detection, and gaze patterns. Additionally, Pupil Player allows for the export of visualized video streams from both the world and IR cameras, as well as timestamped stream data in .csv format, including pupil diameter. For our study, we specifically record pupil dilation diameter (in mm) changes to assess workload.

V.4.2. NASA-TLX Subjective Workload Assessment (for DV-2)

In assessing mental workload, we used the NASA Task Load Index (NASA-TLX) to evaluate participants' perceived workload at the end of the study (Table 2). This subjective, multidimensional assessment is commonly used to rate one's perceived workload concerning a particular task, device, or team (Colligan, Potts, Finn, & Sinkin, 2015). The NASA-TLX was employed to measure participants' perceived workload from the computers they used during their study condition and to consider how different dimensions of workload were perceived during task performance. Originally developed by the Human Performance Group at NASA's Ames Research Center, the NASA-TLX has been validated across over 40 laboratory experiments and widely applied in human factors, aviation, healthcare, and other domains where socio-technical interactions are of interest (Hart & Staveland, 1988a).

Table 2 NASA-TLX survey.

Survey Type Name	**NASA TLX Survey**
Instruction:	*Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.*
Mental Demand:	*How mentally demanding was the task?*
Physical Demand:	*How physically demanding was the task?*
Temporal Demand:	*How hurried or rushed was the pace of the task?*
Performance:	*How successful were you in accomplishing what you were asked to do?*
Effort:	*How hard did you have to work to accomplish your level of performance?*
Frustration:	*How insecure, discouraged, irritated, stressed, and annoyed were you?*

V.5. Study Protocol

V.5.1. Recruitment

The study received approval from our institution's Internal Review Board (IRB). Participants were recruited through the institution's bulk email service, which provided details about the study procedures, duration, inclusion and exclusion criteria, and the compensation of a $20 gift card upon completion. Interested individuals who received the email contacted the researchers to schedule a study session.

V.5.2. Pre-Study

Upon arrival for their scheduled appointment in the researcher's study room (see Figure 3-A), participants are provided with a consent form detailing the study's activities (see Figure 3). After signing the consent form, participants complete an online pre-study survey on a provided 15-inch HP ProBook laptop (Table 3).

Table 3 Demographic survey.

Question 1	Question 2	Question 3	Question 4	Question 5	Question 6	Question 7
What is your age?	What is your gender?	If you are a student, what is your academic study?	If you are a staff member, what is your role?	If you are a faculty member, what is your department?	If you are a faculty member, what is your role?	What operating system do you normally use?

Calibration Process:

The participant was provided with the Pupil Core headset and instructed to adjust the eye-facing and front-facing cameras for optimal eye-tracking. Verbal consent was obtained from participants allowing the researcher to manually adjust the headset if necessary. Upon receiving consent, the researcher adjusted the eye tracker to ensure that the participant's eyes remained visible during movement. The eye-facing cameras were positioned relative to the on-screen images of the eyes to maintain visibility as the participant's eyes moved. The front-facing camera was adjusted to ensure that the laptop screen was within view when the participant's head and eyes were fixated on the computer during activity.

Once the participant's eye model achieved consistent confidence values above 95%, the next step was to calibrate the pupil-detection model using the front-facing camera. This calibration aimed to map pupil positions to gaze coordinates. During calibration, five targets were sequentially displayed on the researcher's laptop screen, positioned at the center and corners. A small green dot appeared on each target when a successful mapping was detected between the pupils and the world camera, indicating the sample points. After recording a sufficient number of samples for each target, the next target was displayed, and the process continued.

Following the calibration of both the pupil camera and the front-facing camera, a validation process was employed to assess the accuracy of the calibration. This process involved displaying sequential targets on the screen, similar to the calibration phase. However, while the calibration targets were positioned at the center and corners, the validation targets were placed between these points on the screen. After completing the validation, a report was generated showing the accuracy error and visualizing the discrepancy between the pupils and the targets. If a high accuracy error was detected, the calibration process was repeated.

We repeated the calibration process a total of six times for each *Wrk-Ctxt* block in both Time I and Time II sub-sessions (described in section *Post study* (below)). This repetition addresses the issue of slippage, a common problem in eye-tracking research where the headset may shift from the participant's head due to movement, leading to reduced accuracy in recorded values. To mitigate the effects of slippage, and following PupilLabs' recommendations, we re-calibrated and validated the eye-tracking setup for each observation block to correct for accumulated errors ("Best Practices: Tips for conducting eye tracking experiments with the Pupil Core eye tracking platform.," ; Niehorster et al., 2020).

Study:

In the study, participants were assessed on their ability to context-switch across different working contexts, based on the type of work context management approach assigned to them (IV). The study session was divided into two sub-sessions: Time I and Time II (see Figure 3 - B1).

During Time I, participants worked on tasks related to a specific work context for 15 minutes, starting with *Wrk-Ctxt 1*. Following this, participants took a 5-minute break to introduce a period of forgetting. This approach was inspired by Smith et al.'s method, where participants left a room after learning word-list pairs to facilitate forgetting before recall (S. M. Smith et al., 1978). After the break, participants returned to the study room and proceeded to the next work context in the sequence, *Wrk-Ctxt 2*, followed by *Wrk-Ctxt 3*. The entire Time I session lasted for 1 hour.

The Time II session began after the 5-minute break following *Wrk-Ctxt 3* (see Figure 3-B2). During Time II, participants revisited the working contexts they had previously engaged with.

This phase focused on examining resumption lag, defined as the time from instructing the participant to resume work on *Wrk-Ctxt 1* to their first intentional action within that context (DV-2).

As participants resumed their tasks, both their physical actions and on-screen activities were recorded to analyze the context reinstatement process. After 15 minutes of work on *Wrk-Ctxt 1*, participants took another 5-minute break outside the room before returning to continue with the next scheduled work context. This sequence was repeated until *Wrk-Ctxt 3* was completed.

V.5.3. Post-Study

Upon completing the Time II session, participants were asked to fill out the NASA-TLX subjective workload questionnaire (DV-1) (see Figure 3 - C). Following this, they participated in a semi-structured interview to assess their overall experience with the study (Table 4).

V.6. Quantitative Data Analysis and Findings

V.6.1. Demographic Survey

A total of 19 university-affiliated individuals participated in the study. We recruited our participants throughout our university using our institution's e-mail service. There were 7 participants in the *Digital Support* condition (5 female and 2 male), 7 for the *Physical Support* condition (2 female and 5 male), and 5 for the *No Support* condition (4 female and 1 male). Participants' age ranged from 19 to 52 years. With respect to academic background, participants were members of the university's College of Engineering (N=6), College of Arts and Sciences (N=3), College of Education (N=1), School of Government (N=1), School of Business (N=2), School of Public Health (N=1), and general studies (N=1). The remaining participants were university staff members (N=4).

Table 4 Post-study interview questions.

Group Name	Question
Strategies for Remembering Prior Tasks:	*What challenges did you face in trying to remember what you previously did in your tasks?*
	Did you face any challenges in coordinating your materials as you return to your different tasks?
Challenges in Remembering Prior Tasks:	*Did glancing at the visual arrangement of your desktop, in its presence state, influenced you in anyway to remember what you were going?*
Role of Paper:	*What role did paper serve in your workflow for the tasks?*
Suggested Changes to Workflow:	*What are some ways that you could see software/hardware or supplies can be designed to better able for you to mentally resume your tasks?*

VI.6.2. Quantitative Results

VI.6.2.1. Eyetracking Data Analysis and Findings:

Across the three project contexts that we had our participants complete, we saw significance in the averaged pupil dilation samples within the first three minutes of recorded activity upon resumption of a project.

Travel Plan Context Resumption:

We found statistically significant differences among groups in the *"Party Plan"* task upon resumption within the first 3 minutes of activity, as determined by a one-way ANOVA for eye-01 ($F(2, 133731) = 24662.20$, $p < 0.05$) and eye-02 ($F(2, 178204) = 78692.96$, $p < 0.05$). For both eye-01 and eye-02, a Tukey post-hoc HSD revealed statistically significant differences across groups (Figure 4). Specifically, Digital Support was associated with significantly smaller pupil diameters compared to the Physical Support and No Support conditions (which did not differ).

Tech Purchase Resumption:

We found statistically significant differences among groups in the “Tech Purchase” task upon resumption within the first 3 minutes of activity, as determined by a one-way ANOVA for eye-01 ($F(2, 111587) = 23080.62$, $p < 0.05$) and eye-02 ($F(2, 164744) = 69853.74$, $p < 0.05$). For both eye-01 and eye-02, a Tukey post-hoc HSD test revealed statistically significant differences across groups (Figure 5), where *Digital Support* was associated with relatively smaller pupil diameters compared to the *Physical Support* condition. Similarly, pupil diameters were relatively smaller in the *Physical Support* condition compared to the *No Support* condition.

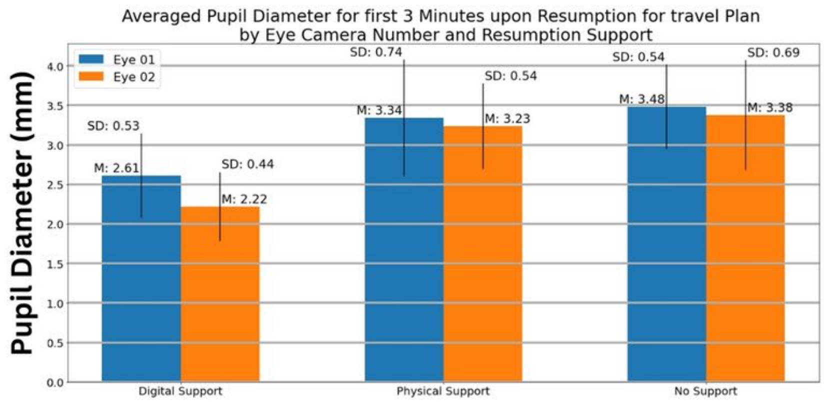


Figure 4 Comparisons across resumption conditions for "Travel Plan" context.

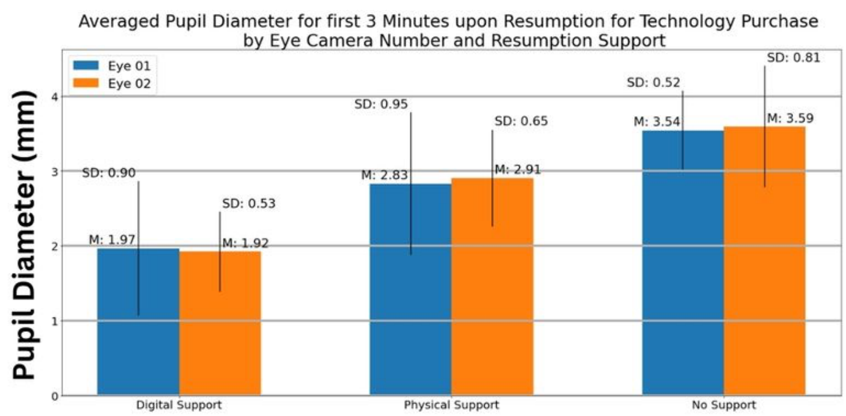


Figure 5 Comparisons across resumption conditions for "Technology Purchase" context.

<u>Party Plan Resumption:</u>

We found statistically significant differences among groups in the “Party Plan” task upon resumption within the first 3 minutes of activity, as determined by a one-way ANOVA for eye-01 ($F(2, 97738) = 4144.40$, $p < 0.05$) and eye-02 ($F(2, 145373) = 30712.17$, $p < 0.05$). For both eye-01 and eye-02, a Tukey post-hoc HSD test revealed statistically significant differences across groups (Figure 6), where *Digital Support* was associated with the smallest pupil diameters, followed by *Physical Support*, with *No Support* resulting in the greatest pupil diameters.

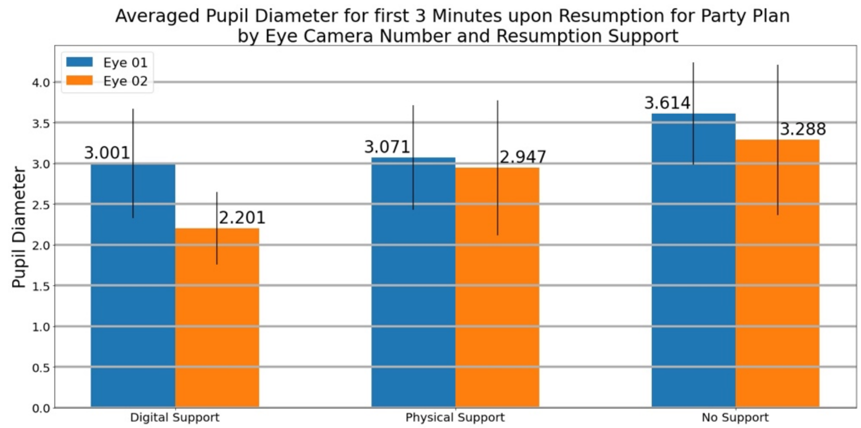


Figure 6 Comparisons across resumption conditions for "Party Purchase" context.

<u>Resumption Lag:</u>

We also used the three-minute window to examine how long it took for knowledge workers (KWs) to resume their work activities in their resumed working context, based on the resumption method (measured in seconds). Averaging performance across projects, the *Digital Support* group tended to start the earliest (M = 42.78 s, SD = 25.62), followed by the *No Support* group (M = 67.67 s, SD = 25.99), with the *Physical Support* group starting last (M = 90.86 s, SD = 53.298).

VI.6.2.2. NASA-TLX Results:

We were interested in identifying differences between the *Digital*, *Physical*, and No Support groups on subjective workload. Owing to the small sample size, we conducted pairwise Mann-Whitney U tests to assess statistical significance between the groups. There was a statistically significant difference between *Digital Support* and *No Support* for Mental Demand, where participants in the *Digital Support* group, on average, reported *"somewhat high"* ratings, while those in the *No Support* group reported "somewhat low" ratings ($U = 30.5, p = 0.041$) (Figure 7). We also observed a statistically significant difference between *Digital Support* and *No Support* for *Temporal Demand*, where *Digital Support* participants averaged *"neither"* and *No Support* participants averaged *"high"* ($U = 4.0, p = 0.03$). No other statistically significant differences were found between the groups for the remaining NASA-TLX items (physical demand, performance, effort, and frustration). Additionally, there were no statistically significant differences between the *Digital Support* and *Physical Support* groups or between the *Physical Support* and *No Support* groups.

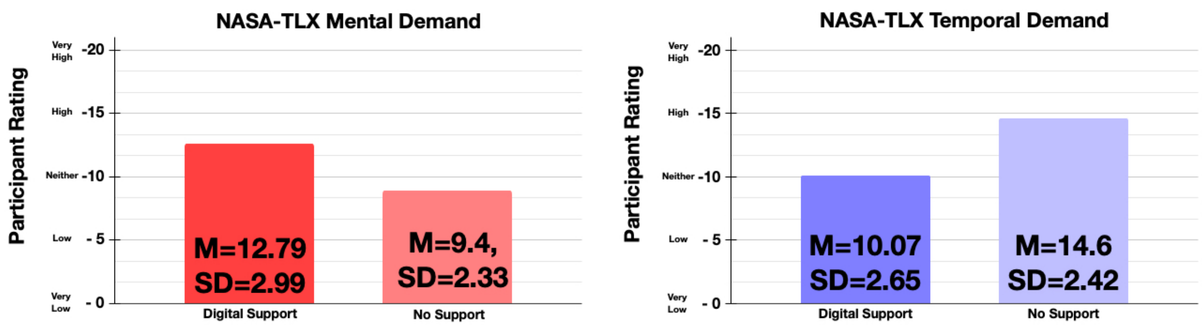


Figure 7 NASA-TLX results for mental and temporal demand dimensions.

V.7. Qualitative Data Analysis and Findings

From our study findings, we will characterize how *Digital Support*, *Physical Support*, and *No Support* influenced participants' experience of context reinstatement of their dormant projects. Transcription of audio-recorded focus group interviews was handled by Descript ("Descript is the AI-powered, fully featured, end-to-end video editor that you already know how to use.,"). Qualitative coding followed the grounded theory approach as outlined by Charmaz and Strauss to generate initial codes during the "open coding" phase (Strauss & Corbin, 1998) (e.g., *"More tabs mean more confusion for task".* Afterwards, similar codes were grouped into related categories during the *"focused coding"* phase (e.g., *"More tabs mean more confusion for task*" and *"Getting lost when returning to task"* are grouped under *"Challenges in attending to materials"*). Finally, thematically related categories were linked during the "axial coding" phase (e.g., *"Challenges in distinguishing between tasks by materials"* and *"Challenges in attending to materials"* are linked under *"Challenges in remembering tasks by materials"*}). Two coders worked on the analysis, achieving an agreement rating of 88%.

We have organized our findings across three high-level categories concerning the ways in which each resumption condition supports the return to a project, the challenges faced when resuming, and the compensatory strategies that participants used or were aware of from their own daily work experiences. We also provide suggestions on what future support for computer-supported work context management may look like.

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V.7.1. Attributes of Resumption

V.7.1.1. Computer Based Factors Towards Resumption:

A commonality across participants in coordinating their work contexts is the use of online word editors (e.g., Google Docs), which act as a base of operations when engaging with their work context. Participants described Google Docs as providing numerous benefits in supporting their work contexts, beyond its explicit role as an online word processor. In this usage, participants described Google Docs as a dedicated workspace, highlighting its utility for context representation and organization. They noted its support in creating bulleted lists, serving as a space to store collected links, and providing a means to organize embedded sub-categories of work contexts or entire work contexts as a whole. Since the participants were engaged in an information foraging task with no immediately clear choice, they used Google Docs as a means of collecting different options and actively used it as a way to compare choices in an organized manner, whether to make a decision immediately or later (Table 5).

Table 5 Google Docs as resumption means.

Digital support participant 2-6-24 female: *The web-page is literally just me trying to research and find information for different options that I would have for each of the following. I want to consider arrangements I need to make needed to make for any of the tasks. In the doc I was just trying to find a way to organize this since this is something that I would have to re-explain and execute later in this hypothetical situation. I also wanted a visual comparison too.*

The physical-support group identified two ways they were able to compensate in re-engaging and re-accessing their work contexts when their information collections were removed between work sessions. First, due to Google Docs' cloud-based platform, participants often noted its affordance in supporting context resumption, whether accessing their information collections from a different personal computer or even in cases where information may have been lost because their personal device had turned off or crashed (Table 6). Second, the participants' web browser of choice maintained implicit cues of their previous activities, such as previous search phrases reappearing in a search engine or links being colored differently when they had been visited before. These cues provided a way for users to return to their context, even when the exact combination of windows or tabs was not present (Table 7).

Table 6 Cloud platform supports resumption.

Physical support participant 2-28-24 male: *I think in general, having all of my currently aggregated information on a Google doc, which I was able to open pretty instantly, was helpful because it just showed me where I was. And then I look over at the hard copy of the task to see what I still needed to do. The websites, yes, I lost that information, but when I realized that was going to be happening, I started copy pasting the links into my Google doc, which I could then instantly reopen if I wanted to revisit a particular website.*

Table 7 Hyperlink color suggests prior activity.

Physical support participant 3-1-24 male: W*henever, I search something, Google, highlighted, purple colored, sites saying that you've already visited this. I might have, took out some information from it. It helped me to reach the correct site that I was looking earlier.*

V.7.1.2. Human Factors towards Resumption:

A commonality across all participants is how even the act of conscious remembering aids in context resumption. Regardless of the condition to which they were assigned, participants utilized their conscious memory to guide resumption actions. One participant explained that the task complexity, which involved three conceptually different tasks, made it easier to organize and separate them, thus creating a simple mental framework to guide their actions (Table 8). Other participants described using a "photographic memory" approach, avoiding reliance on either physical or digital media for context. Instead, they consciously referenced their previous memories, imagined the associated steps and events, and mentally rebuilt their prior mental states to immediately resume work from those states (Table 9).

Table 8 Creating a simple mental framework to guide their actions.

Physical support participant 3-1-24 male: W*henever, I search something, Google, highlighted, purple colored, sites saying that you've already visited this. I might have, took out some information from it. It helped me to reach the correct site that I was looking earlier.*

Table 9 Separating work across dedicated browsers.

Physical support 2-19-24 participant male: *But the thing for me is that I just have three websites I use for all my work right now because I only have One responsibility, which is school. If I had multiple responsibilities, like school and a professional job, I would probably be using that feature.*

For both the physical and no-support groups, time was a factor in how participants resumed their contexts. Specifically, due to perceived time pressure, some participants described why they did not use bookmarks to resume context. The added effort required to find information and reconnect it was a rationale for not using this tool (Table 10).

For the digital group, the opposite effect was observed in one participant. Despite having all available resources at the start of a returning task, this participant experienced a sense of overload, needing to make sense of what was in front of them. This demonstrates that access alone is not sufficient to resume context. Instead, the conscious act of sense-making through interaction with materials—partly through associative memory and partly through the responsiveness of interactive media—is necessary (Table 11).

Table 10 Participant describes using conscious memory for resumption.

Digital support participant 2-6-24 female: *Yeah, so for bluntly remembering I do I guess it just comes into me I have a photographic memory for numbers and texts and so I can just remember I put them like the sake of having them on the desktop document is a bit more just formality and having something to write up the actual document later, but I can just remember it.*

Table 11 Participant describes skipping prior tasks over resumption attempt.

Physical support 2-19-24 participant male: *So in that 15 minutes, I said, rather than spending time going through history and looking at the tabs I was on, I'll just move on to this next sub task. And get that chunk of it done.*

V.7.2. Challenges

V.7.2.1. Challenges for Physical and No Support Group

For the physical and no-support groups, participants described the challenge of recovering a work context when their collected digital information was closed out between sessions. The key issue is how the on-screen digital elements of webpages and applications serve as implicit or explicit handles for resumption. By removing these resumption "handles," participants had to manually guide themselves in rebuilding their working contexts (Table 12).

Often, participants described how the state of their work acts as a resumption handle in itself. When they notice something about the state of their work on-screen, they can recognize unfinished tasks, providing an implicit cue about what they did previously and what they need to do next (Table 13). A key distinction in this challenge is not so much the loss of materials but rather the effort required to find those materials and recall how they were used for the immediate activity.

Table 12 Information overload affects resumption.

Digital support 2-9-24 participant female: *I always had, 30 things open, so I'd have many ways to get to the information I need. I found, it was also helpful to use suggestions, by, the Google has ads, and sometimes I would jog a memory to a different application, and that type of thing. I'd be looking for one type of thing, and I'm like, oh yeah, they also are very good for that type of thing. and then you just all of a sudden, just I, these people, this app doesn't help me. You just type into Google what the question is. Like, where can I find, how much is a comedian in CITY, STATE? You don't have to really have sight, you just have to ask the question.*

Table 13 On-screen elements serve as implicit or explicit handles for resumption.

Physical support 2-19-24 participant male: *I was a little surprised for the second time when I came back for this, and then I could see that on the desktop there was one icon, so I was able to go and okay, so it's like 3D icon, and that's the directory system, so that was the way for you to present it, so yeah, it was a refresh memory for me. So everything had to, again, read, because there were three tasks back to back. So I lost what was in my task plan. So I have to read again and then resume back.*

Of note, one participant described how the loss of resumption handles resulted in a discontinuity in their work. When their previous sub-task focused on finding flight deals, they forgot to return to this task due to the associated windows being closed. Instead, they moved on to the next task that had caught their attention in the sheet (Table 14):

Table 14 Loss of resumption handles resulted in a discontinuity of work.

Physical support 2-19-24 participant male: *I was going through I think three different websites or two different websites to look for flights. I think Expedia and Google. if I had those open, I would have gone back to flight planning. I would have gone back to looking at flights. But since I didn't have those open I thought to myself I'll just look at hotels. I have most of the flight plans anyways. I'll just look at the hotels.*

For participants in the physical and no-support groups, several noted that they grew accustomed to losing their information collections upon return and came to anticipate this issue. They compensated by using strategies such as maintaining links and status within an easily accessible Google Doc. From a resource recovery perspective, this approach would not pose a significant challenge. However, if this ability to maintain context were not supported by Google Docs, participants would still need to exert manual effort to recover and make sense of the resources once they were retrieved (Table 15).

Table 15 Compensation strategies to resume when information is lost.

Physical support 2-28-24 session A participant male: *I think just given how time sensitive the entire task was having to, if I wanted to revisit a particular place, having to take the time to reopen it. And in some cases, the effort to navigate to that place, especially web-pages that are not really able to be stored, or that I wasn't able to store by saving them in the Google Doc. I think that bit was frustrating. probably the most part of that.*

V.7.2.2. Challenges for Digital Support Group

While the digital support group was allowed to maintain their information collections between sessions, they still faced challenges in resuming their work contexts at the start. These issues were attributed to the recall and sense-making processes needed to cognitively re-engage with their working contexts using the materials at hand. Participants described difficulties in remembering what they had searched for on previous websites, initially experiencing a kind of lag in consciously recalling their previous activities. During this lag, if they could not precisely remember what they had done previously for a context, they might inadvertently redo work they had already completed, particularly if they did not have a coordination document to refer to. As one participant explains (Table 16):

Table 16 Participants' difficulties in remembering what they searched for previously.

Digital Support 1-8-24 participant female: *So the thing that was challenging was remembering what websites I had already visited. And if I like, already looked up the previous items, cause specifically for the hotels, I kept running into the same, places I looked at even throughout like different websites, like "Booking.com". I remember specifically, there was like, oh, I'm like, oh, this one's a really cheap hotel, and then I look back on my Google Doc, I'm like, "Oh wait, I already have that one."*

In connection with the theme of losing one's sense of place despite immediate access to work-context related information collections, this "loss" can be attributed to two factors: (Table 17 A) not making explicit notes on what had been completed previously, and (Table 17 B) knowing that a key information item exists but being unclear about where it was located or how it was encountered in the first place.

One factor contributing to the aforementioned challenges for the digital-support group is the size of the display screen itself (Table 18). As mentioned previously, all participants worked on their tasks using a 15-inch HP laptop. Maintaining their digital contents on screen for one context and across all contexts was described as a challenge. The large number of accrued websites, tabs, and documents throughout sessions resulted in added effort to manage the screen, including moving contents around or closing them out.

Table 17 Losing one's sense of place to work-context related information collections.

A) Researcher: *Okay. now, when you're looking at the Google Doc, were there anything that, did you leave any explicit notes for yourself, like meaning, no, you should do this next time?* **Digital support 1-8-24 participant female:** *No, I did not. The only thing that like I could think of is, I forget which example was, but I was trying to calculate the cost as I was going to, so I could be under my budget while looking for the next item.* **B) No Support 2-12-24 participant female:** *Because I ended up closing the tabs, there were a few that I wasn't able to find again. Which was frustrating. Because I knew it was there, but I couldn't, and I tried to retrace my steps, but I couldn't remember how I got there.*

Table 18 Challenges for the digital-support group is the size of the display screen.

Digital support 12-19-23 participant male: *Having just the one laptop with the 1 screen makes organization difficult and flipping between. Tabs and websites, if you could have an extra screen or 2. Or just some kind of a platform that allowed you to multitask or switch places, more quickly and efficiently, than just manually, clicking back and forth, would be helpful.*

As digital-support participants returned to their working contexts, a common theme was the visual clutter that arose over time. This clutter resulted in increased effort to organize when re-accessing and was perceived as confusing upon return, making sense-making a challenge (Table 19).

Table 19 Increased effort to organize visual clutter after return to context.

Physical support 2-20-24 participant male: *But then it got chaotic and it was a little stressful seeing the arrangement of the windows and tabs open.* **Researcher:** *Okay, describe how was it chaotic?* **Physical support 2-20-24 participant male:** *it was just a bunch of, since it's so small I feel like it's just, you're reading so many little things and it can get frustrating when it's not what you're looking for. Or, you're just, you start at the beginning, and then you went to the end, and by the time you found it, it was, like, chaotic.*

V.7.3. Designing for Support to Challenges

One of the final interview questions asked participants to reflect on their prior experiences in managing multiple project contexts and the resources they use to support their practices. We will describe the themes of suggested improvements for supporting working contexts. By asking these questions, we aimed to understand how existing software could be improved or implemented to better support the resumption of computer-represented working contexts.

One participant described having a method for visualizing the history within a given working context. This method involved scrolling through a series of snapshots of their browser at different states of work, allowing them to traverse the working context by the hour (Table 20).

Participants often suggested a smart task aggregator, featuring an intelligent agent running in the background that tracks their activities based on time, frequency, and combinations of information items accessed and edited. This hypothetical agent would be aware of activities at both the project level (Table 21) and the individual task level within a project, provided that the tasks are common enough to warrant a consistent approach (Table 22).

Table 20 Design suggestion: visualizing the history within a given working context.

Digital support 1-8-24 participant male: *I wish there was, like, an easier way to, for if you're using a specific browser to, show, I know, specifically if once you click a browser and you go back to it, it usually turns from blue to purple. But if you, completely, close down the application and open it back up, then, it goes back to being blue. So maybe if there was, like, a way, to put, a window, specifically, working for a project, so that, oh, from this day to this day, from this hour to this hour. Any, links that you open up, it, turns purple and stays purple, instead of, Oh, you close it, you open it back up and you forgot all your web-pages and what you've already visited and all the information you already looked at, so then you're backtracking.*

Table 21 Design suggestion: smart task aggregator for working context.

Digital support 12-19-23 participant male: *Yeah, some kind of, AI or assistive technology, that would possibly help you, let's say that you picked a, price for a certain computer, That would. It would know the number of people that you needed and it would do the math quickly and immediately tell you, what that cost is and where it fits into your budget. So you can make a more informed decision on, maybe that's not the best one. I'll move to the next one and look at the pricing on that. Otherwise, you'd have to write down everything, calculate it. manually enter the budget if there's some kind of an assistive device or technology to do that while you were doing it simultaneously.*

Another suggested design theme was the use of a marker of sorts. While acknowledging the utility of bookmarks for webpages, participants suggested extending this concept to not only organize and consolidate information collections but also provide context on why these collections were formed and how they were previously used (Table 23).

Table 22 Design suggestion: frequent tasks represented as working contexts templates.

Digital support 2-9-24 participant female: *If you had a form for conferences or for vacation that had all of the travel airfare and just being able to take. A web-page or a copy of something and have it know where all the things go, that would be really great. given what is now capable of certain things, it might actually be able to do that. Yeah, just being able to, grab that information or use the form itself to just say, I, have a form that says event. And, these are the things and saying, I want an event that's going to host. Where you just put it in there and say, it's in this location. It's going to, I want it, to have open bar. I want to have, three course meal and entertainment and have it be able to go to the web and aggregate that data out. That would be really helpful. I don't know if it already does that.*

Table 23 Design suggestion: Work context provide history and progress status of work.

Digital support 2-5-24 participant female: *So one thing I noticed, so after my break, I immediately started a new task. so if I'm working on any one task and I, if I'm taking continuous breaks. So like after breaking after the, after my break, when I come back to work, if there, if. Something like, the system tries to remind me of where I was or like, where I like what part of my, what part of my work is still remaining. So if it does, if it just reminds me of what, was the work that was left behind. I can, bring back my focus so that I can start from that point.*

V.8. Discussion

V.8.1. RQ-1: Are there any differences in mental workload in KWs when they are variably given support for computational work context resumption?

We understand intuitively from our own daily work experience that when one loses place or resources in resuming a project especially one that is represented in a personal computer, there is frustration and effort required to re-access these resources, but less obvious though is how we make sense of these resources when they are brought together and assembled in ways that make sense to us. We saw that the digital group had the least pupil diameter change and size during the recovery period, suggesting that this group encountered less cognitive strain when resuming when we compare against the other groups (DV-1:MWL).

When we assemble together our information collections for a context, we don't merely start jumping into our working context. Instead, we observe what is in front of us, working with our previously assigned meanings to the icons and windows on our computer desktop, and mores, their visual arrangements. As Rule et al. 2017 (Rule et al., 2017) described, these on-screen elements can possess cues, whether implicit and/or explicit that can guide us in our sense making efforts, and ultimately leading us to recall. Essentially this period of active sensemaking through the presence of cues related to our on-screen elements is what is responsible for us to "context switch" into a different working contexts.

From a DCog perspective, the cues for context resumption are embodied from their visible state on the desktop by way of their relative location on the desktop, content present in a given window, and also the state of content in a given window (e.g., an incomplete section in a bulleted list). When looking at our results from a CDM perspective, the power of the available on-screen cues to meaningfully inform one's working context are embodied in the extent that those cues as part of an environment can resemble or match the working context environment as experience by the KW, potentially triggering CDM. When participants returned to their individual working contexts, these cues are referred to and are actively used with their own conscious thoughts to make sense of what they see in front of them and get to a point, cognitively, where they understand their perceived context and plan for further actions in said context.

V.8.2. RQ-2: Are there any differences in resumption lag in KWs when they are variably given support for computational work context resumption?

Concerning resumption lag, we saw how the digital supported started earliest, then No Support, and finally, the Physical group (DV-2: Resumption Lag). Resumption lag experienced by participants could be interpreted in the time gap between starting up a previous work context and working intently in it as the time needed to first re-access materials, make sense of those materials, and plan for next actions. Resumption lag can be thought of as existing as a facet within resumption lag both in the perceived pressure to get to an active working point in the work context, but more importantly, in accessing related materials, are they immediately recognized or is there more mental work needed to understand their relevance for a given working context?

In our comparison across the different groups, we were examining the effects of removing these cues variably from digital, physical, to no cues at all. Resumption lag and MWL experienced by participants can be explained as the added as the joint effect of the following: 1) Is previous context related on-screen items are present?; 2) If they are present, are they meaningful for the user to make sense out of?; 3) If they aren't present, what effort is needed to re-access this information to make sense out of it?

We also saw the ways that users can face certain challenges to how resources encountered across conditions can be frustrated. For the physical and no-support group, we found that while there was added effort in resuming a work-context in effort in recovering resources, the effort in this case is more attributed to losing the handles that are the implicit cues of prior activity, and less in the manual recovery of the resources themselves, the end result being discontinuity in re-engaging the work-context, consequences including the potential of unnecessary, rework. Similarly, for the digital support group, the challenges they faced were less in having access to their information collections, but having to make sense of it in the first place. As participants work across their sessions, they collect their information items over time, accruing as tabs and windows. While the resources are available and potentially re-accessible, their function as cues is frustrated where their groupings may be lost or obscured in their tab, window, and desktop arrangements, making it potentially difficult for users to effectively wield them as cues to return back into a given work-context, again resulting in more effort in sense making and potentiality for discontinuity of work.

V.8.3. Native Supports for Computational Work Context Management in personal Computing

Across the three groups under study, we identified the existing ways that personal computing devices aid in work context resumption. For the digital support group, the participants had access to multiple types of resumption means. At the browser window level, we saw that existing supports like tabs, link history, and search query history. Web-applications like Google Docs, maintain context by way of their cloud platforms, ensuring that existing work continues, regardless of what happens to browser windows or which device it is being accessed from. We also saw how, when participants can maintain their information collections, as there work day progresses, accrues, taking on qualities not unlike 'files' and 'piles'. What we have noted so far is not novel. What we like to point out is exactly how these different resources capture context as isolated, discrete elements, rather than reflect their inter-connectivity to one another and how they can embody the meanings for its owners. As some participants noted for the physical and no-support group, when relying solely on Google Docs to aid in context resumption, not everything could be preserved within web-application, working within the limits of it by embedding links and writing notes in it, but losing any cues that arise from the flow of work. The digital support group had their own issue while they can maintain their related information collections, because they accrue over study sessions, can result in visual clutter if screen real-estate is at a premium. Of note, the issue is not so much visual clutter, but how the visual clutter makes it difficult for users to readily identify their information items, their relationship with one another, and effectively organizing them, as suggested by our pupillometry data.

V.8.4. Design Implications

Based on our findings, we provide three design guidelines to inform the support of digitally represented working contexts when situated in personal computing environments.

V.8.4.1. Resumption Beyond Re-access: Meaningfully Informing Context Switch

For knowledge workers (KWs) to effectively resume their working contexts, merely re-accessing the materials is insufficient. Upon retrieval, these materials should provide information that meaningfully informs the state of the working context for the individual. This is achievable by maintaining a clear representation of the working context, arising from the interconnections among the digital resources that comprise it. With a clear representation in view, there is a higher likelihood that this representation will interact with the user's embodied memory, triggering the return to a mental context and reducing the cognitive effort required to consciously recall prior states of work.

In applying this implication, we can consider how a context can provide meaningful representation. A straightforward approach could involve creating a distinct document placed within the immediate location where the contents of a work context are collected, whether in a local file system or a cloud drive. Extending this idea further, one might envision a historical snapshot manager, where a background application can track and manage the evolution of a working context. This tracking could be done explicitly (e.g., the user informs the application that they are working on a particular context) or implicitly (e.g., a sophisticated multimodal model is trained on the user's unique working contexts, identifying relationships based on the frequency of shared use, on-screen activities, and labels applied to documents across applications and browsers). Taking this a step further, such an intelligent agent could infer the nature of the user's working contexts and provide context-aware suggestions based on its continually updated understanding, functioning similarly to an executive assistant typically found in C-suite management.

V.8.4.2. Support Capture and Representation of Digital Handles for Explicit/Implicit Cues

When knowledge workers re-access their materials to resume a context, the cognitive shift from one working context to another is facilitated by the presence of cues. Cues can be understood in two forms: implicit and explicit. Implicit cues refer to the ways in which the state of work is made persistent and can be intuitively recognized by the user. Explicit cues, on the other hand, are more deliberate actions, such as writing a note to oneself, leaving a text document open for reference, or sending a reminder email. The workflows that knowledge workers employ to resume contexts often revolve around capturing and maintaining these cues, as they serve to structure and sustain their work processes.

As a design guideline, it is crucial not only to implement these features but also to understand where they can be effectively integrated and how they can become persistent within one's working context, ensuring they can be reliably used to resume a context. One approach could involve a background agent that captures not only the windows, browsers, and applications in use but also their exact arrangements at different times of work. This method allows implicit cues arising from the natural states of work to be used alongside explicit notes that individuals might leave for themselves as they transition between different working contexts. This approach could also interact with the dynamics of available screen real estate for users. In situations where users are limited to a small display, such as on a laptop, they could create additional desktop spaces—similar to the multiple desktop spaces in macOS—where each space could be treated as a "file" at the scale of a desktop. These spaces could be loaded in and out as needed, rather than being maintained as background processes when not in use.

V.8.4.3. Design for Workspace Interconnectivity Rather Than Task-Specific Focus

For each working context that a KW engages in, there is typically a central goal that is achieved through the production or use of a specific document or application, which serves as the focal point of the activity. In maintaining this context, the document or application acts as a hub, unifying and coordinating all related activities within that working context. We observed how Google Docs often serves as this central hub, but this concept could be extended to any other document, application, or interactive window that fulfills a similar role. However, we also noted the limitations of using such resources as a central hub, particularly with issues like maintaining links solely within Google Docs.

A way to better support working contexts is by focusing on creating workspaces that are not tied to a particular application, but instead allow associated work to be linked, collected, and re-accessed as a cohesive unit. This approach offers the clear advantage of reducing the mechanical effort required to recollect and reconstruct assemblies of work. Additionally, it could enhance the perceived cohesion of the contents from the knowledge worker's perspective.

V.8.5. Limitations and Future Considerations

Our study had sought to understand KWs practices in computationally supported work context management, using a mix of objective and subjective measures of simulated work experiences alongside qualitative interviews to capture the specifics of user behavior in this facet of work. However, our study is not without limitations. First, concerning study design. Our use of a small number of participants is a compromise attributed to the long duration (2.5 hours) of the study. To simulate building and resuming contexts, it was necessary to include the duration of each study block, the number of blocks, and the frequency of re-engagement. Future iterations of this study could address these issues in two ways. First, to improve inferential power with small populations, the study could be modified to focus on two tasks instead of three, placing greater emphasis on eye-tracking during on-screen context resumption activities. Another approach could involve adopting a more naturalistic, longitudinal design, where participants record their on-screen activities and journal their experiences. This would allow us to observe how personal computing context-switching behaviors arise, the strategies employed, and the challenges encountered. Such an approach would shift away from the artificial nature of experimental simulation and embrace the complexities of everyday modern work.

Second, another limitation of the study is the nature of the work context tasks themselves. In the experimental design, the tasks were created in a generic manner, focusing primarily on establishing conceptually different categories. This approach does not fully reflect the complexities inherent in real-world projects. In reality, tasks are often less clean and well-defined, varying significantly depending on an individual's role within an organization or their personal work style. As noted by Gonzales and Mark in their study of working spheres, individuals' work groupings can easily overlap based on shared activities, resources, and the people involved. Future research in this area could explore how conceptually similar working contexts are distinguished from the perspective of their owners and compare these approaches to those used in conceptually distinct working contexts.

Third, the time scale examined in this study. We focused on context resumption within the span of an hour or less. As one participant noted, resuming after an hour may not be as challenging as it would be after a day or even a week. In reality, individuals resume their working contexts at various time scales—whether within the same hour, day, month, or even years later. We chose this approach for pragmatic reasons, aiming to explore computer-supported work context management within a reliable time frame in a single day, rather than extending the study over several days. The effects of resumption lag and the strategies used to effectively cue back into a working context may vary depending on the time elapsed, requiring different strategies to support such workflows. Future studies could incorporate both in-lab and longitudinal designs to investigate how time scales influence context resumption in personal computing workflows.

Finally, concerning our approach in comparing and analyzing the two eyes separately. In our study, there were larger differences between eyes in the Party Plan context over the other task types. There are a number of reasons why the differences could have occurred due to eye scanning or lighting dynamics. Prior work has found how pupil diameter can change asymmetrically depending on task complexity, emotional arousal, and light exposure, which could variably affect cognitive load (Knapen et al., 2016; Pfleging, Fekety, Schmidt, & Kun, 2016). In such studies, it was found that pupil size increased asymmetrically under high cognitive workload conditions. This could be the case during delayed recall tasks, suggesting that mental effort could trigger uneven pupil dilation. Another attribute, concerning lighting conditions, could be attributed to changing luminance of on-screen content. Changes in screen brightness could lead to distinct asymmetric reactions in each eye's pupil; this is the case hen one eye may be more exposed to variations in luminance than the other (Pfleging et al., 2016). For future work, concerning analysis, we will examine to see if there are any statistical significance between individual pupils and averages between the two eyes. By undertaking this analysis, we can understand the efficacy of our data if pupil changes can be attributed to cognitive stresses subject to a task condition variation or extraneous elements in the study.

V.9. Conclusion

Work context management reflects the ways in which knowledge workers regard their projects and how they actively think and engage them through their set of unique tools, goals, and collaborators involved. In contemporary modern information work, work contexts are undeniably represented computationally through the ways that digital and physical media resources are orchestrated together to support activities towards work contexts. In our study, in acknowledgement of the challenges that users face in switching attention between working contexts, we sought to understand how the different kinds of media that are associated with digital working contexts are strategically used to support resumption. Our work illustrated the exact role that implicit cues and explicit cues arise in activity and their effects in the resumption process. Based on the role that cues play in support digital work context management and resumption, future work will examine how the practices of KWs can be supported and augmented in exploratory designs in UI and UX design.

CHAPTER VI THERE AND BACK AGAIN? INVESTIGATING THE ROLE OF CONEXT REINSTATEMENT CUES FOR TELECONFERENCING/ IN-PERSON MEETINGS

VI.1. Introduction

Another facet of contextual modern information work is not only at the individually owned contexts they interact with, but those that are shared with collaborators. Often, such collaborative contexts are engaged via extended in-person meetings. During the 2020 COVID-19 pandemic, this facet of office work was shifted towards the use of online video teleconferencing in an effort for the quarantine lockdown to ensure the safety of individuals while maintaining productivity in shared workplaces. Video teleconferencing has seen increased usage across society since 2020, with platforms like Zoom gaining 300 million daily users ("Zoom says it has 300 million daily meeting participants, not users," 2020). Additionally, Zoom reported earnings of $1 billion in 2021 and holds a 60% market share of teleconference applications (Mendoza, 2021; Preimesberger, 2021).

While teleconferencing technology has been available for several decades (Egido, 1988), its initial design did not consider modern cultural contexts (Wilson, 2021). As teleconferencing has become a key facet of modern information work, individuals and the media have recognized a phenomenon known as *Zoom Fatigue*, i.e., the sense of exhaustion from being on videoconferences all day (J. Bailenson, 2020). Bailenson et al.'s initial studies report that 67% of users experience high levels of Zoom fatigue. Numerous physicians and health organizations have identified this as a growing health issue (Nadler, 2020). Users report symptoms such as reduced concentration during meetings, leading to boredom, loneliness, or indifference, which significantly impact online collaboration (Fu, Li, Liu, Pirkkalainen, & Salo, 2020; Ravindran, Yeow Kuan, & Hoe Lian, 2014). Outcomes of Zoom fatigue include irritability, elevated stress, depression, anxiety, and decreased memory retention (Harvey, Wessely, Kuh, & Hotopf, 2009; Ngien & Hogan, 2023; Williamson et al., 2005).If teleconferencing continues to be relied upon in the workplace, it could reduce the effectiveness of stakeholders and, by extension, organizational functionality.

While the phenomenon of Zoom fatigue is well-documented, there remains much speculation about which aspects of teleconferencing platforms contribute to users' reported symptoms (Nadler, 2020). Bailenson attributes nonverbal overload as a possible cause of Zoom fatigue, citing factors such as close-up eye gaze, cognitive load, increased self-evaluation from video, and restrictions in physical mobility (J. N. Bailenson, 2021). Kleiman et al. and Jushchyshyn et al. argue that Zoom fatigue could result from teleconference interaction outcomes like passive participation (e.g., silently listening to a Zoom call while checking email) and ambiguous social cues (e.g., waiting for a moment to offer a spontaneous thought during a call) (Jushchyshyn & Parks, 2021; Kleiman, Meijer, & Janssen, 2020). These issues may be due to limitations in current teleconferencing platforms, specifically the design of breakout rooms, awareness of others' activities (Bartindale, Chen, Marshall, Pozdniakov, & Richardson, 2021), online learning platforms (Cumbo, Bartindale, & Richardson, 2021), or the spectrum of engagement (e.g., a participant can listen and have their video on but not concentrate on the meeting, or have their video off and appear engaged while actually playing a game) (Kuzminykh & Rintel, 2020). From an embodied-interaction perspective, Dourish suggests that fatigue, boredom, and loneliness stem from the disconnect between our embodied capabilities for collaboration and the design of current collaboration platforms (Dourish, 2001b). As the use of teleconferencing applications grows, it is necessary to understand how stakeholders use and experience these platforms to design effective interaction schemes (e.g., how the speaker and audience are represented on screen) and implement features (e.g., improved document-sharing) that enhance user collaboration and well-being (Ngien & Hogan, 2023).

This paper explores two contributing sources of Zoom fatigue: disembodied context switching across meetings and the lack of physical support and grounding for these cognitive transitions. We aim to characterize the differences between in-person and teleconference-based meetings, specifically regarding how sequential meetings are navigated and the role of inter-meeting traversal in providing cognitive transitions to and from meetings.

First, we need to consider the nature of in-person meetings. These meetings are situated in a specific time and location. After an in-person meeting concludes, several steps typically occur before the start of the next meeting. First, there is travel between meeting sites. Second, upon arrival, there is the recollection and reorganization of relevant materials, whether digital or physical. Third, there is the exchange of acknowledgments and reintroductions among meeting members.

Notably, as one goes through this sequence, they are exposed to a number of features associated with the environment that could aid in memory reinstatement of each meeting site including physical (e.g. the path to the meeting, room, lighting, odors, and persons present) (S. M. Smith, 1979) and digital objects (e.g. specific web pages, documents, and applications present on the shared screen)(Rule, 2015; Rule & Hollan, 2016; Rule et al., 2017). In comparison to in-person meetings, teleconference meeting participants can accomplish meeting transition with a click to a link to a specific teleconference meeting, instantaneously connecting the remote worker with their collaborators, leaving only acknowledgments and re-introductions as the subsequent step in meeting initialization.

Of note, while we could have considered including back-to-back in-person meetings in the same building/room as a another comparison group for our study, and current scope of interest was illustrating the contrast in inter-meeting traversal between in-person and teleconference based meeting scenarios. Future studies will utilize the added variable in comparing between in-person and teleconference meetings by how rooms are held constant for in-person information workers and vice-versa for teleconference meetings (e.g., how might zoom fatigue in inter-meeting context switch be alleviated if the information worker can change physical rooms?).

We hypothesize that the rapid context-switching in teleconference-based meeting transitions impairs environmental reinstatement capabilities. This impairment is attributed to the loss of physical cues associated with travel to a meeting space (S. M. Smith, 1979, 1982, 1984, 1985). Additionally, reinstatement challenges arise from the demand for information workers to manage lingering digital resources from previous meetings while preparing resources for the current meeting (Rule, 2015; Rule & Hollan, 2016; Rule et al., 2017). We pose the following research questions for our study:

- **RQ-1:** How do users' experienced effort toward context switching differ between in-person (INP) and teleconference (ZOOM) contextual collaborative meetings?
- **RQ-2:** How does the modality of a contextual collaborative meeting influence how associated information collections are accessed and used for contextual reinstatement?

VI.2. Theoretical Foundation

In our inquiry towards supporting work context switching via collaborative, sequential teleconference scenarios, it is necessary that we have the appropriate theoretical lens to explain how individuals organize and coordinate amongst themselves through these tools.

VII.2.1. Teleconferencing and Synchronous Group Work

Teleconferencing technology has been around for several decades; in its early use it was primarily used by managers who have to support large corporate meetings (e.g., annual stockholder meetings) (Egido, 1988). Historically, the society-wide adoption of teleconferencing technology was hampered by high bandwidth costs, lack of distant network infrastructure, supportive high-resolution imaging and audio equipment, and a technically-savvy workforce to effectively use it, as was the case of Edigo's review of the state of the technology in the 1980s.

In contemporary usage, as of this publication, the context of how teleconferencing technology is used is markedly different, made possible by the joint technical advancements in video-telephony, computing, and the nature of modern information work. Gonzalez and Mark have identified that most information workers engage in multi-tasking roles across various projects. The demand for this kind of information work is a consequence of companies doing more with less human resources and higher expectations of tasks and responsibilities of each employee, effectively acting in the same capacity as administrators and managers across their projects (González & Mark, 2004, 2005).

VI.3. Meeting Representation Collaborative Laboratory Study

A major requirement for our study scenario is the need to simulate the goal-oriented nature that information workers typically encounter (Drucker, 1974; Kidd, 1994). For the study, we had three participants per study session working together across three conceptually distinct working contexts, each with the end-goal of producing a summary document that outlines their findings and provides actionable suggestions to complete their tasks (See).For example, if the participant is working on a travel budget report for a trip to San Juan, Puerto Rico, the report would include the exact dates, tickets, travel means, and housing accommodations to make the trip possible. The study is designed to create a scenario where individuals work intently within a given working context, stop what they are doing, organize materials for future re-access, and traverse to their subsequent working context, akin to the experience that knowledge workers would experience in their office or remotely.

VII.3.1. Work Context and Task Description

For a given study session, the three participants work collaboratively across three working contexts, each based on a specific set of tasks. The three working contexts include: 1) Travel Planning for a Vacation (Vacation); 2) Technology Purchase for a New Office (Technology); and 3) Planning a Party Event (Party) (See Figure 2). For each working context, there are a set of open-ended activities that are to be completed with respect to a monetary budget to work under. For example, the Vacation working context involves creating a budget report for conference travel that has an allotted budget of $8000; participants will need to work together to research tickets, travel accommodations, lodging, and food provisions for a specified duration, ultimately described in the summary document. The activities are deliberately designed to be challenging, requiring close attention and coordination between two individuals. Importantly, these tasks are unlikely to be completed in a single continuous session, fostering conditions for participants to consciously recall prior activities and recollect resources upon their return.

To facilitate these tasks, participants are provided with laptops equipped with a range of applications, documents, and web pages. The laptops were 14.5 inches in display size and ran the Windows 10 operating system. Participants are encouraged to leverage these resources in crafting the summary document.

VII.3.2. Role Distribution

For each individual study session, a collaborative team of three participants, designated as *'P1'*, *'P2'*, and *'P3'* jointly engages in tasks across three distinct working contexts. Within each study session, participants are assigned specific roles for each working context, (*i.e., project lead or project assistan*t). The project lead, defined as the individual responsible for assessing tasks at a given time and delegating specific responsibilities to the project assistant, plays a crucial role in guiding the team's efforts. While tasks within a working context are shared between the project lead and project assistant, the project lead holds the authority to approve or correct actions undertaken by the project assistant. To ensure a balanced distribution of responsibilities, each participant is assigned one working context as the project lead and another as the project assistant. Figure 8 Schedule of meetings during the study. Figure 8-A illustrates the allocation of participants (*designated as P1, P2, or P3*) across the various working contexts, specifying their roles as project lead or project assistant. For instance, in Figure 8, section A, the participant designated as P1 serves as the project lead for the Vacation working context and as the project assistant for the Party working context.

VII.3.3. Variables under Consideration

VII.3.3.1. Independent Variables

The between-subjects study manipulates the independent variable of collaborative activity type between the conditions of in-person (INP) and Zoom-based (ZOOM) meetings. We defined the INP condition where participants for a given task scheduled for a particular block of the schedule meet in a specific, predefined office room to work on the task specific to that space. When time is up for the given time block, researchers led participants to their next room where they work with a different partner for a task, where the participant acts as a project lead or as a project assistant (Figure 8-B). The ZOOM condition differs where participants work with one another in different specified breakout rooms and are manually moved to specific breakout rooms by the researcher. To maintain control, the same study facilitator was employed for both the in-person and teleconference-based collaboration studies.

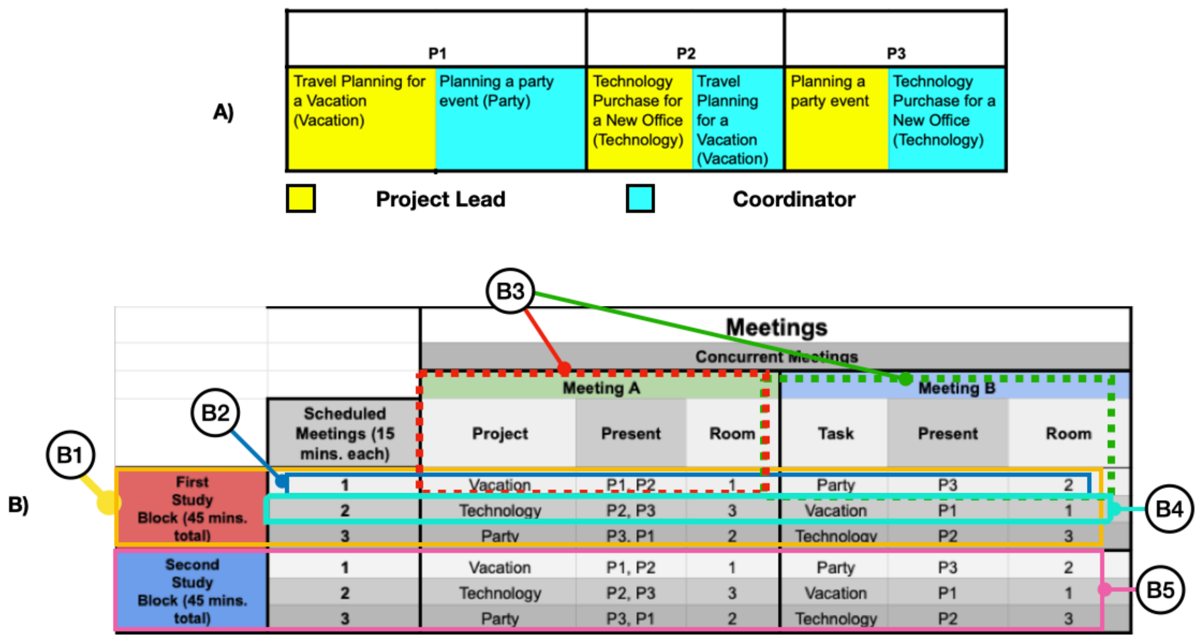

Figure 8 Schedule of meetings during the study.

When all participants arrive at the researcher's lab, they are given a consent form that describes the study's activities. After participants sign the consent forms, they are given a pre-study survey to account for the kind of work they do on a regular basis (i.e. whether or not they are an information worker), the types of resources they use in managing their work contexts, and the challenges (and respective solutions) that they frequently encounter (Table 3).

Study: Figure 8-B illustrates the structure of the study schedule. The annotations B1 through B5 provide a guide on how the agenda unfolds. Beginning at B1, we note that the study is divided into two distinct, repeating blocks, each lasting 45 minutes. At B2, we illustrate that within each block, there are three meeting times scheduled sequentially, each lasting 15 minutes.

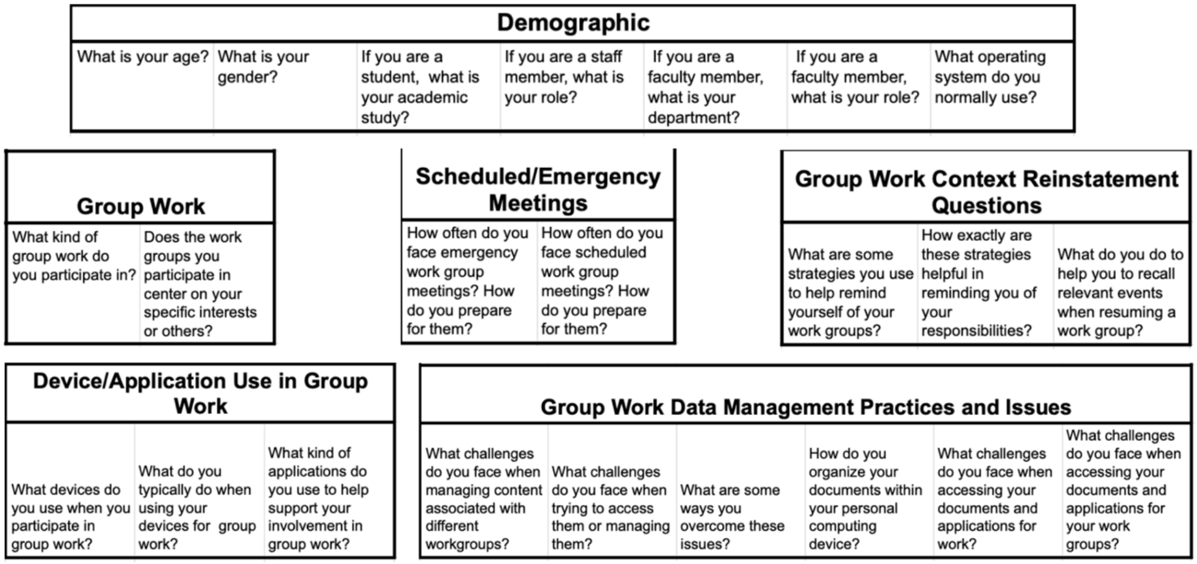

Figure 9 Pre-study survey.

At B3, we note that during each meeting duration, two simultaneous meetings take place, each in its designated setting: either a physical room for the INP condition, or a teleconference breakout room for the ZOOM condition. During each meeting time, participants are arranged either in pairs or individually, depending on the specified task for the scheduled meeting and the participant's designated role, i.e. project lead or project assistant (see Section, *Role Distribution* (above)). For example, during the 1st meeting time, P1 acts as the project lead while P2 serves as the project assistant; concurrently, P3 works alone on their assigned project as project lead.

Of note, within each 15-minute meeting sub-block, a solo participant engages in a dedicated session. This period allows individuals to make continuous progress independently, without the presence of the project assistant. The purpose of this intentional inclusion is to simulate a scenario where each participant experiences working alone, as a preparation phase before a meeting with another collaborator takes place. We had made this design choice to reflect the diverse scenarios individuals encounter in meetings, whether actively participating in a project meeting or preparing for one. The design facilitates coordination across the three participants providing a sufficient number of opportunities to change attention across working contexts while being cognizant of time constraints for the experiment. If we had only two participants working together across different working contexts, while a switch would be possible, the participant a would still be working with the same partner for the other working context. Had we gone with 4 or more working contexts, while this would allow for more opportunities for context-switching within the study, the added working context would increase the time for the both study blocks while increasing the collective study time needed for completion. Altogether, the choice of using 3 participants for a given study session represents a compromise between practicalities of conducting the study in spite of time constraints.

Moving on to B4, we progress to the subsequent row, illustrating that after the first project meeting time expires (i.e., the vacation and party project meetings end so the participants move on to the technology and vacation meetings), the researcher guides participants to their meeting. The researcher adjusts the exact pairing for each successive meeting; this pattern is repeated in the subsequent row.   Finally, at B5, After the third meeting is completed for the first study block, the second study block begins participants are lead to their first project meeting from the start of the block, repeating the overall study sequence once more.

VII.3.3.2. Post-Study:

Upon completion of the final scheduled project meeting, researchers assessed the cognitive workload experienced by the participants in the study. We used the NASA Task Load Index (NASA-TLX), a subjective, multidimensional assessment that is used to rate one’s own perceived workload with respect to a particular task, device, or team (Colligan et al., 2015), to measure the participants’ perceived workload from their supplied computers during their study condition and to consider how differently dimensions are perceived during performance (see column A of Figure

10 for the original NASA-TLX survey design). The NASA-TLX was originally developed by the Human Performance Group within NASA's own Ames Research Center, validated across over 40 laboratory experiments and used across the domains of human factors, aviation, healthcare, and anywhere there are socio-technical interests (Hart & Staveland, 1988b).

	A	B	C	D	E	F
Survey Type Name	**Original NASA TLX Survey**	**NASA-TLX Survey (General for Study)**	**NASA TLX Survey (Apps)**	**NASA TLX Survey (Documents)**	**NASA TLX Survey (Operating System)**	**NASA TLX Survey (Websites)**
Instruction:	*Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.*	*Instruction: Please respond to the survey with respect to your ability to reengage the websites you need for your different tasks.*	*Instruction: Please respond to the survey with respect to how you were able to re engage the apps associated with your different tasks.*	*Instruction: Please respond to the survey with respect to your ability to re-engage the documents you need for your different tasks.*	*Instruction: Please respond to the survey with respect to how the operating system enabled you to re-engage your different tasks.*	*Instruction: Please respond to the survey with respect to your ability to reengage the websites you need for your different tasks.*
Mental Demand:	*How mentally demanding was the task?*	*How mentally demanding was it to return to your work during the study?*	...	...	...	...
Physical Demand:	*How physically demanding was the task?*	*How physically demanding was it to return to your work during the study?*	...	...	...	...
Temporal Demand:	*How hurried or rushed was the pace of the task?*	*How hurried or rushed was the pace to return to your work during the study?*	...	...	...	...
Performance:	*How successful were you in accomplishing what you were asked to do?*	...	...	...	...	...
Effort:	*How hard did you have to work to accomplish your level of performance?*	...	...	...	...	...
Frustration:	*How insecure, discouraged, irritated, stressed, and annoyed wereyou?*	...	...	...	...	...

Figure 10 Adapted NASA-TLX for study.

For the study, we adapted the NASA-TLX to consider how work context switching is experienced as a cognitive load from the perspective of the activity as a whole and with respect to elements that represent computationally represented working contexts these including applications, documents, operating system UX/UI design, and websites (see row "Survey Type Name" and columns B through F of Figure 10). In terms of adaptation, we changed the instruction for each based on the perspective of activity of interest (see "Instruction" row, columns B through F of Figure 10) and the three demand questions (i.e., mental, physical, and temporal) (see rows 3-5 of column B). The only questions that were modified were the 'performance', 'effect', and 'frustration' (see rows 6-8 of column B).

In the interest of gaining granularity of the participants' experience in context-switching across projects, between meeting modalities, we created a set of questions to use as interview questions to be conducted at the end of the study. The researcher conducted the interview with a prepared set of questions, following a semi-structured format, to gauge the participant's experience of the study (see Table 4).

VI.4. Study Results

VII.4.1. Study Participants

A total of 29 university-affiliated individuals participated in the study. We recruited our participants through advertisement to the overall university community by using our university's e-mail service. There were 15 participants in the INP condition (7 female and 8 male) and 14 for the ZOOM condition (9 female and 5 male). Participants' age ranged from 18 to 45 years. With respect to academic background, participants were members of the university's college of engineering (N=8), business (N=2), architecture (N=7), agricultural and life sciences (N=4), arts and sciences (N=1), general studies (N=5), and two were faculty members.

VII.4.2. Quantitative Results

We were interested in identifying differences between the in-person and teleconference-represented collaborative groups. Owing to the small population, we ran Mann Whitney U tests on participant's NASA-TLX survey report, testing for statistical significance between INP and ZOOM groups. The INP group was significantly higher than the ZOOM-represented group for *Mental Demand for Documents* ($U = 162.0, p = 0.04$), *Physical Demand for Documents* ($U = 162.5, p = 0.0477$), *Effort for Documents* ($U = 164, p = 0.0415$), and *Physical Demand for Websites* ($U = 158, p = 0.0284$) (Table 24, Table 25, and Figure 11). There were no statistically significant differences between groups on the NASA-TLX items for websites (mental demand, temporal demand, performance, effort, and frustration) and documents (temporal demand, performance, and frustration).

Table 24 Statistical analysis of NASA-TLX subjective ratings (documents and websites).

	Documents		Websites	
	Statistic	P-value	Statistic	P-value
Mental Demand	162	0.0499	127	0.2730
Physical Demand	162.5	0.0477	158	0.0284
Temporal Demand	122	0.4762	122.5	0.3385
Performance	116	0.5708	124	0.3154
Effort	164	0.0415	141	0.1174
Frustration	96.5	0.8290	104	0.6383

Table 25 Statistical analysis of NASA-TLX subjective ratings (OS UX/UI and applications).

	Operating System UX/UI		Applications	
	Statistic	P-value	Statistic	P-value
Mental Demand	129.0000	0.2460	128.5	0.2522
Physical Demand	124.5000	0.3081	134.5	0.1792
Temporal Demand	104.5000	0.6307	110.5	0.5332
Performance	137.0000	0.1535	129.5	0.2389
Effort	123.0000	0.3306	151	0.0541
Frustration	81.5000	0.9019	94	0.7804

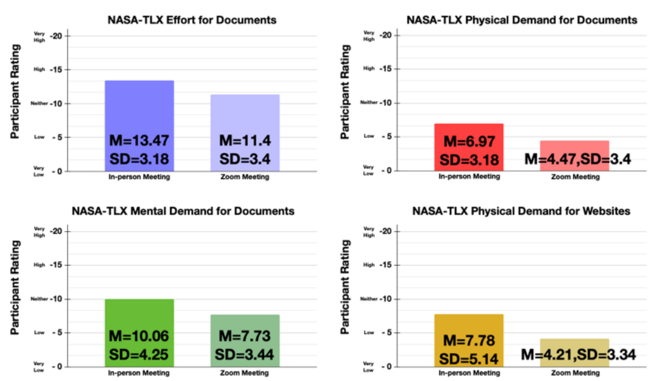

Figure 11 Comparison of subjective workload scales between in-person and Zoom represent meetings.

VII.4.3. Qualitative Results

From our study findings, we will characterize how in-person and teleconference based context reinstatement takes place across subsequent meetings. Transcription of audio-recorded focus group interviews were handled by Descript ("Descript is the AI-powered, fully featured, end-to-end video editor that you already know how to use.,"). Qualitative coding followed the grounded theory approach as outlined by Charmaz and Strauss (Strauss & Corbin, 1998) to generate initial codes for the "open coding" phase (e.g., *"More tabs mean more confusion for task").* Afterwards, similar codes were situated in related categories during the *"focused coding"* phase (e.g., *"More tabs mean more confusion for task"* and *"Getting lost when returning to task"* are related under *"Challenges in attenuating to materials*"). Finally, thematically related categories are linked to one another during the "axial coding" phase (e.g., *"Challenges in distinguishing between tasks by materials"* and *"Challenges in attenuating to materials"* are linked to "Challenges in remembering task by materials").

Our analysis surfaced a set of four categories that illustrate how the participants were able to engage in work context reinstatement in online collaborative environments via video teleconference. First, in *"Similarities between In-Person and Teleconference Meetings"*, we identified the similarities between in-person and teleconference meetings resume, look to how ways physical, digital, and social environments support context reinstatement. Second, in *"Differences between In-Person and Teleconference Meetings"* we characterize the differences between in-person and teleconference meetings, looking at the role that traversal between meetings influence meeting reinstatement. Third, in *"Teleconference Participant's Reflected Comparison to In-person Meeting",* we ask teleconference participants to reflect on the differences between meeting modalities and its potential influence on productivity outcomes. Finally, in *"UX/UI Suggestions by Teleconference Participants",* participants provide suggestions towards improving teleconference applications and how these suggestions could be leveraged to support context reinstatement.

VII.4.3.1. Similarities between In-Person and Teleconference Meetings

We observed that in both conditions (i.e., in-person (INP) and teleconference (ZOOM)), participants reported a number of challenges in maintaining and resuming specific working contexts for each meeting, including issues of re-finding specific meeting resources (i.e. specific web pages and documents related to the present meeting) due to having too many windows and tabs that participants collect as they proceed through the meeting schedule.

Ways of Remembering Task by Materials:

Participants stated that they relied upon three types of on-screen resources to give them context when they return to their specific task. First, browser tabs acted as a handle to determine recent action and how to navigate after the fact (Table 26). Second, the content of opened windows were another informative cue to piece together prior activities (Table 27). Third, participants also describe general screen locations that they had worked on previously as a kind of cue (Table 28).

Table 26 Ways of remembering task by materials , "Browser Tabs".

11_3_A_INP_P2: "Um, some of the things that helped me when you going from a lead to a system was keeping the computer tabs open. So something I was doing previously, like say I was looking at then used, I like to keep the venues tabs open. And then when I go over to become an assistant for PARTNER-NAME, then I wouldn't be able to make new tabs. Those are types of searches on those separate tabs. When I go back, I can go to them other times."

Beyond the use of digital media, participants also noted that they used the provided task description sheet (*see "Use of Task Description Sheet for Remembrance"* in Table 29) to aid them in remembering their tasks or not at all (see "*Non-use of Task Description Sheet for Remembrance"* in Table 29). While the task description sheet serves the purpose of listing the set of activities for each meeting, participants relied upon it to reference their status for their activity. Essentially, for some participants, the task description sheet became a thinking tool to extend their cognition.

Table 27 Ways of remembering task by materials, “Content of Browser”.

12_8_ZOOM_P1: "Some of, some of my web-pages were already opened, so I was able to, um, I guess it jerked my memory that, oh, I was looking at this for a particular reason. And then of course having the assignment in front of me, I was able to kind of look, but, um, back and forth. To do my searches.”

Table 28 Ways of remembering task by materials – established on-screen locations.

12_6_ZOOM_P1: "Um, I had the document that I had been previously working on was in the same spot that I had been in and same thing with the Google sheets that I was on. So I was able to visually see where I had been working, um, in addition to opening and Chrome, the tab that I was on helped me see what I had been working on most recently."

Meeting Reinstatement Challenges:

As participants return to their meetings for the second time, given the 15 minute time length, it was imperative that the participants can quickly and efficiently reinstate both their contexts and resources. Here, we have identified the ways in which participants encountered challenges in accessing their digital media for a given meeting. Participants indicated what added effort was needed to coordinate with their partners (Table 30). In addition, participants provide to address experienced issues. Participants describe a variety of challenges in using their set of digital resources in supporting their ability to remember the prior task when returning for the second time, such as not being able to distinguish which resources are associated with a given task. One participant characterize this issue of resource misplacement in the way mixing tabs between tasks can *"pollute"* one's work flow owing to how the tabs, in of themselves, appeared similar to one another at first glance (Table 31).

Table 29 Top: Use of Task Description Sheet for Remembrance. Bottom: Non-use of Task Description Sheet for Remembrance.

12_7_ZOOM_P1: "*To me, it was a visual artifact of like what I'm currently doing. Okay. Yeah. And again, it's funny, cause I don't really have a lot of paper lying around or use it for that purpose, but it's interesting to think about how I would use it as a reference, just to look over and think about. Maybe I'll start keeping paper by my desk and just write tasks on them.")*
12_15_ZOOM-P2: *"Um, I mostly relied on my memory and in case I did not remember it, I just looked at my document again and I didn't bother much about missing out on, uh, what I did last because I, my goal was to fill out the document anyway. So if I missed out on what I was doing, I would while filling out the document. I would still remember that this was the last thing I searched for.").*

Even when resources for specific meetings were readily available, the issue of attenuating to materials to wield them for meeting discussion was still an effort (

Table 32). A final issue noted was on how resources were kept between meetings. Participants would accrue various documents and webpages and implicitly assume that they would still be available at a later point, however, as participants got involved across more meetings, this information would be lost as tabs are subsumed for other in-the-moment interests (Table 33).

Table 30 Added effort in differentiating sets of tabs across tasks.

11_9_INP_P3: *"I think again, there was an advantage and disadvantage to that part, like having multiple tabs open. Uh, so, but I had, so I had like almost 10 to 15 tabs open. So I had to search for like establish which one. Uh, so from that point of view, it was a bit messy, and like, I could have kept two different separate browser windows for that. I just realized."*

Table 31 Mixing tabs between tasks can "pollute" one's work flow.

12_6_ZOOM-P3: "Yeah, for me, it was definitely the tabs, like switching between tasks that have a lot of tabs open from the last task and that sort of pollutes your work flow. You keep ending up looking at stuff from the last thing, because it's impossible to open and close all the tabs. As you should, if you want to keep organized, mainly that."

VII.4.3.2. Differences between In-Person and Teleconference Meetings

In-person Traversals as a Contextual Cue:

In-person meetings differed where participants had a heterogeneous mix of environmental features to use as a support for contextual memory. In-person participants describe the benefits of physically moving from room for each meeting and how the act of moving influenced how they were able to perform a context switch between meetings.

Table 32 Challenges found in applying attention to resources for a task when made available.

11_3_B_INP_P1: *"Um, I definitely think that I probably could have gotten faster to like each assignment. Because I had them both and just mixed in there. So then eventually I just like opened a new tab, put it on a different thing and did all my individual thing on there. And then whenever we came back, I just left all the ones that we did together."*
12_7_ZOOM_P2: *"So I usually open two tabs and it will be the browser and then the Google docs or the document. And at times it will be hard because I couldn't see too well on there and Google what I was looking for. So I had to kind of make it, make my Google docs a little bit smaller and stuff like that. Just play with this screen because I'm used to a big screen. My laptop is bigger, so that was a little bit weird."*

Regarding meeting transition, participants describe how changing environments helped to cue them in anticipation of a future meeting. Participants suggest that they form associations between their working context activities and the specific room they worked in, as one participant would describe (Table 34). For such participants, the changing of environments, especially when it's a specific path to a specific room, provided an opportunity for participants to engage in prospective memory (Table 35).

The travel between rooms was also described by participants as a clear demarcation between meetings. Here, the path that one takes towards a meeting, by its perceptual elements like its interior design, could elicit a shift in focus, allowing for the participant to mentally reset before the upcoming meeting (Table 36).

Table 33 Meeting Reinstatement Challenges - Losing resources that were previously thought to have been preserved.

12_8_ZOOM_P2*: "Mainly because I was kind of discovering my way to work as I was going. Um, it, it especially came up, um, in the party planning aspect because I came on some meta pages, I guess, you know, lists of a paid, that was a list of a bunch of things. And, um, so we ran into some venues where. I said, well you know, we will have to click the link to, or to put in for a quote or something where actually this, this main hub website had fake dollar figures there. We would still really want to double check that. But yeah, I did. That was one thing that I lost, um, some information that was on that hub that wasn't on the ultimate link of the place it was pointing to. Um, that I just, I, uh, that was lost because I didn't anticipate such a thing would exist in that, that it would have different information."*

When participants finally meet with their respective partners in their physical rooms, they would go on to describe how both their partner's presence and their shared collection of work-context-related documents supported their work context reinstatement. Resumption of meeting through co-located partner was used for a variety of purposes such as trying to remember what needs to be accomplished, what is left to do, and what are the immediate actions to take to guide into re-contextualization of the project (Table 37).

Beyond the use of digital media, participants also noted that they used the provided task description sheet (Table 38). While the task description sheet serves the purpose of listing the set of activities for each meeting, participants relied upon it to reference their status for their activity. Essentially, for some participants, the task description sheet became a thinking tool to extend their cognition.

Table 34 Participants suggest that they form associations between their working context activities and the specific room they worked in.

11_3_A_INP_P3: *"Changing environments did help me, um, kind of cue what needs to be done. Um, every single time I've been in this room specifically, uh, where we are, it was always me and focusing on my task was the third task."*

Table 35 Specific path to a specific room, engages in prospective memory.

11-3-A-INP-P1: *"Yeah, for me, um, when I went back to the environment, it did give me a snapshot of sort of different clips of the laptop that I had seen. Um, and so when I went back to the task with, uh, the assistant, I realized, oh, this is very familiar. Uh, this is helped jog my memory for a task a bit because I had sort of cues around the environment to remember. So I had the pen located right here. I was doing this particular task at the time."*

Table 36 Traversals as a contextual cue: travel before meeting provides a mental reset.

11-3-A-INP-P2: *"Um, if there was some influence there would have been as my partner cited, it was like at most during the travel, it'd be been like some, uh, random intrusive thoughts, mostly about the weather, how cold it is and how I don't want to slip that. It's usually just on my mind. And then it just, since there is that break in between of switching tasks, um, it does make it a bit harder to recall, um, what I was going to do next or what I was doing previous."*

Table 37 In-person traversals contextual cue: resumption through co-located partner.

11-3-A-INP-P1: *"While traveling from one location to the other, I had forgotten some of the things. Again, I have to depend on the, uh, example of PARTNER-NAME. Given a primer, uh, reviewed some of the things that was left off the front of what he was doing in individually. So that was helpful. PARTNER-NAME had brought up, um, some suggestions and it allowed me to remember, oh, okay. These are suggestions that were referenced to what we're doing, but I did, um, get distracted while traveling. Um, the weather was part of it because it made me focus on. Like be comfortable. Yeah. And when I arrived at the desk, I was too busy trying to get set up comfortably that by the time I went back, I realized that I needed to refer to the participants with me, refer to the notes and the environment that was set up and hopefully be in a state where I look competent with my peers, because I actually forgot."*

Meaning Applied to In-person Traversals:

In the in-person condition, participants describe a few ways how changing rooms for each working context represented a shift in task (Table 39 - Top). For some participants, the change of rooms represents either the end of a task, a different moment in time, or an indication of what is possible or not possible within a given room space. Another way that participants described the physical traversal of meetings is how the act of movement served as a kind of flow or ease-in transition for activity (Table 39 - Bottom).

Participant's Regard to Partners as Environmental Cues:

Another cue that participants described in reinstating their meeting context was the visual and audible presence of their partner for a given meeting. Participants' characterized their partner's presence as an environmental cue either in terms of implicit (Table 40 - Top) or explicit reminder (Table 40 - Bottom).

Table 38 Use of task description sheet for remembrance.

12_15_ZOOM-P2: *"Um, I mostly relied on my memory and in case I did not remember it, I just looked at my document again and I didn't bother much about missing out on, uh, what I did last because I, my goal was to fill out the document anyway. So if I missed out on what I was doing, I would while filling out the document. I would still remember that this was the last thing I searched for.").*

Table 39 Meaning applied to in-person traversals. Top: Change of rooms represents end of a task. Bottom: Traversal of meetings is transitional flow.

11-3-A-INP-P3: *"Changing environments did help me, um, kind of cue what needs to be done. Um, every single time I've been in this room specifically, uh, where we are, it was always me and focusing on my task was the third task. And every time I switched up to the other room, it was always, I had that mindset of this is no longer my task."*
11-10-INP-P3: *"I think, I guess the only thing I would say, maybe the change of environment, the walking kind of like helped ease. The fact that it's like the time conscious kind of thing. Cause like I was still like a bit, oh, I don't have enough time. I dunno how many times."*

Other participants noted that seeing their partner on-screen gave them a kind of hyper-focus, placing more attention to their partner than they would if they were sitting side-by-side in-person (Table 41 - Top). Participants did note that Zoom collaboration enabled them to be aware of one another's activities and interrupt their partner's activities when needed (Table 41 – Bottom).

Table 40 Meaning applied to in-person traversals. Top: Seeing partner as an implicit reminder. Bottom: Seeing partner as an explicit reminder.

12_6_ZOOM_P3: *"It was the faces for me as well, like switching to a specific breakout room. It's all just this same gray web-page, but seeing the face has definitely helped me break it up a little bit."*
12_6_ZOOM_P2: *"I think for me it had some impact because I was remembering the task and I was associating it with the person's face. For her, she was assisting me. So I had to ask her for like, I had to get her command that helped me in this."*

Table 41 Participant's regard to partners as environmental cues. Top: seeing partner gives hyper-focus. Bottom: awareness of partner's activities and opportunities for interruption.

12_6_ZOOM_P1: *"Because if I'm only seeing the person that I'm working with, that gives me. More focused on just them rather than sitting next to two people that are doing related, but like different things on the same project. So being able to focus on just what I'm doing with the collaborator that I'm with or by myself, I feel like actually helped more so than actually being in, you know, four people around a table or such."*
12_6_ZOOM_P2: *"I think it is a convenient on Zoom. Because we can simultaneously do our own work and help the others also. But if you are like, working in-person, then they'll be like "Oh, have you done my work?". Or like, they can, they can interrupt in that way. I think so."*

Added Effort in Environmental Context Reinstatement and Modification:

While window and tab management was unsurprisingly a common issue for both conditions, teleconference meetings had a minor difference (i.e., an added complication of managing the application window during meeting activities). One participant mentions the need to consciously re-adjust their Zoom screen-share to ensure that not only they but their partner is able to see the same content to support discussion (Table 42 - Top). Even when the Zoom window was the central focus of interaction between participants, the window became one more element to manage on their screen, as seen as when one participant had to navigate between windows just to share a link to their partner (Table 42 - Bottom).

Table 42 Added Effort in Environmental Context Reinstatement and Modification – Top: Consciously re-adjustment for Zoom screen-share. Bottom: Need to navigate between windows just to share a link to their telecon partner.

12-13-ZOOM-Participant-3*: "Another difficulty that I faced was the zoom window , always open on all the web pages. We had to toggle it either to the left or the right in order to see the complete window so we can get all the information that is available on screen. Right. So that was. Problems in resizing of the members that we have to do in order to see the, web-pages."*
12-7-ZOOM-Participant 2: *"So as for me, I was jumping around the Zoom in the documents in the Google because I was trying to send him links. So how to open the zoom and then I try to like minimize this zoom, so I could just have the little square on top, but I couldn't because it was recording too. I had to just open my docs on top of Zoom. Sometimes it was, it wasn't messy sometimes, but I just kept clicking, like "open close open close" until I found one."*

In the ZOOM condition, the challenge of coordinating materials became a joint effort where additional time is expended for both partners to recreate their context before resuming activity and modifying the separate work-spaces when understanding of the tasks continues to develop. Screen share was a feature that participants selectively used during task (Table 43 - Top). Often, participants would not use screen share. When participants chose to use screen share, it was for the purpose of supporting partner awareness (Table 43 - Bottom), so to come to a common understanding before proceeding (Table 44).

Table 43 Coordinating materials as a joint effort among telecon users.

12_8_ZOOM_P8: *"We ended up with two untitled documents until I realized I remembered I could go back to the drive view and rename it there. It took extra time to do that. Um, but I also had to decide, "Should I take that extra time to do that?". " So that, that burned a little extra, extra time. Um, just making that decision and going through just to get things find-able."*
12_8_ZOOM_P1*:* *"I guess the main challenge for me was understanding what the task was asking me for. After having a discussion with my partner on separate tasks, things became a lot more clearer. So the second time around, I was like, "Oh, I need to change my whole approach or my whole research for this task.". So the challenge for me was, um, not having a good understanding at first and then discovering that maybe I should have a different approach."*

Meeting Traversal between Breakout Rooms:

In the case of the ZOOM condition, we were interested to see if this kind of ease-in break experience had some analog when all the meetings were represented via teleconference (Table 45 - Top). First, the change of breakout represents a gradual transition between working contexts. Second, for some participants, the change of the breakout room represented a kind of clean break of the meeting (Table 45 - Bottom).

The effort in moving across breakout rooms is a result of a shift of focus from different points of attenuation. First, participants describe how the researcher's own announcement acts as a triggers to change focus (Table 46 - Top). Unlike the case for in-person meetings, there is less effort in performing a switch between the different meetings (Table 46 - Middle). However, participants did describe that after switching attention, there is a need to settle their mind when switching, supported by some kind of document to settle themselves (Table 46 - Bottom).

Table 44 Screen-share for decision making.

12_8_ZOOM_P1:*"Oh the screen share with both of us. I think was good. And that way we were able to, like, I think I mentioned before, as I saw him with, with delegated tasks. So as I saw him completing his tasks, I was like, oh, okay. Partner, you need to catch up. So, um, you know, in real time I was able to, we will be able to enter stuff and even, um, make decisions in real time, you know, so immediately we decided, okay, this is not what we're going with. These were some of the things that we wanted to go with."*

Table 45 Top: change of breakout represents a gradual transition between working contexts. Bottom: change of the breakout room represents a clean break of the meeting.

12-8-ZOOM-Participant-2: *"Um, at first I wanted to call it, um, gradual, but I think it's more, that it's hard, but there's a process. Uh, I mean there are, there are multiple steps and so, you know, you're, your interruption kind of abruptly stops things. Maybe I'll finish, you know, one line or something. Uh and then now we close the windows."*
12-7-ZOOM-Participant-1: *"Okay. I need a moment to kind of finish my thoughts when I'm doing something. So for instance, leaving the first task, I was pretty satisfied that I'd covered everything, but it was getting a little bit fast at the end. So I took a moment even when we were starting the other task. It's like a pipeline flush of the CPU. I had to kind of finish all this stuff, just get something written down. And then I switched the sheet of paper and I'm like, okay, I'm on this task . Now. It was actually harder for me to leave the joint task and go back to the other".*

While the effort needed to change between breakout rooms was low, the actual process of coordination and switching was described to be effortful. Participant states that they realized the way they wanted to work by starting to close windows to clear for next window (Table 47 - Top). Of note, one participant characterizes the lack of a clear buffer space between meetings, which made it difficult to have a context switch (Table 47 - Bottom).

Participants also describe how the sudden shift breaks one's thinking process where while they are conscious of the new working context and can access resources, there was still the mental reconfiguration work to become operational (Table 48 - Top). Because of a clear separation of working contexts by breakout rooms, even when participants were engaging in the different contexts, they were still thinking about remaining tasks from the previous meeting as they moved breakout rooms (Table 48 - Bottom).

Participant's Meaning Assigned to Breakout Room:

Breakout rooms in the context of the Zoom platform are designed to separate a Zoom meeting into an upwards of 100 separate sessions referred to as breakout rooms. Depending on the settings of the host, participants of a meeting could be guided from one room to another, or participants can traverse breakout rooms as they see fit. For this study, we were interested in understanding how participants understand breakout rooms as part of their user experience.

The breakout rooms were used in the study as a kind of approximation for the different rooms that individuals would meet in for in-person meetings. Participants describe what changing breakout rooms represent to them for each meeting they were a part of either an immediate change (Table 49 - Top), a reset of contexts (Table 49 - Middle), or nothing at all (Table 49 - Bottom). Participants describe the various ways they are conscious of which breakout room they are in. As participants changed breakout rooms, they characterize the process as shifting focal points between meetings as features of the on-screen environment are moved in and out of focus so to prepare the immediate workspace on one's computer (Table 50 - Top) and how focus was maintained within a specific breakout room (Table 50 - Bottom).

Table 46 Effort in moving across breakout rooms is a result of a shift of focus from different points of attenuation.

12-15-ZOOM-Participant-1: *"Um, so when we did switch, when I got the cue from you, that we are switching over to the, to the, the collaborative task, uh, I kind of in my brain, I got in just shifted to party planning. Uh, I'm not sure if I can say that looking at the zoom screen and the other participant, necessarily helped me. It may have. I just don't know. I, I, you know, in my brain, I just kind of switched tracks from conference planning to party planning."*
12-15-ZOOM-Participant 2: *"For me, I'm switching to a different room, did not make as much of a difference as, uh, switching to the document that I was working on. So I'm switching to a different document on the notepad, but made, made much a bigger difference than just switching on zoom, uh, a different room on zoom did not make much of a difference to me."*.
12-1-ZOOM-Participant-1: *"When I went from arranging, the party and then I was switched to the destination thing. First of all I just open my word pad with just how I did it in previous task. So it gave me a better idea that how much, like, how should I start for the second one?"*

VII.4.3.3. Teleconference Participant's Reflected Comparison to In-person Meeting

<u>General Audio Issues</u>

We asked Zoom participants to consider the ways in which their experience of teleconference compares to in-person meetings. On the topic of sound, participants noted two aspects of how this computer-supported modality supported their activities. Typically, when sound was working, participants were able to proceed with their activities. However, when the audio was dropped during a Zoom call, this resulted in time by both parties to acknowledge the issue and find solutions towards it (Table 51 - Top). Even when the audio was working, when participants are in transition between breakout rooms, a participant would be speaking to their partner, and as they traverse, a participant would be cut off before completing their thought mid-way, similar to cases where a meeting is officially adjourned and a speaker is talking while members leave the meeting instantly (Table 51 – Bottom).

Table 47 Meeting Traversal between Breakout Rooms – Top: Transition between meetings by closing windows of a given meeting. Bottom: Lack of a clear buffer space between meetings makes for difficult context switch.

Researcher: *"When you were ahead you moved from room to room, did the act of leaving a task or returning to a task influence you in any way in any way?"* **12-8-Zoom-Participant:** *"Um, I think mostly it was just the transition, um, uh, I felt myself snap out of a flow state more or less, and just kind of felt it moves this way, you know, kind of a reset, you know, flushing that stuff away. And as I, uh, as I realized the way I wanted to work, that also involves starting to close windows, um, or partial research so that I could clear this clear this light so we could start the work for the next window."*
12-13-ZOOM-Participant 2: *"Yeah, we don't have that, like the space buffer space in between. It was just continuous. So yeah, it was like, it was quite quick, so it was difficult to like switch mentally from place to.".*

Table 48 Meeting Traversal between Breakout Rooms – Top: Sudden shift of breakout rooms breaks one's thinking. Bottom: Lingering thoughts on prior breakout room meeting when starting in subsequent meeting.

12-13-ZOOM-Participant 3: *"Moving from different breakout rooms, like breaks your thinking process and you'll be completely focused on new things. Like you're confused for at least the beginning one minute, one or two minutes, like what you are going to do and what you have left. So you want to save your work and you want to continue with the new work. So it was kind of challenging for the initial one to two minutes of the transitioning from another."*
12-6-ZOOM-Participant-1: *"Um, so for me, the, for my own project, I felt more responsible and more invested in it. So whenever, no offense, whenever I was helping with hers, I was still in the back of my head thinking about mine. So the transition from mine to hers was always me trying to finish up the last thing I was doing to. To get it done, get it ready for when I came back to it. But whenever I was done helping her, it was always straight back to mine because that was what, that was the forefront of what I was thinking about was, was my own work. So like when the, when the breakout rooms changed, I didn't really stop to think it was finished up my stuff or go straight back into my stuff. That was that's what my priority was, so."*

When one works collaboratively, this phenomenon arises not only through verbal communication with one another, but also in how we explicitly or implicitly communicate our work activities or current status towards completion (Table 52).

From one perspective, for some teleconference participants, they saw no general difference between in-person and teleconference meeting, where given the information-centric work that is being conducted, there is little to no difference between mediums. Participants also noted the extent to which they can control the privacy of their activities from their partners. In cases where participants would like for their partners to be aware of their activities, in-person collaboration is faster because of the co-location of collaborators (Table 53).

On the very same idea, another participant noted that such ease of awareness that comes with in-person meetings is not always beneficial, where having the lack of a co-located space could be advantageous to maintain privacy (Table 53).

Co-presence and awareness in Teleconference Meetings

One participant pointed out the degree to which in-person and teleconference meetings differ in how many collaborators may be co-present for a meeting. Specifically, participants describe how supporting focus, there was enough similarity between meeting modalities (Table 54 - Top). The same participant would also point to how teleconference meetings cab help to provide a focal point of collaboration with another member within a larger group across meeting modalities (Table 54 - Bottom).

Decision to use Screen-share

Teleconferencing applications like Zoom serve the purpose of multi-modal communication. This is enabled by joint video and audio linked telephony. In this communication, meeting members are not always passively engaging the teleconference in discussion, but the medium serves the purpose of providing a virtual, common space to share information and understanding (Table 55 - Top). Generally, the screen share function in most teleconference applications is broadly used for establishing common ground among co-viewers of a given teleconference. However, we can see that there are nuances in how this function is used for collaboration.

Table 49 Participant's Meaning Assigned to Breakout Room - Top: Changing breakout rooms represents an immediate change. Middle: Changing breakout rooms represents a reset of context. Bottom: No meaning assigned to breakout room.

Participant 2: *"Um, I think mostly it was just the transition, um, uh, I felt myself snap out of a flow state more or less, and just kind of felt it moves this way, you know, kind of a reset, you know, flushing that stuff away. And as I, uh, as I realized the way I wanted to work, that also involves starting to close windows, um, or partial research so that I could clear this clear this light so we could start the work for the next window."*
Participant 1:"*I need a moment to kind of finish my thoughts when I'm doing something. So for instance, leaving the first task, I was pretty satisfied that I'd covered everything, but it was getting a little bit fast at the end. So I took a moment even when we were starting the other task. It's like a pipeline flush of the CPU. I had to kind of finish all this stuff, just get something written down."*
Participant 1*: "Actually, it looks, it was like a timer. Like I have to keep doing the task and then you just asked me to do something so leaving and entering. Is we don't. I mean, at least for me, from my perspective, I don't see that as a concept of entering room. Right. Leaving it's like a timer and start end something like that. That's the way I felt."*

Participants describe using screen-share to establish awareness of one's actions to their partners and what actions are taken place that can be understood retroactively. This awareness was described for the purposes of supporting decision-making (Table 55 - Middle). Screen-share, while easily accessible and always available for the participants, was also acknowledged when exactly it was not in use. Often, participants would not use screen share for coordination because other resources, such as websites like Google documents, provided built-in support for coordination (Table 55 - Bottom).

Table 50 Participant's Meaning Assigned to Breakout Room - Top: Changing breakout rooms was a shift of focal points of on-screen environment. Bottom: Maintaining focus within breakout room.

Participant 2: *"Um, I think mostly it was just the transition, um, uh, I felt myself snap out of a flow state more or less, and just kind of felt it moves this way, you know, kind of a reset, you know, flushing that stuff away. And as I, uh, as I realized the way I wanted to work, that also involves starting to close windows, um, or partial research so that I could clear this light so we could start the work for the next window."*
Participant 2*: "Um, I think mostly it was just the transition, um, uh, I felt myself snap out of a flow state more or less, and just kind of felt it moves this way, you know, kind of a reset, you know, flushing that stuff away. And as I, uh, as I realized the way I wanted to work, that also involves starting to close windows, um, or partial research so that I could clear this clear this light so we could start the work for the next window."*

VII.4.3.4. UX/UI Suggestions by Teleconference Participants

Application reminder system and larger screen real estate

Zoom participants provided some suggestions on how to improve the work context-reinstatement experience. One suggestion was an explicit reminder system integrated in context-situated applications (Table 56). Another suggestion by Zoom participants was towards gaining larger screen real-estate to better-manage the numerous applications used in conjunction with Zoom for coordination (Table 57) or to better-support mental resumption to specific working contexts (Table 58).

Optimizing apps for zoom collaboration:

During the study, participants often had to manage features of the Zoom application with other applications they were using (e.g., Using screen share to show a document that was the focus of discussion at a moment) (**Table 58**). In recognition of how they used Zoom to provide way to share their information collections, participants suggested future implementations for teleconferencing applications. One suggestion, in form of document and web-page integration with teleconferencing applications, one participant recognized how Google web applications are used for collaboration in conjunction with Zoom.

Table 51 Teleconference Participant's Reflected Comparison to In-person Meeting - General Audio Issues: Top: Acknowledge sound issue and find solutions towards it. Bottom: Abrupt cut-off when leaving teleconference meeting mid-sentence.

12-16-ZOOM-P1: *"Oh, I think I must say that it will be much faster than this. Because you know, uh, talking face to face. Uh, it would, uh, first of all, like, uh, there will be no connectivity issues or sound issues. Yeah. That also plays a huge role because, you know, "Can I hear you? You can hear me or can you be audible?" It is frustrating."*
12-6-ZOOM-P2: "I think in-person it would have been better because while the breakout rooms are changing. Um, I was like, uh, saying something and in the middle, the breakout room changed and I couldn't finish my, uh, what I was saying. So in-person, uh, if I was doing the same thing, they wouldn't be a problem like this.").

Table 52 Participants needed to socialize among themselves before working on context.

12-7-ZOOM-P2: *"I have a couple comments on this too. I think one consideration with this is that we had not done a joint task together before, because we haven't met. So the first time I felt like it took a few minutes. To, to understand the work structure. But the second time we came back, I was like, "Oh, I'm visiting an old friend. Now I know how you work." And, and that's what I can do when I'm working with people in person in Zoom that I know, I kind of understand the structure of how they work."*

VI.5. Discussion: Implications for Teleconference Collaboration Organization

VI.5.1. RQ1: How do users' experienced effort toward context switching differ between in-person (INP) and teleconference (ZOOM) contextual collaborative meetings?

Subjective workload comparison showed that INP participants reported a higher workload across multiple facets of website and browser management than the ZOOM participants. While not in accordance with what we intended to prove in our hypothesis, it is understandable. One possible reason for the discrepancy is a misunderstanding of the focus of the workload questions where participants interpreted context reinstatement as the singular action of showing up for a meeting and participating. Perhaps what was not considered was the full range of actions that preclude to an in-person meeting (e.g. walking to a specific meeting room, acknowledging members, providing updates, or setting up relevant resources). If this is the reason, let's consider what teleconferencing affords users: instantaneous video telephony any time, any place, through most devices. A major advantage of video telephony is that it levels the distance between contacts, where one could easily telecon with a colleague down the hallway as one could with another halfway across the world.

Table 53 Teleconference Participant's Reflected Comparison to In-person Meeting - Interpersonal Dynamics: Participants needed to socialize among themselves before they can proceed for each working context.

12-16-ZOOM-P1: *"Oh, I think I must say that it will be much faster than this. Because you know, uh, talking face to face. Uh, it would, uh, first of all, like, uh, there will be no connectivity issues or sound issues. Yeah. That also plays a huge role because, you know, "Can I hear you? You can hear me or can you be audible?" Yeah and then, uh, if, if this happened again, then it frustrates someone's mind."*
12-6-ZOOM-P2: *"I think in-person it would have been better because while the breakout rooms are changing. Um, I was like, uh, saying something and in the middle, the breakout room changed and I couldn't finish my, uh, what I was saying. So in-person, uh, if I was doing the same thing, they wouldn't be a problem like this."*
12-6-ZOOM-P2: *"I think it is a convenient to work on Zoom. Because we can simultaneously do our own work and help the others also. But if you are like working in person, then they'll be like, "Oh, have you done my work?" Or like, they can, they can interrupt in that way. I think so."*

One particular challenge to teleconference-based participants, they pointed to, was the effort and time required to re-instantiate a particular meeting. Again, while starting a meeting instantaneously brought participants together, the initial time within the meeting was dragged by the needs to establish familiarization between participants, to coordinate shared documents whether on an individual basis(i.e., gathering the exact documents and web pages for the present meeting), or as part of a collaborative effort (i.e., arranging computer desktop for screen share). These activities are required to fully engage in a meeting, thus taking what little time is available within the meeting (i.e. 15 minutes). This poses a challenge to both how context dependent memory functions, where the resources that are need for resuming a task, acting as consequential cues, are not within immediate view to support transition into the working context. Another issue, from a DCog perspective, highlights how individuals work together to build up a context and how that arises through parallel and shared resource management and organization. If these issues arise in a single meeting it's not too burdensome but it is likely these coordination and memory impairments could stack as more meetings are scheduled sequentially.

Table 54 Teleconference participant's reflected Comparison to in-person.

12-15-ZOOM-Researcher: *"How would the collaboration would have been different if you were co-located with your partner?"* **12-15-ZOOM-P1*:*** *"Maybe like using a pen and paper instead of like writing, but then, um, um, it could also have to do with, uh, maybe one person using the laptop, writing stuff down, the other person just researching. Um, um, and then even in person, I guess, thinking in terms of like the real world projects that I've done with other people, even though we would be in proximity in person, um, we would have like different workstations computer workstations, and then use something like Google share documents or something like that to actively like in real time share, um, and collaborate on like documents, which would be like real easy.")*
12-16-ZOOM-P1: *"The other thing is if the person is sitting next to you, they can also see what physical work you are doing. From that also yours, you can get, get some more idea about that."*

In recognition of the phenomenon of back-to-back teleconference meetings, a feature of remote and hybrid workplaces (see section VI.1.Introduction), Microsoft's Human Factors Lab (Ho, 2020) conducted a study on worker's well-being during sequential teleconference meetings. Through the use of electroencephalogram (EEG) equipment, the research group compared brainwave activity between those in groups who had continuous back-to-back meetings, and those in groups who had 10-minute breaks in between each meeting. Their study yielded three takeaways: 1) Having breaks helps the brain to "reset", removing accumulated stress from meetings; 2) Consecutive meetings bring an impaired ability to focus and re-engage while interspersed meetings with breaks in between, were associated with greater attention and interaction during subsequent meetings; 3) Shifting between meetings without breaks can introduce additional stress on workers. In summary, the study suggests that breaks, even as little as 5–10 minutes, can make a difference in reducing accumulated stress in consecutive teleconference meeting environments. Our own study reflects this finding, pointing to opportunities for breaks in the form of the travel time between meetings, as is the case for consecutive in-person meetings. In addition, our study points to contributors to stress for sequential teleconference meetings, the need to re-access and re-organize materials, and the need to establish shared presence and space through teleconference meetings.

Based on our findings and prior work, we would like to offer the following design considerations to work context management and sequential teleconference meetings. Echoing Microsoft's Human Factor Lab's findings, regarding practice, consecutive teleconference meetings should have a break buffer of some length to encourage focus, engagement, and organization outcomes for meeting interactions. If it is not possible to schedule buffers in between meetings, there should be awareness to accommodate for necessary work context re-instantiation practices (e.g. gathering resources, organizing materials, reconnecting with colleagues) before the meeting agenda resumes properly. In accordance to this design consideration, there are a few opportunities for future implementations of teleconference application design that can support the aforementioned needs. Microsoft Teams introduced a feature called *"Virtual Commute"* (Ho,

2020) that is designed around creating explicit boundaries and structures between meetings and work at large, simulating the experience of a physical commute between work and home. The *"Virtual Commute"* feature works by asking users to schedule a commute at different points of the work day for different activities that are not work related (e.g., *"Scheduling a "commute" for the beginning of a workday means setting aside time to prepare for work, whether it's going for a walk or planning tasks with a cup of coffee.").* The virtual commute is designed carve out an explicit time block of uninterrupted time to provide a mental transition between different points of time at work. Another approach, recognizing the role that narrative serves in re-instantiating a meeting towards productivity, can capitalize on the captioning feature of teleconferencing applications and coupling this caption with a GPT like ChatGPT to act as a stenographer of sorts, aiding in the resumption of a meeting among colleagues.

VI.5.2. RQ2: How does the modality of a contextual collaborative meeting influence how associated information collections are accessed and used for contextual reinstatement?

We saw the ways in which in-person and teleconference groups compared and contrasted on how they were able to switch context for each consecutive meeting. Between in-person and teleconference meetings, we saw what features of each meeting both groups fixate on. Meeting re-instantiation cues include the set of digital resources (i.e., whether they be specific documents, applications, or web pages), the level of abstraction they use to attenuate to these resources (i.e., locations on the desktop, windows, or tabs), and the task description sheet. Where these two groups diverge can be attributed to their modality. For in-person meetings, there were cues in the form of the room where meetings take place, the path to get to the meeting room, and shared co-located space among collaborators (i.e., the table strewn with laptops and papers). Teleconference meetings were characterized not by what they had, but by what they did not have.

Table 55 Decision to use screen-share: establish awareness of one's actions to their partners.

12-8-ZOOM-Participant 1: *"I felt pretty aware cause we had the document."* **12-8-ZOOM-Participant 2:** *"I think the last thing, thanks to the document because I could see where he was and why he was editing. So I knew what was left or what had to be done. And he was giving a lot of comments as well as what, what he was doing while I was doing it."*
Participant 3: *"Uh, honestly the change in breakout rooms never really registered with me. It was just sort of like, okay, this space is here. I need to help them out. Or okay. This face is here. I need to give them something to do. So it was really just like, how does, uh, how do other people showing up affect how I'm able to work on my project?"*
Participant 1: *"Yes. Um, having, having been in, in breakout rooms before most breakout rooms have a time limit. So yeah, so, you know, um, with that said, we didn't spend a lot of time socializing. We were very focused, like, okay, this is what we have to do. How are we going to approach. Let's get to it, you know? So, um, with the, I would say, yes, Being a brokered room kind of sets you free for me, personally sets me up, where, what are we doing? It puts me in a very focused mindset. What are we doing? What are we trying to accomplish? And at least let's attempt."*

There are several opportunities for environmental cues to aid individuals in reinstating the context of their meeting, including the path, the room, and individuals involved. Together, these aforementioned elements make up one's own representation of the specific meeting site. Now, consider environmental cues for teleconference meetings. For the user, there is no need for travel to a specific meeting site, unless there is a need for a more secure, ambient environment to situate the meeting . For teleconference participants, what remains are the cues present on-screen (i.e., window stream of a collaborator from a prior meeting).

Table 56 UX/UI Suggestions by Teleconference Participants –Application reminder system

12-16-ZOOM-P1: *"Yeah, you know I can say that if I get this pop-up that reminds me that I was doing something I need to get back on that. From my search and everything, if someone can just remind me that I was on this task and I need to complete this first. They can, it can remind me and tell me what I need to do for completing the task... It can be application or reminder system which is taking down what we're doing on a computer.")"*

Table 57 UX/UI Suggestions by Teleconference Participants - Better-support mental resumption to specific working contexts.

12-15-ZOOM-P2: *"Uh, the software maybe, um, uh, there's something called work-spaces that you get on Linux where you can, um, uh, have a set of windows open on one workspace and another set of windows, open another workspace. And there's a, usually a keyboard shortcut or that shortcut that you can use to switch between those, uh, if, if I can see, one of the documents open in one workspace and another document, open another workspace. It, it helps me cleanly the switch to another task. So I'll be able to see, uh, this is a list of things that I have to do.").*

For video telephony, seeing your collaborator serves a dual function: to re-familiarize yourself with your peer and a cue to remember meeting-centric events. The sudden jump into the meeting could potentially make these cues occur simultaneously, making it difficult for the user to focus on any one particular sub-element of the present teleconference meeting to properly re-contextualize themselves. Next, there is the physical space that the user is surrounded by during the teleconference meeting. The surrounding space is likely to have no linkage to the specific teleconference meeting, assuming that this same space was used for several other distinct teleconference meetings, creating a fan-effect as Smith et al. suggests (S. M. Smith, 1982; S. M. Smith & Manzano, 2010). While it is not impossible for one to use cues to support context reinstatement in teleconferencing scenarios, the approach would have to rely on conscious effort on the user's part to create and organize cues.

Table 58 UX/UI Suggestions by Teleconference - Optimizing apps for zoom collaboration.

12-7-23-ZOOM P1: *"I think a larger workspace would have been a little bit easier, but in terms of the tool design, um, it's hard to, you know, Google docs is pretty well optimized for like being able to see where the other person is editing and changing."* **12-7-23-ZOOM P2:** *"Maybe on when we were sharing the links. I know there is some, uh, The applications are not where you called safer link and it will save itself or send it or something. So I don't know, maybe that could be something that could help just by clicking a link twice.*

CHAPTER VII TEST IMPLEMENTATION OF WORK CONTEXT MANAGER (WCM)*

VII.1. Introduction

Taking consideration to how physical artifacts are used in context switching of projects, this chapter seeks to understand how the re-representation of "working context" through physical proxies can better support the context switching strategies of information workers. A prototype system referred to in this chapter as "Context Manager" is studied, to help us to understand how users interact with physically represented digital work contexts. In this investigation, two key research questions are posed: **RQ1** ("*What physical properties of the proxies do users recognize in aiding context switching?")* and **RQ2** (*"How does digital context switching by physical proxy compare to other existing strategies employed by users?"*). In answering these two research questions, the paper is organized as follows. First, the implementation of a "Context Manager" is detailed. Next, the evaluation study is described. The results of the evaluation study are analyzed in accordance to grounded theory approach. Finally, findings are discussed, highlighting user's reactions and suggestions for the design of the system.

VII.2. Context Manager System

"Context Manager" is a tangible user interface that creates digital work contexts and links them to blank credit-card-sized RFID-infused physical cards ("13.56MHz RFID/NFC Card,") (Figure 12 and Figure 13). The digital work contexts in the system are modeled as consisting as the set of webpages, applications, and documents involved in engagement of a task. When a digital work context is created and named, a user can drag related documents and folders into the "Context Information" bar as seen in the middle of the screenshot in Figure 14. Alternatively, users can save a digital work context by session. A work context can be linked to an RFID card by tapping the

*Reprinted with permission from "Facilitating context switching through tangible artifacts" by Okundaye, O., Quek, F., Sargunam, S. P., Suhail, M., & Das, R., 2017. Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems, 1940-1946, Copyright 2017 by The Association for Computing Machinery.

card and pressing the “associate” button on the right half of the interface. When switching to a specific work context or between them, users can do this by either tapping a card on the reader (Figure 13) or pressing the switch button on the right top half of the screen (Figure 14).

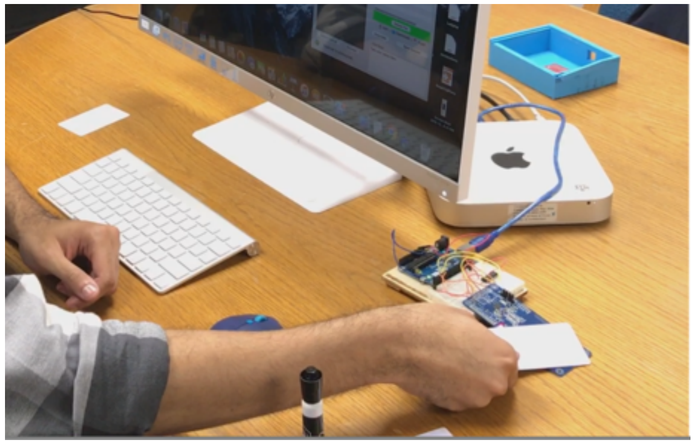

Figure 12 Context manager system. Reprinted with permission from (Okundaye et al., 2017).

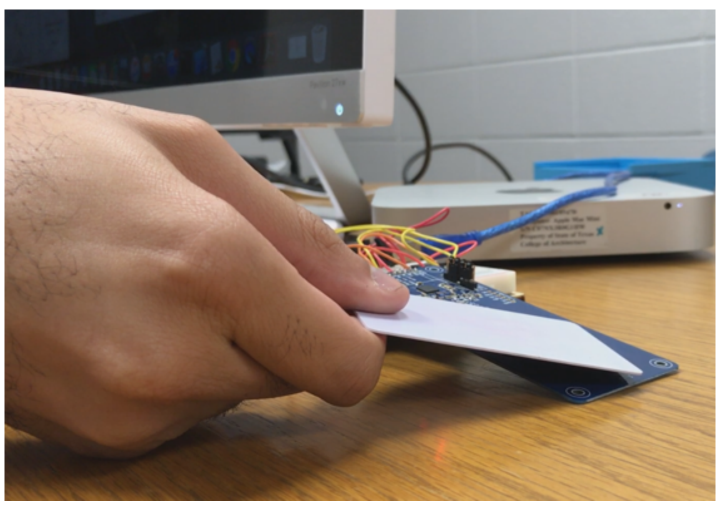

Figure 13 RFID card interaction. Reprinted with permission from (Okundaye et al., 2017).

Context Manager as a interactive system is organized in between two major components. Hardware implementation consists of multiples of RFID cards ("13.56MHz RFID/NFC Card,") (Each card possesses a unique 16 digit identification number), an PN-532 breakout board ("PN532

NFC/RFID controller breakout board - v1.6,") (receives data from RFID cards), and a Arduino Uno microcontroller ("Arduino Uno Microcontroller,") (transfers data from the breakout board to a PC by serial link). Software side development was written for MacOS in the Swift programming language ("Swift Programming Language,"). ORSSerialPort library ("ORSSerialPort - Serial Port Library for Objective-C and Swift OS X Apps,") was used to handle serial port communications with the Arduino. and Apple's CoreData framework ("Core Data Programming Guide,") was included to support database management.

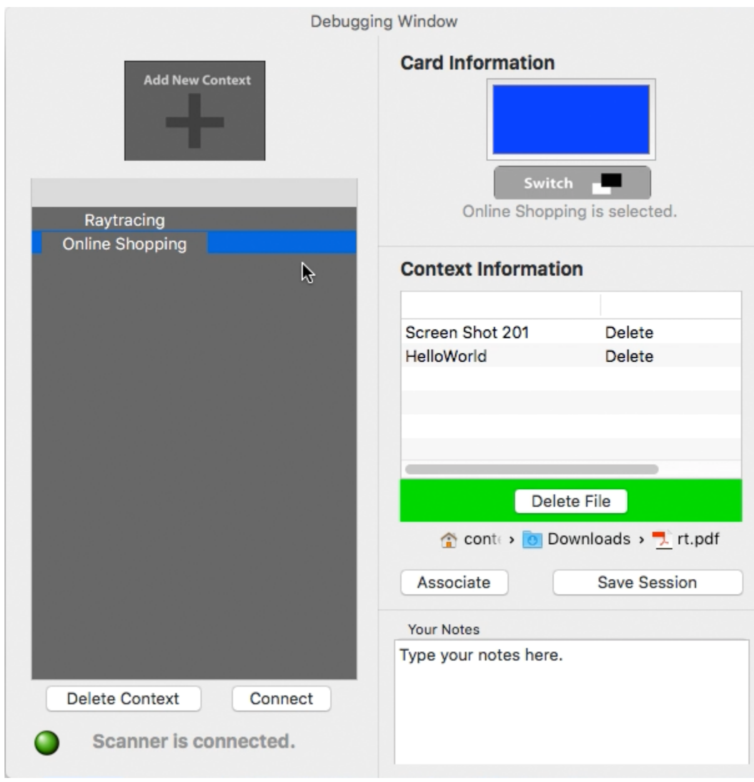

Figure 14 Context manager application. Reprinted with permission from (Okundaye et al., 2017).

VII.3. Evaluation

The goal of the evaluation was to elicit a reaction from the user's engagement with the system. We sought to find out how the system compares to their existing practices or how it might be appropriated into them. A total of eight graduate students participants from Computer Science or related fields were recruited.

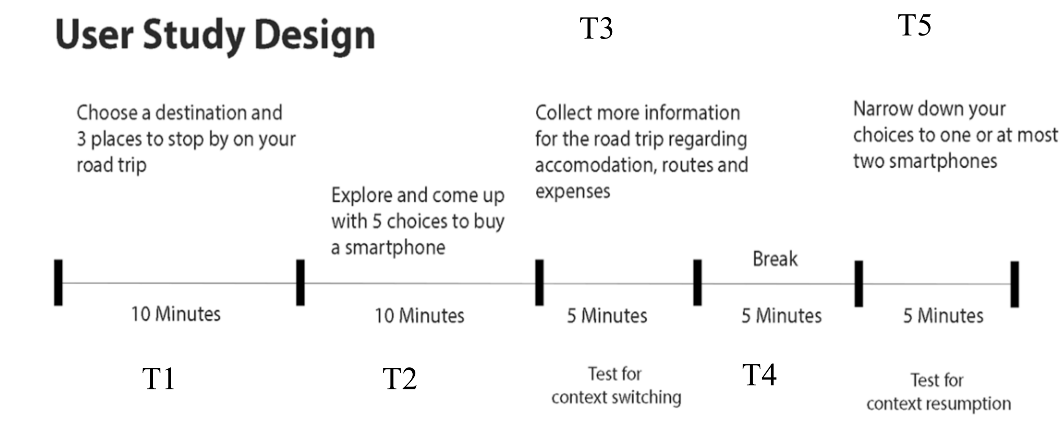

Figure 15 Evaluative study procedure. Reprinted with permission from (Okundaye et al., 2017).

Each participant followed a sequence of timed activities for each observation session conducted (See Figure 15). Parts T1 and T2 alternate between two conceptually different tasks, serving the purpose of creating the initial work contexts (Figure 4). When switching tasks from T2 to T3, it acted as a test for context switching as they return to task established in T1. During T4, the participant is given a 5 minute break and is removed from the study room. As the participant returns to the room in T5, the participant is being tested for context resumption, as they resume the work that was started during phase, T2.

After the main study, participants are asked two sets of questions. The first set of questions (Figure 15 – T5 and Figure 16), serves the purpose of triggering participants to access either one of the two generated work contexts in the system to answer the question. The second set of questions were for a semi-structured interview to account for the participant's experience and thoughts towards the prototype system (Figure 17).

Transcription of audio recorded data was handled by Inqscribe (Inquirium) and subsequently generated documents underwent qualitative coding through Max QDA (GmbH). During qualitative coding, the grounded theory approach used by Charmaz and Strauss (Sullivan, 2001) was used to generate codes during the *"open coding"* phase. Next, codes were organized with similar codes under related categories in *"focused coding"* phase. Finally, categories were organized from thematically related categories to broader themes in the *"axial coding"* phase.

Question No.	Task No.	Context Specific Question
1	1	"How distant is your destination and what is the route you will be taking?"
2	2	"Which mobile deivce has the higest screen/display resolution?"
3	1	"What are your cheapest options for travel accomodations?"
4	2	"Which of your chosen potential smartphone purchases has the greatest procesing power?"

Figure 16 Context trigger questions used in recall phase. Reprinted with permission from (Okundaye et al., 2017).

Question No.	Interview Question:
1	*"If you had the opportunity to use this device/application solution in your day to day practice, how exactly would you useit? How useful would it be?"*
2	*"How does this means of interaction compare to your current strategy in managing multiple project contexts? "*
3	*"What would you suggest for future iterations? If you had the power to change any element, what would it be? "*
4	*"Recall how swiching is peformed through the application. You have the option to perform this through either the digital "Switch"button or through the cards. What are your thoughts on the use of the cards in of themselves? Do you see any benefit in using them? "*

Figure 17 Questions Used in semi-structured post study interview. Reprinted with permission from (Okundaye et al., 2017).

VII.4. Results

Following the analysis, generated codes were organized into four major high level categories.

VII.4.1. Current Context Management Strategies

This category highlights comments users made in reference to their existing strategies for digital context switching after engaging with the prototype system.

VII.4.1.1. Multiple Computing Device Use

One user, who regularly finds themselves working with multiple computing devices, manages his contexts by way of the cloud based services such as *"Google Drive"*, taking it upon himself to assemble his project´s contents and reintegrating them with their cloud-based representations (e.g., **P0:** "*I use Google drive folders to manage multiple projects...I make sure to update to the file with version names and dates.*").

VII.4.1.2. Workspaces and Virtual Desktops

Some users manage multiple work contexts through the use of "Virtual Desktops" as common in "Windows" and "Linux" operating systems or "Spaces" in MacOS. One user maintained his work contexts by keeping certain project collections running for extended periods and organizing them in specific "Spaces". This approach however, was not without its own issues (P2-"*Because the apps will be opening and closing, it takes time to do it. Also, one of the biggest issues in switching between tasks because you wind up switching basically all the desktops spaces until I find the one that I was looking for.*").

Other users manage contexts in a similar manner as those using *"virtual desktops"*, where instead the unit of organization could be a single window manifesting in the foreground as tabs

(P0- *"I usually organize my work with one browser. I click a bunch of tabs to find out what I'm doing."*) or as bookmarks to be accessed (P4- *"In managing multiple projects for websites I would save bookmarks but those can get quite cluttered quite easily."*).

VII.4.2. User Response to Content Saving

Participants of the study noted the immediate benefit of saving a session where for some, its benefit was derived from being able to persist a work session between shutdown (e.g., **P2:** "*Also the idea that maybe I can save between sessions between my computer turning off and on again, that would be very useful.*") and subsequently resuming it as before (e.g., **P6:** "*We do a lot of programming on web applications like Cloud 9. We use it when we have multiple projects. Being able to save a sessions and resume it would be pretty exciting and I have never used anything like that before.*").

Following from their experiences, participants provided suggestions on how to better improve the session saving functionality of the current system. A request shared by participants *"P1"*, *"P6"*, and *"P7"* is the expansion of the kind of application sessions save (e.g., **P6:** *"Right now your functionality extends only to browser. If it extends to other software then it would be definitely really more helpful."*) as well as the quantity of saved session windows. Another idea proposed by two separate participants suggested supporting the saving of not just one session per context but to contain several time displaced versions of the same context, acting as a rollback feature of sorts (e.g., **P5:** "*If I forget to save a session, when I come back, it might not be there. Also if I saved it, there is no way of going back to previously saved versions. If there is an option of rolling back to what session it was before that would be great.*")

One noted issue observed during one study was the tendency of users to forget to save a context unless otherwise told to do so before switching. This issue could be explained by a sentiment expressed by one participant stating (e.g., **P5:** "*Right now, I have to maintain a context, create a context, and save it. If there is some way that I can bypass like an interface that you can do all that like save it.*").

VII.4.3. User Response to Switching

The switching functionality of the application, broadly seen as a benefit across participants for managing multiple tasks, held diverse opinions of which implementation was preferred.

VII.4.3.1.User Reported Benefits of Switching

Users noted that the card's benefit in context switching was the reduced amount of time in gathering one's resources (P4-"*Whereas it would take me a couple of minutes to load up everything but if I could save the project on here so all I had to do was swipe this thing and 10 seconds later I was back to where I used to be.*"). For some participants, it was the reduced effort in searching that the switching functionality derived its benefit (e.g., **P2**: "*I like that I don't have to be searching for the workspace I was going to do the work in. I can just scan it and have everything available.*").

VII.4.3.2.Reported Benefits of Card Based Switching

Broadly, users noted that the card offers an immediate means of re-accessing one ́s information (e.g., **P7:** *"It was more work to move my mouse and find where to click, choose it click it, change sessions. With this you can just tap it and it brings it up. If I'm giving a presentation or something, I can just use the card and tap rather than using the mouse and click on it."*)

VII.4.3.3. Physicality of the Cards

Users when reflecting on how the card was used in supporting context switching, frequently noted the card's physical attributes contributing to user experience. For some users, being able to hold the card enhanced the experience of switching by notion of simply being able to hold the interaction means (e.g., **P4:** "*Uh right now with the current iteration, the switch button* *on the application itself and the cards perform the same task so there isn't much of a difference rather than hitting the button, the switch on here. Swiping the card. But I will say that swiping the card feels a lot more better than just hitting the button***. Interviewer:** *And why is that?* ***Participant:*** *Why is that? You can hold it. Its tangible. It feels nice. It also feels faster*"). The previous sentiment was not shared by other participants, where they saw the card's physicality as a burden in the switching experience either in terms of its size (e.g., **P1:** *"Limited space on the card to write and Sometimes have to remember what project the card denotes."*), appearance (e.g., **P6:** *"But the cards are not always distinct. So I would have to search for them on my own."*), or what it entails in potential space consumption (e.g., **P1:** *"Cards need physical space to store all of them."*).

VII.4.3.4. Understanding of Card Representation

Users based on how they described their interaction with the system suggested their own understanding of what the cards themselves represent with respect to supporting context switching. Three users thought of the cards as physical analogs of their respective projects, with one user extending this line of thinking as to why cards would not be effective in scaling with the quantity of projects (e.g., **P1:** "*One card per tasks will make me have lots of cards for multiple tasks.*"). Another user provided a different mental model, likening the card as not a representation of the project itself, but rather serving as a key to re-access those contents and consequently regain context (e.g., **P2:** *"What does the card represent to me? It kind of represents a shortcut. But at the same time, it's more than a shortcut. It opens everything. Automatically. So it's a "key", that brings you back to where I was."*).

VII.5. Discussion

VII.5.1. RQ 1

Users as a whole when engaging with "Context Manager" noted that the spatial, visual, and tangible attributes supported context switching. The notion of the cards consuming space can be considered both beneficial in terms of searching by it being visibly seen or detrimental in just one more item taking up space within one's physical workspace, as claimed by one participant. The tangible properties of the cards inspired different meanings from users ranging as a kind of key to a work context or as a handle to it. As one user stated, he was well aware that switching between both card and button had the same result, but the difference was that being able to handle the card enabled him to give it a special kind of regard as a real entity, the context, than what it might be possible if it were purely digitally represented.

VII.5.2. RQ 2

The system's approach to digital context management differed from user's reported existing strategies in regards to how it handles notions of spatial organization and persistence of work. While spatial organization was simulated by digital representation, this was limited as one's display would allow. A technique like a "virtual desktop" aids by creating space and persisting content, this is in a destructive manner, removing a work context of an unrelated working context out of view. The "Context Manager" system attempts to support both issues by moving organization out into the physical work desk, allowing for multiple contexts to be in focus but also in one's periphery.

VII.6. Conclusions:

Context switching through the use of artifacts throughout physical and digital media is key to this practice. When engaging in context switching in regards to digital contexts, issues of visuospatial organization alongside screen space and content persistence pose a challenge to this activity. Noting the use of physical attributes of the artifacts that users employ when context switching between projects, this study sought to understand how these same attribute can be used to support digitally represented work contexts. The initial results of our system, “Context Manager”, suggests that the use of physical proxies by way of cards potentially allows users to organize elements of a digital work contexts in a manner similar to their physical counterparts. Future studies, as detailed in the sidebar, seek to further understand the user’s experiential understanding of this approach.

CHAPTER VIII IN-THE-WILD AND FURTHER EXPERIMENTATION OF WCM

VIII.1. Introduction

This chapter aims to contribute to our understanding of how Tangible User Interfaces (TUIs) can support users' cognition in their interactions with their digital information, particularly within the area of context management. Context management refers to practices taken on by information workers as they manage multiple ongoing projects and the ways in which they coordinate their attention across the goals, timelines, and resources of each project. Given the cognitive burden created by context management, it serves as an ideal testbed to understand how TUIs can support cognition.

The idea of TUIs was proposed by Ishii and Ullmer who recognized the need to move away from Graphical User Interfaces (GUI) as the dominant interaction models. They argued that GUI models fail to fully support the human ability to process information because of their lack of tangibility (Miyata & Norman, 1986). They further posited that the issue with GUIs is how interactions between users and digital information are removed from the physical environment in which they are situated.

The power of TUIs comes from how they augment "real physical world by coupling digital information to everyday physical objects and environments" (Ishii & Ullmer, 1997). A few examples of how TUIs support this coupling can be found in how they support users to communicate their work state to themselves and others (Bannon et al., 1983; Bondarenko & Janssen, 2005) or to guide attention during activity (Mugellini et al., 2007; Zuckerman et al., 2015). It is argued that the cognitive support in these examples is through the offloading of mental representations onto features of the environment in a manner evocative of the 'the method of loci'

(Yates, 1966), a memory enhancement technique where features of the environment are used as mnemonics to aid in the recall of information.

This work presents a study about how TUIs can support cognition in information workers in a manner similar to traditional physical artifacts like sticky notes. Unlike sticky notes however, TUIs provide the advantages of computational power such as the ability to handle large amounts of data. This paper will proceed as follows: First, we review three theoretical lenses by which we may understand the capacity of tangible physical objects to support cognitively intensive tasks like work context management, existing approaches towards digital context management, and tangible interaction. Next, we provide an overview of 'Working Context Manager' (WCM) system that we designed to enable our studies. Following that, we overview the context and methodology of two studies and describe their results. We conclude by discussing the findings with respect to how tangible interaction can support context management.

VIII.2. The 'Work Context Manager' (WCM) Extended

To enable our investigations of how cognition may be supported by interactive tangible objects for the purpose of work context management, we designed a Work Context Manager that was motivated by our theoretical discussion and by the pragmatic considerations as follows:

The system should enable the user to construct their own representation of their working contexts (much the same way one might organize their work in a set of named manila folders)

The system should not require the user to reorganize their logical filing schemes;

The system should be lightweight and not add any significant overhead to curate their working contexts;

1. The system should allow the user to customize their digitally-enhanced physical artifacts and determine the association of these artifacts to their working contexts.

2. The physical artifacts should be portable and support visual review and spatial organization.

VIII.3. Implementation of WCM

The 'Working Context Manager System' (WCMS) comprises a light-weight software component (Figure 18), the 'Working Context Manager Application' (WCMApp) (see Figure 19), and a hardware RFID card subsystem (see Figure 20). A card reader paired with the WCM application allows the users to associate RFID context cards to their work contexts. We chose to use standard RFID cards for two specific reasons. First, the form factor of the cards that resemble credit cards make them quite portable and easy to stack and hold in one's hand. Second, we apply a standard label sticker to one side of the card to make it easy to write on. This enables the cards to be easily wielded as proxies (Vygotsky's Material Carriers) and allows the user to write notes and captions so that they may serve as cues for context reinstatement.

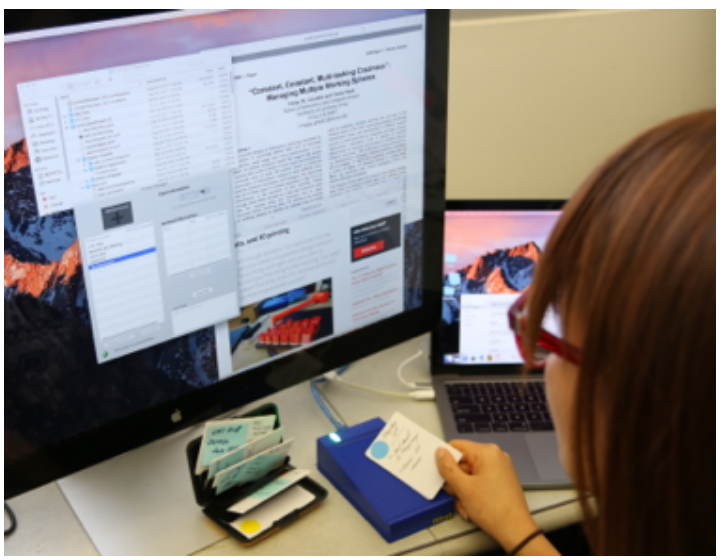

Figure 18 Work Context Manager in use.

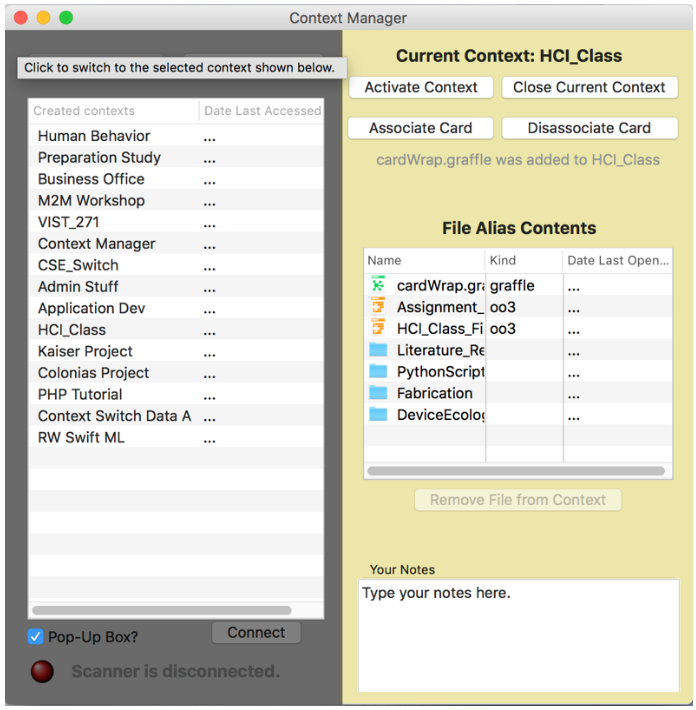

Figure 19 WCMS user interface.

Figure 20 Work Context Manager reader and cards.

The WCMApp is a desktop app developed using the Swift programming language (Rebouças et al., 2016) for Apple's MacOS environment. ORSSerialPort library (Madsen, 2019) was used to handle serial port communications with the Arduino (Arduino, 2015). Apple's

CoreData framework to support database management (Arachchige Shidhara, 2024). The Hardware implementation includes multiples of RFID cards (preprogrammed with unique 16-digit ID code) (Finkenzeller, 2010), an PN-532 breakout board (receives ID data from RFID cards) (Eridani et al., 2018) , and a Arduino Uno microcontroller (relays data to a PC via serial link) (Arduino, 2015).

VIII.4. Interaction Design of WCM

Users can use the WCMApp to define a working context by first creating a context and naming it as they see fit. The left panel of the WCMApp GUI in Figure 21 shows a list of work contexts that a user has created and named. A context may be associated with a set of objects from the file system by simply dragging the objects and dropping them onto the right side of the WCMApp interface. These objects may be folders, document files, web-blocs, or applications. The objects associated with a context in WCMApp remain in their locations in the file structure. The WCMApp simply creates aliases to the objects to allow them to be launched through the WCMApp GUI when the context is active. Figure 22 shows a set of objects that have been associated with the 'HCI Class' context, for example.

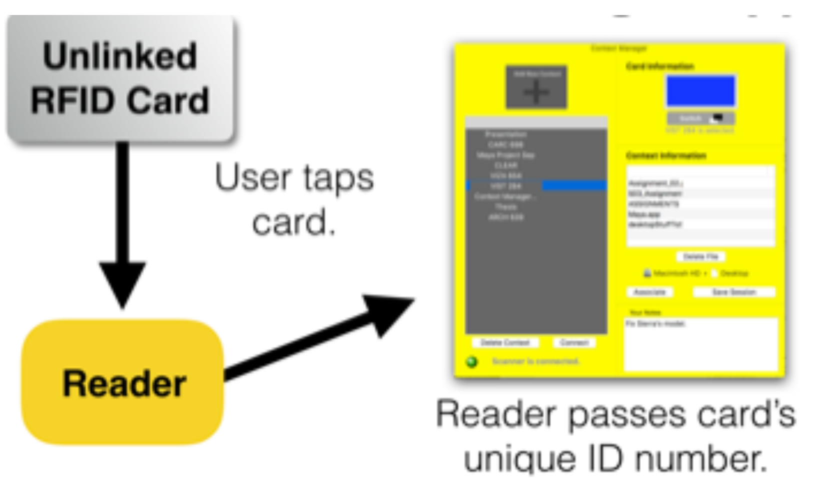

Figure 21 How unlinked RFID cards are associated with a working context in WCM.

A working context may be associated with a context card by placing a fresh card on the card reader and selecting the Associate Card button on the WCMApp interface. Figure 21 illustrates how an unlinked card is associated with a selected working context.

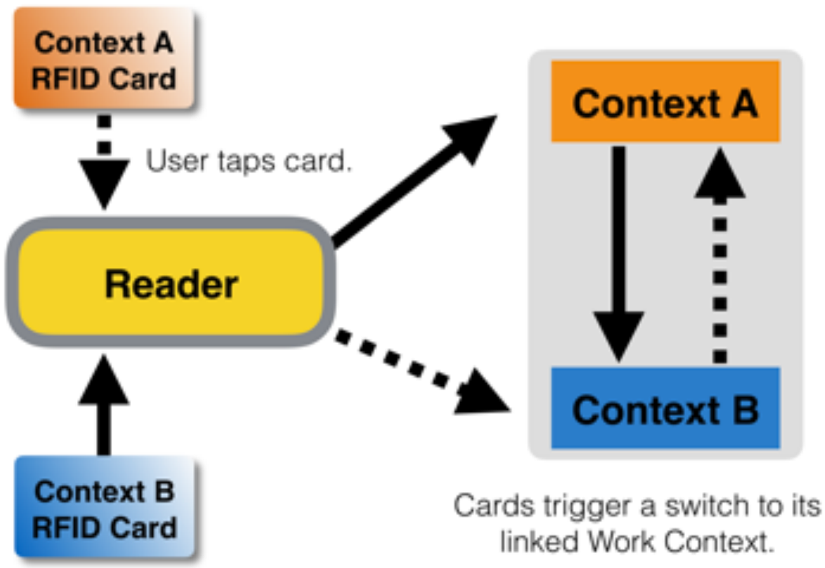

Figure 22 Invoking a context through the card reader.

A working context may be activated in one of two ways: First, users may select a working context on the WCMApp interface and clicking on the Activate Context button. Second, users can simply place a context card that was previously associated with the working context on the card reader (Figure 22). Once a working context is activated, the selected context is highlighted and the associated objects may be launched by double-clicking on the object's alias in the WCM App interface. Each working context has an associated 'default finder window' and 'default web browser window' that is automatically launched when the context is activated. The states of finder and web browser windows are preserved across activations and deactivations of the context to provide continuity of work across activations.

A working context may be deactivated either from the WCM App interface or by removing its associated card from the card reader. The user has the option of keeping a context open when its card is removed from the reader by dismissing (and not accepting) the ‘close context’ dialog box that appears when the card is removed.

VIII.5. Research Questions

We conducted two studies to answer the following overall research question: Does TUI support digital work context management better than a digital-only approach? If so, what are the characteristics of TUI that allow it to support digital work context management?

Through our experimental study and indirectly by our qualitative data, we will use the following research questions to ground this overall question:

- **RQ-1:** Are there any differences in digital work context resumption between the WCM App Card approach versus existing strategies?
- **RQ-2:** Are there any differences in the time of organizing and creating digital work contexts between the WCM App approach versus existing strategies.

The first study consisted of a lab-based study using a simulated scenario to engage users in work context switching; and the second study was a longitudinal case study to examine how the system may be used once users are acclimated to it over longer periods of time.

VIII.6. Study 1: Lab-based Study

IX.6.1. Study Design

The study used a within-subjects design with a single independent variable (system type). System type had two levels, standard Mac OS system and WCM system. In the standard system condition, participants employed task management capabilities afforded by the native Mac OS system (a MacBook Pro 13" inch 2016 model was used), and in the WCM condition, they used our custom system for task management. We chose not to counterbalance the systems because we surmised that the users already employed strategies using standard tools. Hence, we felt that exposing them to ’WCM’ may alter their regular practice that we wanted to observe. Engagement in the system type conditions took place across two separate study sessions (study sessions I and II) on two different days that were one week apart, so as not to cause participant fatigue.

Participants were asked to engage in two types of tasks during the study to allow for work resumption tests: an information foraging task and a consumption task, with the information foraging task always preceding the consumption task. The information foraging task was to plan a vacation road trip (work context-1), and the consumption task was to simulate purchasing a technological device (work context-2). The order of the two tasks was counterbalanced across all participants.

IX.6.2. Study Procedure

There were 26 participants (Male = 15, Female =11). Ages of participants averaged at 27.48 (SD = 5.12). Participants included masters (N=10), doctoral (N=12), undergraduate (N = 3), and one research scientist. Participants came from the academic disciplines of architecture (N = 10), computer science and engineering (N = 10), education (N =1), chemical engineering (N = 1), and electrical engineering (N = 1).

The general study procedure for both study sessions I and II is summarized in Figure 23. For session I, upon giving consent, participants were administered a pre-survey to elicit their current strategies for and experience with task switching and context maintenance. In addition, participants were asked a series of questions themed around the aspects of ‘Task Attributes’ (*e.g., “What kind of tasks do you have?”*), ‘Memory Recall’ ("What are some ways you use to help remind yourself of your tasks?"), ‘Personal Information Management’ (e.g., *“What challenges do you face when trying to access your project related information?”*), ‘Task Switching’ *(e.g., “How do you resume your task after interruption?”*), and ‘Functional Working State’ *(*e.g.,*“How easily* *are you able to resume work after an interruption?"*). They were then made to engage in the work tasks using the standard system.

For session II, participants were first given a demonstration of how the WCM system functions. Participants were guided by the researcher on using the system to establish *"Work Contexts"*, to add and remove information resources with the context, to associate contexts with context cards, and to make use of both switch capabilities (digital and card-based switch). The participants were then encouraged to repeat the process to familiarize themselves with the system.

For both sessions, engagement in the two tasks proceeded as follows: participants would engage task 1 (the information foraging or consumption task, depending on order assigned) for 10 minutes and transition to task 2 for another 10 minutes. They were then interrupted and asked to resume the task 1 (e.g., using what was found during information foraging for a vacation to decide on a specific vacation) for 5 minutes, after which they were given a 5 minute break. After the break, they were asked to resume the task 2 for 5 minutes.

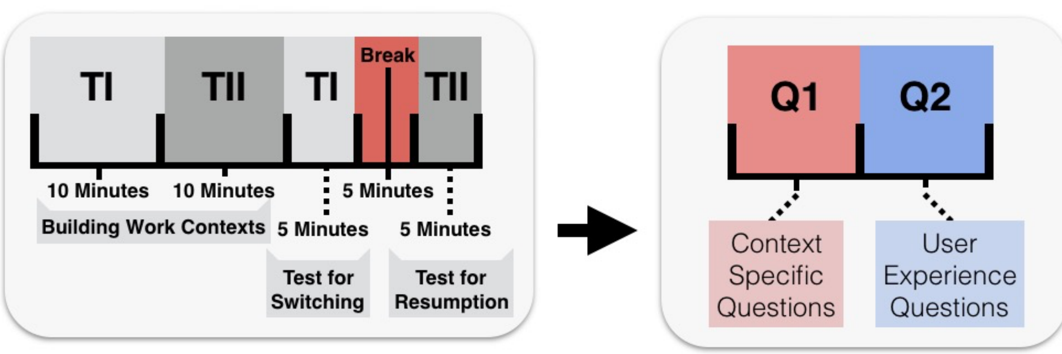

Figure 23 Study 1 laboratory procedure for both sessions.

A researcher observed and took notes of all of the participants' activities. After completing the sequence described above, the participants were administered a semi-structured interview containing two sets of questions. The first were context-specific questions related to the two tasks just completed. The participants were allowed to use the Context Manager to access their data, if they could not recall information from memory. The second set of questions elicited the participants' experience of the Context Manager and card reader system. The participants were asked to explain the strategies they employed in using the system. Besides experimenter notes, the interview was audio-recorded for further analysis.

IX.6.3. Data Analysis

First, collected audio interview data were transcribed using the transcription software 'Inqscribe' [23]. Next, interview data and pre-study questionnaires were coded qualitatively through the 'MaxQDA' software [24]. Qualitative coding followed a grounded theory approach as employed by Charmaz and Strauss [26]. Initial codes were generated during the open coding phase (e.g., *"P4 says search is annoying"*). Next, the generated codes were organized under related categories during the *"focused coding"* phase (e.g., Code, *"Effort"* comes from *"Not much mental load"*, *"Focus on what I need to"*, and *"Little effort in switching"*). Finally, thematically related categories were interrelated during the *"axial coding"* phase (e.g., Axial code, *"Describing Mental Effort in Switching"* from category codes *"Effort Expressed"*, *"System automatically opens"*, and *"Affective Response"*).

IX.6.4. Lab Study Quantitative Results

<u>IX.6.4.1. RQ-1: Average Time Spent in Creating Context (Card vs. No Card Session):</u>

The Wilcoxon signed-rank test was conducted to compare the effects of the card condition on performance in two contexts. We found no statistically significant difference between *"Card"* (M = 7:29 minutes , SD = 0.096) and *"No Card"* (M = 8:17 minutes, SD = 0.067) sessions for *"Context 1"* creation, (W = 7.0, p=0.297). For the creation of the *"Context 2"*, we found a statistically significant difference between *"Card"* and *"No Card"* sessions, (W = 3.0, p = 0.039), where more time was spent in creating the context in *"No Card"* session (*M*= 6:55 minutes, *SD* = 0.065) over the "Card" session (*M* = 8:38 minutes, *SD* = 0.10 (Figure 24)).

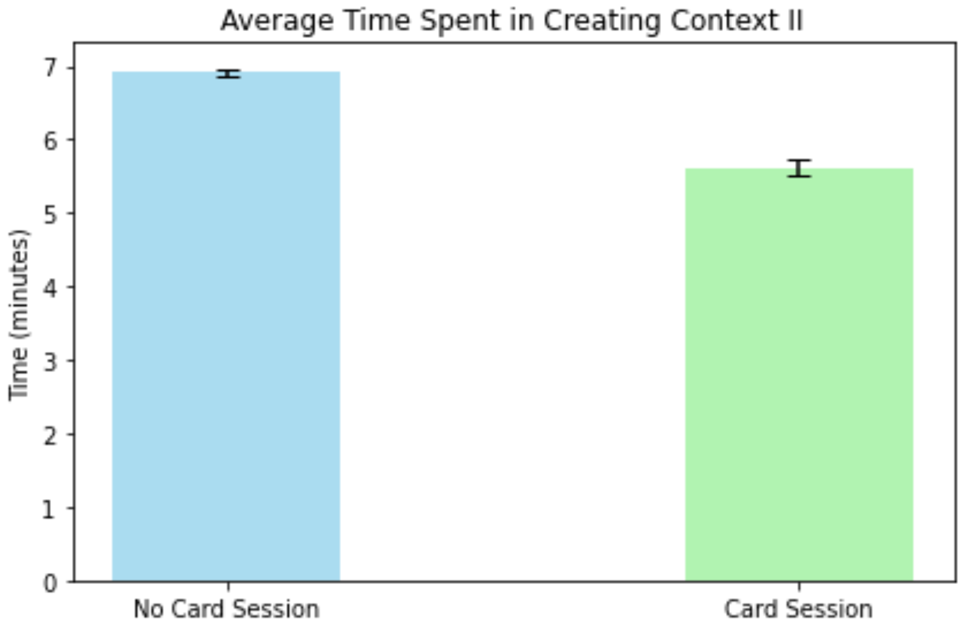

Figure 24 Average Time Spent in Creating Context 2.

IX.6.4.2. RQ-2:Elapsed Time Before First Significant Action in Resumed Context:

The Wilcoxon signed-rank test was conducted to compare the effects of the card condition on elapsed time before first significant action when resuming a given working context. We found no statistically significant difference between *"Card"* (*M* = 0:52 minutes , *SD* = 0.073) and *"No Card"* (*M* = 0:10 minutes, *SD* = 0.012) sessions for *"Context "* creation, (*W* = 13.0, *p*=0.083).

IX.6.4.3. Quantity of Safari Tabs Opened:

The Wilcoxon signed-rank test was conducted to compare the effects of the card condition on Safari browser tabs maintained during context creation. We found no statistically significant difference between *"Card"* (*M* = 3.45 , *SD* = 1.77) and *"No Card"* (*M* = 3.167 , *SD* = 1.89) sessions for *"Context 1"* creation, (*W* = 12.0, *p* = 0.733). Similarly, we found no statistically significant difference between *"Card"* (M = 4.54 , SD = 2.02) and *"No Card"* (M = 3.67 , SD = 2.30) sessions for *"Context 2"* creation, (W = 9.5, p = 0.445).

IX.6.5. Lab Study Qualitative Findings

Participants indicated that they used a variety of strategies to man- age their work contexts in their day-to-day work with existing file systems, or with the standard system that was given to them during the study. These strategies included the following:

IX.6.5.1. Desktop Level

Use of windows management techniques such as manually moving and minimizing windows (e.g., *"With the mouse and keyboard I have to figure out where windows in the desk- top are hidden behind and search for it in all the clutter."*), use of shortcuts (e.g., *"I can use command tab to switch through I guess the application that was in or whatever"*), and the use of virtual desktops (e.g., *"Most of the time its 'pretty straight forward when switching between workspaces."*).

IX.6.5.2. Window Centric

At an individual window level, context is retained by keeping activities restricted to a given window (e.g, *"I had them all in one document so I didn't have different workspaces."*). Context was said to be resumed by using either tabs (e.g., *"I think by having instant access to a webpage that would take you eight clicks, you have another tab opened to a page that takes you five clicks."*), or skimming the contents of a window (e.g., *"when I was required to return to my original task, the road trip, I just switched tabs back, playfully just skimmed the page, re-contextualized myself.").*

IX.6.5.3. Multiple Windows on Screen

Participants use windows as unit of work to represent their work, where each window corresponds to a given project (e.g., "...when doing any type of projects, you'll always have a window for one thing and next thing you know, you'll have like a billion of windows open.").

IX.6.5.4. Relying on Memory to Resume Context

Participants regain a context either referring to their own memory (e.g., *"I do a lot of things in my head....Normally I would write the address. I felt I need to write more because you wanted me to go into fine detail."*) or referring to the desktop elements in front of them (e.g., *"Whereas when you normally do that you have to like open up everything back up and figure out where you were or figure out what you're doing."*). Against this backdrop of strategies used with current non-tangible systems, qualitative findings with respect to the WCM were grouped into 6 categories, each with several themes that emerged from our analysis.

IX.6.5.5. Card Representation:

The cards were understood as a proxy for abstract concepts as well as for digital objects. Abstract concepts that the card represented for participants included the following:

- **Task:** *"The card, I guess that would represent almost like picking up a pencil. Like I know I need to write something down. It represents a task at hand." For some, it represents the state of an activity: e.g., "Um the card that this is the project. My projects on the card that makes it all my research and stuff but its also like its not like its does save everything but its more of a progress so I know I can easily ah I don't have to save all my links in that kind of thing I can easily take it off and leave everything open."*
- **Certification of Access:** *"It kind of me simulates oh you're being given this top secret access you know just like with the lab , we need a card for the most part to get in. Without*

it no one can get into it. So with the card no one else can really get into whatever you're working on."

- **Collection:** *"Uh, okay I know that this card has all the information that I have for the road trip. Whatever I have searched for it. The excel table I have made. I forgot to drag it into the application."*

The cards were understood as a proxy for digital objects that participants would encounter in their daily life. These included:

- **Desktop:** *"To me, it represents, kind of like the context of a workspace. Like in other applications, like if you had Photoshop, you have a bird– A workspace set up and you can pull all your different tools and palettes and arrange them around, and you can save that so every time you load it up, you'll have that setting."*
- **Window:** *"The card represents for me whatever I did for that task. At first I wanted to say that safari window but then I have a text file up so yeah I expect the safari window and the text edit file to both open."*
- **Folder:** *"You know to me it's very similar to a big folder that has like a bunch of I guess my materials um I really like it."*
- **Button:** *"I'm doing the same physical movement here it's not like I can tell the computer through my mind tell me to move to some location the movement to digital button versus moving the card is essentially the same to me in that it still requires my hand to do something."*
- **Tab:** *"I think I mean it almost feels like the information is not on the computer, almost. It feels like the information is on the card. So or it also feels like its uh a tab."*

Less common were references of the card being a proxy for physical objects, such as another computer or a portable drive (e.g., *"So, like if say because it has the same it reminds me of a USB, with the USB you have to plug it in and click on everything and remember everything you had opened prior. But with this you can just (sound effect) opens all on its own. It reminds me of a USB and stuff."*).

IX.6.5.6. Affordances of Card Tangibility:

Participants related different kinds of advantages that they experienced with the tangibility of the card. Five themes were uncovered in that respect:

- **'Annotating Cards':** The ability to write on the physical card supported participants to leave notes on the cards (e.g., *"The cards are acting as a kind of note."*) or to be able to distinguish cards from one another (e.g., *"Well if I don't write it on the card, I will probably be confused like which card is for which it's kind of annoying you have to like see like tap each card to see which card contain which contents"*).
- **'Security of Information':** The physical cards provided participants with a sense of security that comes with being able to handle one's activity context (e.g., *"I like the tangibility of knowing that, like, everything has an actual associated thing. It can't be tampered with or accidentally deleted. I don't know if it's true or not, but it kind of felt like it that."*).
- **'Mental Recall Support':** The card was described as supporting context reinstatement by acting as a cue for upcoming activity (e.g., "Okay is there a difference between clicking on the like quickly clicking from one project to another versus I'd look and then I take something. These two seconds. For three seconds. Are enough to kind of mentally prepare us to switch tasks.").

- **'Perceived Speed of Access':** Participants perceived the physical card approach to be faster because of the need of what they perceive to be a single physical action for its use (e.g., *"Uh, it is a little.... uh, it is a little faster because you just physically put this over that."*; e.g., *"Instead of me clicking every single page that I've used, I can just physically move it and that takes. It's more intuitively easier"*).
- **'Maintaining Focus of Attention':** The physicality of the card use seemed to allow participants to remain in a focused state of mind (e.g., *"I don't have to break my immersion to task, I can quickly switch it just with the... in the sense that it's embodied like in the switch than [..] with the mouse and figure out which window this desktop thing is hidden behind and I have to search for it in all the clutter but I can just quickly, quickly [...] back in."*).

IX.6.5.6. Challenges in Using the System.

As participants interacted with 'WCM', they indicated certain challenges in using the system:

- **'Cards afford Misplacement':** Participants noted that one could lose the cards over time (e.g., **Interviewer:** *"I see. So um, what would you think the benefit of having a digital version of the card rather than a physical?"* **P2:** *"It's more flexible. Physical cards maybe you lose this one. While you enter or log into your account."*).
- **'Getting Used to Card System Model':** Participants had issues with establishing a mental model for using the cards in the system since it is different from existing file management approaches. First, users referenced a learning curve (e.g., *"I think that in the beginning, learning how to use the context switch, you had to get used to it."*). For others, system feedback was lacking given that the physical cards themselves were static (e.g., *"Uh*

actually, I wasn't clear when I was not sure I have associated all the changes to the correct card. Then uh , um I couldn't remember if I had done all the steps right.").

- **'Lack of Portability':** Participants noted that the large size of the card reader discourage portability (e.g., *"The card thing is okay but I think the only reason I wouldn't use it is because it's kind of big. It would be a hassle to carry everywhere. At home maybe it would be fine but then also might not."*).
- **'Closure of context'**: Participants perceived the tapping of a new card as the full closure of one work context and the opening of another. The maintenance of the previous work context (e.g., having its files remained open) was seen as undesirable (e.g., *"I would have preferred switching like you know switching between cards that have like the programs closed.").*

VIII.7. Study 2: Case Study

In order to understand how TUI can support cognition in work context management, it is necessary to consider the lived-in context in which IWs engage in their work contexts. In this section, we will describe our longitudinal case study in which our 'WCM' was deployed in the wild.

IX.6.6.1. Study Procedure:

Participants were involved in a four-week longitudinal study using the 'WCM' system. Participants were given a WCM system and at any point during the study, they could create work contexts based on their own needs in their daily practice. When a user engages a specific 'work context', the application starts a background timer that records the start of a session and end of a session. After participants have the contents of the 'work context' open and are prepared to work intently within it, they press a button on the interface to indicate activity. This action was used to assess time expended in their engaged work context. While an ‘work context’ is engaged, an additional timer will be activated. The timer activates a ‘pop-up’ window every 30 minutes that will ask if the participant is actively working in the opened ’work context’. For every time the user responds to the pop up, the system registers that the participant has engaged in the ‘work context’. Should the user not respond, the ‘pop-up’ window will close after 1 minute. In this scenario, the system will register there is a break in activity in the opened ‘work context’. For each week of the study, the participant returns to the researchers’ laboratory for a semi-structured inter- view to assess users’ daily experience of ‘Context Manager’. At least 3 interviews were conducted for the four-week period. Participants were brought back to the researchers’ lab to conduct a final semi-structured interview.

IX.6.6.2. Example Cases

Participants were recruited through word-of-mouth took part in this study. Two cases are presented here that are illustrative of the broader findings are presented here. Pseudonyms are used to preserve the participants’ anonymity.

Case I.

Roger is the dean of his university’s School of In- novation. Roger handles several ongoing projects, spanning from university-based affairs, scholarly research in patent law, and per- sonal projects. Roger used ’WCM’ to create a ’work context’ for a recent patent law scholarly paper he was working on. The ’work context’ itself consists of several versions of the same paper he was working on at the time. He would use these various versions to compare changes that he would integrate into a final copy. Traditionally, when Roger resumed a work context such as this, he would often have to navigate through file directories or through a "recents" page on a word processing application, in order to access the exact document that he needed at a time.

Roger noted that ’WCM’ supported his ’work context’ by pro- viding a direct link to the unique set of documents that he needed for that project. As Roger engaged ’WCM’, he noted that he would use it to preserve specific Google scholar links that he has up. Noting the issues that comes with. To address the cards how the cards can take up much-needed deskspace, Roger placed all his cards on a traditional upright card holder. He stated that he would assign meaning to them based on whether they were standing upright (urgent) or sideways (not active). Roger said that the card at first reminded them as something similar to a hotel key but as he considered the cards’ meaning and how it was used, he added, that the card acted as an abstraction to entry to one’s work context. In regards to the act of physically switching work contexts through card, Roger offered that the experience was unusual, likening it to the use of floppy discs in earlier computing systems. Roger was skeptical to the value of using cards in WCM if it was possible to access work contexts through a selection on the main app screen. However, Roger remarked on an anecdote on how he got back to a months long forgotten project through an chance view of its one of its documents on his desk. When asked if such an experience could be afforded through a traversing the file directory, he responded that he never had such an experience. In this instance, the card could have provided for Roger a chance moment to return to a previously stored away work context.

Case II.

Jan is an executive secretary to the dean of the School of Innovation. In describing her usual workflow, Jan stated that her work revolves around task-based activities over project- based activities. From her experience, Jan would define tasks as events that are taken care of immediately and quickly (e.g., paying department bills, working on human resources on-boarding, and scheduling), whereas a project is ongoing and indefinite over time (e.g., writing a grant proposal). To maintain her attention across the day, she relies primarily on email applications for incoming events and tabs for current tasks at hand (" My job is reactive. I'm always responding to the latest email, latest calendar request."). She created work contexts based around certain tasks she typically engages in (e.g., Academic Affairs Services, Expense reports).

Jan primarily used 'WCM' in the office, where she typically engaged in multi-tasking workflows. She relied more on the multiple tabs from system to aid in remembering context at the end of the day, Jan stated, (""Once, you're out of the task, you're screen is back to where you were before. Keep track of where you were before."). Jan noted how the system supports keeping tab collections set in one place ("It does a good job of having everything you need all in one place. I'm ready to do expenses, I throw it on there and it pops it up. Before, I have to go through the bookmarks and find where I'm going. It saves time that way."). For Jan, the card acted as a direct route to the specific data she needed for a task, circumventing any distractions that might come along as she would traverse pages normally ("You can always get distracted while doing the task. You're opening something and there's a banner. If you go to the university-buy system, there's a new message. You click, and lose attention. System takes you to exact tab while avoiding the distractions to traverse to it."). In Jan's experience, the card represents a conglomeration of bookmarks that are specified for a given task. For Jan, the physical act of tapping the card represented change. It indicated the moment in which she is changing tasks. Upon engaging in this action, she thought of it as akin to checking something off a list. Through this, Jan describes this could help her to avoid getting lost as she deals with minute-to-minute demands.

VIII.8. Discussion

We discuss our results within the context of our three lenses to understand how the tangible properties of physical objects supported digital work context management.

Sign Mediation Theory:

Our results suggest that representing one's digital work contexts through the cards gave participants a special awareness of their work contexts and how they engage them in practice. For the participant, the work context is fluid in its meaning and can act as a proxy for their work context, standing for its state of activity or level of attention. These meanings are not static and could potentially shift as users engage deeper and deeper into their work context. Of note, because of the physical nature of the cards, the cards themselves acted as tools of thought when people were engaged with the reader. When invoking a context switch, the physical act itself of either placing the card or removing it imparted unique meaning to the user. For example, placing a card could mean more than simply access but take on meanings such as access through a route, a unique window of viewing, or a fresh start to work. In the case when the card was not actively used with the reader, as Roger demonstrated, the cards can still act as tools of thoughts where users can define specific orientations and positions of the cards to represent different work contexts.

VIII.8.1. Distributed Cognition:

Representing one's work contexts through the cards enabled users to reduce their cognitive workload in two key ways. First, the cards served to provide a perceivable abstraction of a work context. While individuals may possess an awareness of their work context and its elements, special care is usually needed to keep these elements together. In our approach, the cards alongside the WCMApp provides an abstraction in both physical and digital form for this needed cohesion. Second, through the role that the cards play in invoking a work context, the cards take on a secondary role of facilitating access to one's contents. Previously, when switching among work contexts, participants would have to manually collect the contents needed for their work contexts or add them to the desktop resulting in clutter. The cards in this instance act as an abstraction for a mechanical action in retrieving content.

VIII.8.2. Context reinstatement:

The cards provided participants a mnemonic to remember the state of their work contexts. The card in supporting episodic memory supported this function in two ways. First, the cards acted as a visual cue, providing a visual and tangible representation to reinstate one's work context. This is similar to the role of traditional office artifacts such as post-it notes or documents left on one's desk. Owing to the coupling of digital information with tangible artifacts, the act of reinstating a work context is engaged in terms of the set of memories associated with the card and the resources that are invoked on screen.

VIII.8.3. Broader Implications

Our results suggests that a potent avenue of research for tangible interaction resides in its use to support cognition – in a sense, to explore how 'embodiment ascends to mind'. By showing how tangible objects may be wielded as material carriers of thought, tangible interaction has to potential to complete the connections that bridge our cognitive, physical, and informational worlds. Within the do- main of work context management, our results show promise for bringing physicality into the loop of our context management and awareness. However, we note that unlike physical manila folders of the past, the physical proxies do not also serve as the 'true containers' of the associated information. As such, maintaining the physical proxies pose an additional load in the context management activity. Care needs to be paid to the design of such proxies to 'add value' to their use (such as allowing them to be writable in our design) so that the user can encode relevant information physically to support memory and context reinstatement.

VIII.9. Conclusion

In this chapter, we wanted to understand how TUIs can serve as tools for supporting cognition. In pursuit of this inquiry, we chose the area of work context management as a testbed to explore this idea. Following theoretical lenses that suggested that physical artifacts may have an important role to play in supporting context switching in IW's tasks of finding and reminding, we developed the WCM App. Through the design of WCM App, users can create explicit digital representations of their work contexts. The cards in our system can be coupled with users' digital work contexts and consequently be used to invoke and close out work. Because these cards are linked with resources and certain mental representations of work, we found that the cards in themselves changed the way in which work contexts were understood and engaged in by participants.

CHAPTER IX CONCLUSION

IX.1. Overview Discussion

In this dissertation, we've examined how knowledge workers represent their ongoing projects on their personal computing devices. A commonality among knowledge workers is how these projects are represented by idiosyncratic groupings of applications, documents, and webpages, alongside the on-screen status and state of work completed using these resources. We refer to these collections of digital information as a working context. These working contexts serve as both an organizational unit, defined by the knowledge worker, that aids in the persistence of work through the practical arrangement and access to their contents, and a means of preserving their state to support more effective thought and reflection in work.

Working contexts do not exist in a vacuum but are a byproduct of the embodiment of work. Knowledge workers possess several working contexts that shift in and out of focus as their own goals and those of others in the environment demand a context switch. Working contexts can be shared by multiple individuals, but they may perceive them differently in terms of urgency and whether the context is central or peripheral to their goals.

Another way that working contexts are embodied is through their materiality. Working contexts do not merely reside in digital media but emerge from the mental relationships formed between perceivable objects that are interrelated for a self-directed goal. The modern office environment reflects this embodiment, as paper-based media support the creation and consumption of information through structures like files, folders, and cabinets for storage, and desktops for holding active groupings of information for immediate use or short-term persistence.

The digital desktop metaphor has been prevalent in modern computing since the advent of windowing systems for OS interfaces. In fact, the terms just described for physical media is equally applicable to personal computing. In personal computing contexts, files are the core unit to data organization that are organized into cascading organizations of folders/directories that support long term persist whereas the digital desktop supports the active use of this information via application editors and are maintained in the short term on the desktop. The ubiquity of personal computing in modern society can be attributed to this successful implementation of metaphors and affordance akin to its physical analog.

However, there are issues in work context management within digital computing systems. These issues can be attributed to the continued use of the same desktop metaphor and contemporary practices around information creation and consumption. Digital representation supports our work context management practices when they mirror their analog counterparts in physical media. When these practices diverge, complications arise. This divergence requires us to extend our thinking beyond existing practices, focusing instead on the affordances of digital media and how it can interact with and support cognition.

One approach to addressing this problem is the examination of how contexts are constructed, perceived, and supported in digital media and modern computing. We investigated these practices both experimentally in single and collaborative work context scenarios. Additionally, we examined a research test bed that represents digital working contexts as a bridge to physical media, incorporating the physical affordances that come with it. Through these studies, we sought to answer the research questions posed earlier in this dissertation. Below, we will review each research question, consider the findings presented previously, and suggest design principles and potential applications that can support digital work context management.

IX.1.1. Sign Mediation Theory and Material Carrier (SMT-MC)-1: How are conceptions of working contexts represented via physical and digital media?

By considering MC, we can understand how a KW grasps the scope of a project, forming a label—a kind of cognitive handle—that organizes all the relevant concerns for the project. This label is then externalized through the organization of resources in the media where the work is performed, which in this case is digital media.

In digital work context management, we observed how KWs externalize and organize their working contexts at different levels of abstraction. In both individual and collaborative studies, participants described abstracting their digital work environments at the level of individual windows or groups of windows. These abstractions allow meaning to be inferred from their state, such as gauging progress by an incomplete section of an open document or arranging windows in specific locations as an organizational pile, serving as a proxy for the OS's file browser system.

Due to the utility of internet browsers in contemporary computing, they often serve as the primary hub for activity and coordination in digital work context management. Browsers provide multiple functions for KWs, frequently replacing traditional productivity suites like Microsoft Office with their web-based counterparts, such as Microsoft 365 or Google's cloud suite. This doesn't mean that KWs don't use other applications in their workflow (e.g., a designer using AutoCAD alongside a browser for an engineering design project), or that their entire digital work context is confined to the browser (e.g., a designer's work context may be centered in AutoCAD). However, the key point is that KWs increasingly rely on browsers as their primary coordination tool, rather than the desktop environment as a whole.

We also observed how MCs for digital working contexts can easily break down or be lost. When the organization of an MC is based on an internet browser, meaning can be diluted if too many tabs are accumulated across different tasks. This can cause the browser to lose its symbolic value. Similarly, as more tabs are opened, the text descriptions of each tab become shortened; in extreme cases, only the icons remain, offering minimal information about the resource accessed. A similar issue occurs with windows on the desktop—when many windows are open, the clarity of which context is active becomes blurred, requiring additional effort from the KW to resolve the confusion.

The WCM research prototype aimed to address the fragility of digital work context representation through a lightweight aggregation software that allows users to create explicit digital work context representations, saved as files accessible within the WCM application. This exploratory representation enables WCM to unify disparate digital items—such as websites, applications, and documents—into digital work contexts, creating a parallel folder system that highlights the semantic relationships between these items from the KW's perspective. Since WCM provides an explicit representation of a given digital work context, it allows for the representation to be maintained and accessed in new ways. For instance, access to a digital work context could be linked to specific commands (e.g., a user clicks on their CSCE-611 work context to focus on that particular class), a subset of a project (e.g., a professor views last year's working context for their design course), or the state of the KW's personal computing environment (e.g., when collaborators for a research proposal are present, shared elements of their working context are presented through WCM).

A key takeaway from this work, in relation to MCs, is how KWs understand their working contexts and represent them through the organization of digital information abstractions. It also highlights the inherent fragility of these collections as they are organized. For designers, it is important to consider how digital information is used in personal computing environments and to create systems that not only accommodate the KW's idiosyncrasies but also ensure their organization is sustainable and maintainable.

IX.1.2. Episodic memory (EPM): What features of digital and physical media aid in cuing episodic memory of digital working contexts?

Recall and reorientation to previous work states are essential in work context management, especially when those contexts are digitally represented. KWs often work in parallel across different contexts to maintain progress on multiple projects, ensuring that no single project dominates their time. KWs achieve this by re-accessing their work contexts and voluntarily or involuntarily recalling events related to a given context by observing its contents. As discussed earlier in relation to MCs, work contexts take shape digitally through the media in which the work is conducted.

Our studies demonstrated how digital work contexts are recalled using different persistence strategies. For example, KWs may keep windows open for an ongoing task throughout the week or create structures where information can be easily found and referenced, such as a Google Doc for an ongoing meeting with weekly updates and embedded links. Regardless of the approach, recall is supported by establishing a persistent structure that can be associated with both work-related information and cognitive cues. When this work context is accessed in the future, it serves as both a container for related tasks and a trigger for recalling previous states of work.

The utility of recall support was evident in our studies through the strategies KWs employed. Interestingly, these supports were not always digitally represented; they were also facilitated by physical media and co-located collaborators. However, we also observed how this utility could be hindered by digital representation, where the focus was more on re-accessing information (i.e., finding and opening digital information collections) and less on active recall—the process by which information helps to inform previous states of work.

Previous research highlights the role that information items play in supporting recall, showing how work cues, whether explicit (e.g., understanding the state of work from notes left on a document) or implicit (e.g., inferring work progress from desktop arrangements), assist in this process. Drawing on user habits of utilizing both types of cues, WCM was designed to incorporate work context recall as an explicit feature. For explicit cues, WCM's work context data structure allows users to associate notes with a specific work context, capturing the state of their work. Implicit cues are supported by the system's ability to save the arrangement of windows and tabs in an internet browser, preserving the state whenever the user switches to another work context. This feature helps avoid the need to constantly keep the contents of a work context open, while also protecting the context from losing its associated information.

The takeaway for designers is to recognize how cues are embedded in the content that KWs use in their work. In supporting the recall of a given digital work context, the focus should not only be on preserving the information within a file but also on providing support in both explicit and implicit ways that inform prior states. This can be achieved by maintaining the exact working state at the time of switching to another work context.

IX.1.3. Distributed Cognition (DCog)-1: How is traversal of working contexts distributed across media?

Organization of information and recall through these groupings are two major facets of digital work context management. However, there is a third pillar that supports this practice: the way in which work context-related items are conferred upon to understand and inform current states and future goals. In this work, we utilized DCog to examine the role that information items play in supporting digital work context management.

In the individual studies, we observed how information items are actively referenced when resuming a piece of text. This resumption was not a straightforward process; instead, it involved a series of examinations and reflections as related information items were present and interpreted. Similarly, in the collaborative studies, we found that this sense-making process occurred where information items and associated partners within a working context acted as distributed cognitive centers, supporting both sense-making and eventual resumption.

We also observed decreased performance in resumption when recall was split across different media, as seen in the individual studies, and in in-person meetings where parallel organization and coordination were necessary to support resumption. The commonality in both instances of reduced performance lies in the fact that engaging with the working context required parallel attention and organization of materials, rather than focusing solely on the goals of the working context itself.

The interaction design of WCM addresses the need for distributed cognition through the card system that automatically saves, closes, and re-engages a working context based on proximity to the NFC reader. Currently, the system is straightforward; it requires users to manually place the RFID card to indicate which context should be active or inactive. However, because we have 1) an explicit representation of a digital working context and 2) a system that actively updates and launches these working contexts through both these elements and IoT sensing technologies, WCM can be extended to respond to the state of the embodied world that the user inhabits. This means it can bring in working contexts based on factors such as location, time, or individuals present.

For designers, a key takeaway is to identify how resources within a given digital working context are used for both re-access and recall of prior work states. It's important to explore ways to automate re-access through organization and triggers, while also ensuring the information is readily accessible and usable. This enables users to actively engage with the information, make sense of it, and eventually facilitate recall.

In closing, this section, a scenario is provided that illustrates how a future system design can be utilized within the typical working environment.

IX.1.4. Design Fiction for Digital Work Context Management:

Susanne is an interaction design professor at Texas A&M University. Before Susanne arrives at her office, she reflects on her various responsibilities: instructor of record for her course load, research lab principal investigator, committee member for community outreach, and a collaborator on 3 cross-department research projects. Each of Susanne's responsibilities are all equally demanding for her attention and are frequently urgent.

When Susanne enters her office, she opens a binder on her desk. The binder, when opened, reveals sheets of numerous RFID cards. Each RFID card has a name written on it, acting as a physical proxy for each ongoing or dormant projects. Susanne has written and rewritten the labels on each of the RFID cards, reflecting her ongoing understanding of her projects. She takes 5 RFID cards from the binder and place them on her desk. Each of the cards laid on the table are tied to a different activity she will be involved in today.

Susanne takes one of her cards, labeled *"CHS Small 2024*", and places it on a medium-sized flat tray that is connected to her laptop. The tray has a RFID reader embedded in it. The card activates the Working Context Manager (WCM) application, a project management tool. WCM identifies the *"CHS Small 2024"* card and changes its window contents, listing the set of applications, documents, web pages, and notes that represent her last state of work when she last worked on grant project. In the bottom right-hand corner of the WCM window, there is a section that list notes that she left for herself at different points in time when working on the project. Susanne, upon glancing this information, knows exactly what she was working on previously and what else remains to be done.

Susanne uses the contents associated with the CHS Small 2024 project in the WCM application, resuming her task in writing her draft. She would continue writing her draft for an hour until she notices her three teaching assistants peeking through the glass window of her door; it's time for her weekly course planning meeting. Susanne, unbothered, types a quick note in the WCM window associated with the grant, writing *"Contact John for his bio sketch and ask Wu for her update on the study design section"*. Susanne removes the *"CHS Small 2024"* card from the tray; WCM subsequently closes the project window, reverting to its default display window. Susanne places the *"CHS Small 2024"* card in near her laptop, anticipating that she will get back to project as soon as her course planning meeting is over.

Susanne welcomes her teaching assistants and start the meeting. Susanne places her card, titled *"Vis-Comp-101_2023"* on her tray to get its associated data, providing a general overview of the state of the class from Susanne's own view. As the group discuss the state of the class, each teaching assistant places their own card associated with the class, representing a different section of the class (i.e., a subset of the data shared both by each teaching assistant and Susanne). Before each student removes their card, she types a quick note particular to the teaching assistant's section.

As the teaching assistants are leaving, one of her collaborators, Nadine, enters the office. Nadine asks Susanne about the curriculum design project they worked on together 2 years back. As Susanne discussed the project with Nadine, she was having some problems recalling the exact details of her contributions. Susanne opened her folder of context cards and finds the old RFID card named, *"Curriculum Design Ideation 2021*". Susanne slips the card out and placing it on the tray, activating the WCM application.

The WCM application shows the resources that were used since the last time she worked on her curriculum design project, displaying notes and screen shots of her last action. Susanne glanced WCM's window and thought, *"Looks like I was editing the syllabus for the pre-approved class."* With this information at hand, Susanne was able to jump into discussion with Nadine about further changes requested by the department. Susanne agreed with Nadine on the changes and types a few notes on the current card's context window and removes it as Nadine begins to leave. Susanne, then looks at the periphery of her laptop and notices the card closest to it, *"CHS Small 2024",* she grabs it and places it on her tray and begins where she left off.

The aforementioned scenario describes a novel way that we could represent and manage our flows of work. This dissertation proposed the study of tangible and embodied interaction as a means to support task switching across different project contexts. Such an approach could support work when we consider how work can be thought of as existing as a series of contexts. What do we talk about when we talk about context? Smith describes that context generally describes that which surrounds. When we take this basic definition, we can extend context to be *"bounded by time, by space, by circumstances and by meaning"*. In the cognitive psychology literature, such conceptions of context have been used to describe such terms like temporal context, environmental context, situational context, situational context, and semantic context (S. Smith, 2007). In the consideration to work, as we described in the scenario above, work can be thought of as existing in different contexts.

IX.2. Conclusion and Future Work

This dissertation is focused on the problem of work context management, the ways in which KWs are able to effectively organize, access, and wield their information collections as they re-engage them between work periods. KWs are able to reinstate their working contexts through their embodied capabilities to offload onto the environment and use their perceptible environment to represent and hold information. It is through this representation that KWs are able to traverse across their different working contexts. In acknowledgement of the role that the perceptibility of information serves in reengaging one's working contexts, this dissertation proposes an exploration of the design space of digital computing systems by considering the linkage of digital information with associated physical and digital artifacts of a given working context to support KWs and work context management practices.

In closing the proposal document, the delineate the ways in which the proposed research has value in contributing to the computer-human interaction literature is to by pointing out the inherent value and limitations present. Using Carmel and Sawyer's future of work (FoW) (Carmel & Sawyer, 2023), key dimensions, the following subsections will close as follows. First, in identifying the alignment of the proposal to the wider computer-human interaction literature, the FoW dimensions will be used to point out present and future issues of work and how the work proposed here can address those concerns. Next, the limitations of the dissertation, pointing to aspects of the FoW dimensions that suggests potential complications to the base assertions of the dissertation; the goal of which is not to suggest not to engage the dissertation research, rather, to properly frame it within a scope that does not attempt to provide a broad solution to the problem posed. Finally, we will identify a portion of the FoW dimensions that while may not be relevant to the present dissertation study, however can be relevant with respect to future extensions of the work.

IX.2.1. Relevance and Timeliness of Research Topic

'*Locus of Place'* considers how knowledge work can be disconnected from the traditional physical office, raising questions of the extent to which work can be effectively virtual. Owing to the primary purpose of knowledge work in the production of information and its consumption, Carmel and Sawyer (Carmel & Sawyer, 2023) note that as telecommunication technologies improve, there will still be continued interdependence among knowledge workers. While the physical space associated with different working contexts may not always be present (Sandoval-Reyes, Idrovo-Carlier, & Duque-Oliva, 2021), knowledge workers will still function contextually, in that the mental context of knowledge workers consist of multiple elements, which includes the specific documents, applications, and individuals associated with their different working contexts (Okundaye et al., 2017). As knowledge workers work across their different working contexts across remote and in-person settings (Jarrahi & Thomson, 2017), the dissertation research should investigate how mental context can be engaged differently depending upon how a context can vary with respect to the built or environment. Specifically, given how one's own mental context may have variable congruity with the physical, ambient context (S. M. Smith, 2013), how can different contexts be distinguished from one another when the surrounding environment can be static (in the case of working from the same home office across working contexts) or dynamic (in the case of when the knowledge worker is working across different sites) with respect to one's own computational context?

'Structure of Work', is relevant to the dissertation research as it is aligned with the fluid nature of how knowledge workers establish their working contexts, this attributed to their relationship with information. Kidd (Kidd, 1994) describes that organizations employ knowledge workers for their ability to self-generate solutions to work-related problems. Knowledge workers solve organizational problems either directly or indirectly. First, knowledge workers directly solve organizational problems by actively seeking information about the posed problem and, ideally, finding an existing solution that can be suggested to the organization. Second, knowledge workers can indirectly solve organizational problems by finding information to actively change their thinking or practice in their activities.

‘Technologies’ Roles’ considers the role that advances in technology could impact work with respect to automation of roles, substitution of human work (Balliester & Elsheikhi, 2018; Santana & Cobo, 2020) while highlighting the ways in which human work could be changed where artificial intelligence acts as a form of cognitive augmentation or collaborator in knowledge work (Grønsund & Aanestad, 2020; Zuboff, 1988). ‘Technologies Roles’ is relevant to the dissertation research with respect to how a specific form of artificial intelligence, this being pre-trained transformers and its implications towards information production and consumption tasks. First for information consumption, pre-trained transformers (George, George, Baskar, & Martin, 2023) can aid knowledge workers by improving the quality of search results by returning results based upon the semantic context of the initial search. Regarding research on a relatively new concept to the knowledge worker, pre-trained transformers can provide customized and user specific summaries based on the individual needs of the knowledge worker to gain a foothold on a new concept. Second, for information production, pre-trained transformers can aid in the initial stages of a project from generating ideas, acting as a brainstorm partner for a topic, or provide boilerplate text for article sections. Pre-trained transformers can be used in the editing process also used as a kind of grammar/language validator to ultimately create documents that follow the convention of a specific venue. Collectively, pre-trained transformers can serve to take on the low-level work that requires careful aggregation automatically, enabling the knowledge worker to focus on higher-level concerns of creativity, criticism, and domain expertise application.

'Locus of Decision Making' is somewhat related to 'Technologies Roles' as a category of relevance to the dissertation research, specifically how it can serve to move more of the onus of decision making onto the individual knowledge worker, however supported by the collective knowledge represented by large language models like GPT-4 (K. Sanderson, 2023). Large language models are created by initially generating a model (pre-training) based on a large-scale text data set, initially finding connections between words without prior guidance (Need, 2017), an approach known as unsupervised learning. During pre-training, the model is generated to create a prediction of the next word within a sentence based on prior words within in a sequence, an approach known as "masked language modeling" (Devlin, Chang, Lee, & Toutanova, 2018). In training, the transformer model can create predictive windows that can determine what words are likely to follow in consideration to the specific set of words present, inferring semantic context. Knowledge workers can be supported by these models by how these models can establish a context, one part made explicit by the knowledge worker by their queries, and one part implicit, partly by how the model can provide suggestions that may have not been aware by the knowledge worker or prompting a deeper introspection on the knowledge workers' own line of thinking by retrieved results.

'Leadership model' points to the sudden shift from well-defined task-oriented working styles to a more open-ended, collaborative style of work. In this growing paradigm of work, knowledge workers, as Wilkinson points that knowledge workers are increasingly engaging in "*technologically-enabled era of self-generated work*" (Wilkinson, 2016). In this likely future, knowledge workers act as innovators and managers all in one, where the terms of a given is holistic in nature *"not expecting contractual relationships and full clarity*" (Carmel & Sawyer, 2023). Gonzales and Mark (Gonzales & Mark) share a similar sentiment, emphasizing that knowledge workers need to assume multiple roles and establish initiatives; effectively, the kind of work that traditionally be performed by administrators and managers. Given this likely future, this category has relevance to the dissertation research, as the need to manage multiple flows of information while maintaining the higher level concerns of relationships, procedures, and means of project outcomes are fluid, and will require investigation on how personal computing systems can better support such use cases.

IX.2.2. Limitations of Present Research Topic

'*Worker expectations'* considers the range of ways workers derive personal meaning from their work, whether it may be something that defines who we are versus a means to an end to simply live or to have the life that one wants. With respect to the dissertation research, *'worker expectation'* could challenge its rationale as the kind of work that knowledge work entails tend to be concentrated within a specific class of worker. Allison Kidd first drew attention to the idea of the knowledge worker in HCI by introducing the term from the organization and management fields (Kidd, 1994). Kidd used the concept of knowledge worker to motivate her discussion on how such workers maintain their work contexts and how they resume them. Peter Drucker originally coined knowledge workers to describe the role that most employees served in business organizations (Drucker, 1974). Kidd suggested that Drucker's knowledge worker concept could identify a type of computer user and inform how computer tools could be better developed to support knowledge workers in their daily activities. In Kidd's categorization of office workers, knowledge workers represent a subset of office workers (Figure 25). Of note, Kidd's classifications of office workers are not meant to be discrete characterizations but rather the type of activity that each type of worker is likely to engage in in most situations. The takeaway here, is that while more and more workers are taking on more, less-defined tasks, self-initiated work, but the extent to which there is a need to support context switching may be a short-term need for those whose work revolves around primarily communication or clerical work, whereas the case could be needed for research and development.

IX.2.3. Irrelevant Topics and Consideration towards Future Work

The work, following from this dissertation, can consider how specific digital work context management practices may vary by the demands of specific industries and how technology can be designed towards the embodied situation of the KW's working environment. FoW dimensions including '*Work-Life*', '*Firm's Value Creation*', and '*Labor Market Structure*', have the least relevance to the dissertation research, at least within the present scope. A commonality of these categories is how the concerns of work intersect between the individual, the community, and the organization. In conveying this idea, an embodied lens can help to explain this.

To start, embodiment, as defined by Dourish (Dourish, 2001a), states that *"Embodiment is the common way in which we encounter physical and social reality in the everyday world. Embodied phenomena are ones we encounter directly rather than abstractly"*. Embodiment, does not simply refer to how an entity can be physically manifested, but instead how entities are grounded in everyday, mundane experiences; the ways in which people, practice, and technology are engaged practically and how meaning is derived from their interaction.

Using embodiment as a lens towards the future of work, the specific categories of '*Work-Life*', '*Firm's Value Creation*', and '*Labor Market Structure',* point to the ways in which the interaction of changes in technology, by way of the growing prevalence of artificial intelligence, computation, and robust networking capabilities, has changed the practice of work and the power dynamics inherent within and outside of organizations. 'Work-Life' is concerned with the workers' mental model towards work and its relationship to their personal needs. For some workers, having a balanced work-life is essential for the continued relations between employer and employees, where for others, a work-life balance is not feasible, whether it may be because of challenges in maintaining their job or because of the nature of the job itself (e.g., being on call all the time). 'Firm's Value Creation' is concerned with how organizations view themselves, either taking a stakeholder centric view (i.e., What does the firm owe to society and the environment?) or a shareholder centric view (i.e., How does the firm provide value for its shareholder?). Finally, '*Labor Market Structure',* considers the economic context of work as ongoing negotiations between workers and firms regarding their protections, working conditions, job flexibility, training, and education.

Office Worker Type	***Definition***
Knowledge Worker	Knowledge workers are changed by the information they process. They define their personal work objectives in relation to the objective to their company.
Communications Workers	Communication workers are individuals who aggregate information from other sources and redirect them to others in an effort to change other individual's behaviors for the interest of the company.
Clerical Workers	Clerical workers are individuals who are agnostic to the information that they transform and are not changed in conjunction with this information. They serve their company by knowing which information is to be applied in and doing so in a way that is consistent and efficient in terms of time and resources.

Figure 25 Kidd's Categories of office workers.

The scope of the dissertation research was primarily concerned with how to better understand how workers perceive contextual relationships within their work and how human-computer interaction can inform how these perceived relations can be better conveyed for individual and collaborative work. However, because the dissertation research ultimately seeks to inform the efficient design of knowledge workers' computer represented working context practices, such work could open the way to understand how tangible, embodied work context management empowers the individual within firms and as a second-order consequence, influence the three categories included in this section.

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APPENDIX A EXPERIMENTAL SCENARIO TASK SHEETS

Task 1: Travel Planning for a Conference/ Vacation

- **Budget:** $5000 per person
- **Timeline:** Summer
- **Where:** Somewhere you haven't been before
- **Need:**
    - **Purchase tickets for conference**
        - **Stage 1:**
            - Research the conference and learn about what is taking place during its events.
            - Determine which events you are interested in.
            - Determine length of time you will be at conference.
    - **Stage 2:**
        - Select the package of the conference you are interested in and get the price for it.
    - **Hotel arrangements:**
        - **Stage 1:**
            - Compile a list of 5 hotels that are within walking distance of venue
            - Compile a list of 5 hotels that are cheapest
            - Compile a list of 5 hotels that have the best reviews
            - Identify 3 hotel venues that best capture these constraints
        - **Stage 2:**
            - Get the price of the hotels and determine the dates that coincide with the conference.
    - **Purchase Tickets for Airplane:**

- **Stage 1:**
    - Determine airline and compare prices and dates.
    - Determine airlines in terms of price.
    - Determine airlines in terms of times.
- **Stage 2:**
    - Select airlines based on price and time and add to document.

- **Travel Means:**
  - **Stage 1:**
    - Determine the cost of renting a vehicle for the conference. See if there are parking costs to consider.
    - Determine the cost of using a rideshare app. Determine availability in area.
  - **Stage 2:**
    - Get costs and report it.
- **Food Budgeting:**
  - **Stage 1:**
    - Determine approach for food during the conference and create a budget accordingly.
- **Itinerary:**
  - **Stage 1:**
    - Research attractions that are near the conference venue.
  - **Stage 2:**
    - Determine costs associated with attractions.
    - Determine times of availability.

- **Stage 3:**
  - Report on costs for budget.
  - **Note:** There are multiple tiers of involvement

- **Output:**
  - Document that summarizes the trip plans

Task 2: Technology Purchase for a New Office

- **Budget: $50,000**
  - **Scenario:** You will need to purchase a set of appropriate office equipment for a firm of about 25 individual workers. Currently, each office worker is working from home before the office is fully set up.
- **Computers**
  - **Stage 1:**
    - Determine the range of computers that are appropriate.
    - Look at reviews.
  - **Stage 2:**
    - Compare price and value for selected computers.
  - **Stage 3:**
    - Decide on computers.
- **Displays**
  - **Stage 1:**
    - Determine the range of displays that are appropriate.
    - Look at reviews.
  - **Stage 2:**
    - Compare price and value for selected displays.
  - **Stage 3:**
    - Decide on displays.
- **Peripherals (keyboard, mouse, digitizing tablet)**
  - **Stage 1:**
    - Determine the range of peripherals that are appropriate.
    - Look at reviews.

- **Stage 2:**
  - Compare price and value for selected peripherals.
- **Stage 3:**
  - Decide on peripherals.

- **Software**
  - **Stage 1:**
    - Determine the range of software that is appropriate.
    - Look at reviews.
  - **Stage 2:**
    - Compare price and value for selected **software**.
  - **Stage 3:**
    - Decide on **software.**
- **Storage:**
  - **Cloud/Hard Disk:**
    - **Stage 1:**
      - Determine the range of **storage devices** that are appropriate.
      - Look at reviews.
    - **Stage 2:**
      - Compare price and value for **storage devices** .
    - **Stage 3:**
      - Decide on **storage devices**.
- **Output:**
  - Write a document that lists the kinds of things that would need to be purchased, why, and also provide a budget for bulk purchase.

Task 3: Planning a Party for an Organization

- **Budget: $5,000**
  - **Need:**
    - **Event Location:**
      - **Stage 1:**
        - Find an appropriate city to plan a party for your organization.
        - Look at reviews.
      - **Stage 2:**
        - Find and compare venues.
      - **Stage 3:**
        - Decide on venues.
    - **Food and Drinks:**
      - **Stage 1:**
        - Determine the kind of food and drinks you would like to serve at the party.
        - Look for potential catering venues in the city you are located. Compare it with the on-site event catering if possible.
      - **Stage 2:**
        - Compare price and value for different catering services.
      - **Stage 3:**
        - Decide on catering service.

- **Entertainment:**
    - **Stage 1:**
        - Determine what kind of entertainment you would like to have at the party (DJ, comedian, musicians, etc).
        - Look at reviews.
    - **Stage 2:**
        - Compare price and value for different entertainment options.
    - **Stage 3:**
        - Decide on entertainment.
- **Party Favors:**
    - **Stage 1:**
        - Determine the kind of party favors you would like to give.
        - Look at reviews.
    - **Stage 2:**
        - Compare price and value for selected party favors.
    - **Stage 3:**
        - Decide on party favors.

- **Output:**
    - Write a document that lists the kinds of things that would need to be requested and justification.