The Moving Context Kit: Designing for Context Shifts in Multi-Device Experiences

Katie O'Leary[1] *, Tao Dong[2], Julia Katherine Haines[2], Michael Gilbert[2], Elizabeth F. Churchill[2], Jeffrey Nichols[2]
[1]The Information School, University of Washington | DUB Group, Seattle, WA, USA
[2]Google Inc., Mountain View, CA, USA
kathlo@uw.edu; {taodong; juliahaines; mdgilbert; echurchill; jwnichols}@google.com

ABSTRACT
Multi-device product designers need tools to better address ecologically valid constraints in naturalistic settings early in their design process. To address this need, we created a reusable design kit of scenarios, "hint" cards, and a framework that codifies insights from prior work and our own field study. We named the kit the **M**oving **C**ontext **Kit,** or McKit for short, because it helps designers focus on *context shifts* that we found to be highly influential in everyday multi-device use. Specifically, we distilled the following findings from our field study in the McKit: (1) devices are typically specialized into one of six roles during parallel use—*notifier, broadcaster, collector, gamer, remote,* and *hub,* and (2) device roles are influenced by context shifts between private and shared situations. Through a workshop, we validated that the McKit enables designers to engage with complex user needs, situations, and relationships when incorporating novel multi-device techniques into the products they envision.

Author Keywords
Multi-device experiences; design process; design tools; field study; privacy; device use; context of use

ACM Classification Keywords
H.5.2 User-centered design

INTRODUCTION
People interact with many devices in everyday life, but face challenges managing multiple platforms, form factors, and applications. For example, it is difficult for users to manage attention across many screens, learn different interface and interaction conventions, and sync content [9,20,34]. Novel multi-device interaction techniques have been proposed to relieve these pain points by helping users migrate information across device screens [16] and allowing users to combine computing resources from many devices [43].

DIS 2017, June 10-14, 2017, Edinburgh, United Kingdom

ACM ISBN 978-1-4503-4922-2/17/06.
http://dx.doi.org/10.1145/3064663.3064768

While users find these new interaction techniques useful in lab-based studies (e.g.,[16,31]), it is unclear whether the conclusions drawn about these designs are ecologically valid. In the design of interactive systems, ecological validity means how users might appropriate these techniques in their everyday lives [4]. One of the major challenges to the ecological validity of multi-device systems is that sophisticated multi-device *systems* (consisting of devices designed to collaborate with one another in a particular ecosystem), and ad hoc multi-device *collections* (consisting of devices a person uses together in specific situations) co-exist in users' everyday life. This makes it difficult to envision and test new multi-device interactions in the context of users' existing device collections and behaviors, which is one reason that few of these techniques are tested outside of the controlled environment of the lab, with the exception of Chen et al.[6]. Moreover, research has shown that technology adoption and use are influenced by many contextual factors, including the physical and social setting [30], privacy considerations [19], and local values and norms [42], yet these factors are not currently well-represented in existing multi-device design tools [7,8,31]. Thus, our goal in developing a design kit was to help designers address ecological validity by considering contexts of use grounded in field research when envisioning multi-device experiences.

Specifically, we created the **M**oving **C**ontext **Kit,** or McKit for short, to help designers consider shifts in privacy needs, device roles, and device relationships that we found to be particularly influential on the use of multiple devices in everyday settings. Our design kit is both lightweight and reusable, suitable for use in envisioning workshops, design sprints, and reflective design processes (e.g., [17,22,36]). It provides product teams with familiar design aids and prompts, including scenarios and personas, to engage with complex and rich field data on multi-device use. The McKit is composed of several components†:

- A set of context-shifting scenarios from our field research

* This work was done while the first author was an intern at Google.

† The McKit is at: https://sites.google.com/view/mckit/

- Three sets of "hint" cards that remind designers of various multi-device interaction patterns, potential device roles, and known user burdens
- A framework that sensitizes designers to shifts in contexts, tasks, and relationships we found especially important in multi-device use
- Worksheets that scaffold the process of combining the design kit components

To develop these context-rich materials, we followed a 4-step process. First, in the **analytical step**, we analyzed insights from prior work related to multi-device design and use, and used these to inform our design kit components. Second, in the **empirical step**, we went to the field to collect rich examples of technology use in naturalistic settings. Our methods included experience sampling and field interviews with 25 participants from four diverse U.S. regions (Detroit, Boston, Miami, and the Bay Area). While some of our findings echo prior studies [20,21,34], our inquiry also yields new insights into multi-device use. We found that participants specialized their devices to perform six roles—*notifier, broadcaster, collector, gamer, remote, and hub*—in related and unrelated parallel use. We also found that device privacy and sharing considerations influenced device roles. In particular, when devices shifted from private use to shared use, users shifted the roles and relationships of their devices within a multi-device configuration. In the third step, the **codification step**, we distilled these insights in scenarios that force context shifts, cards that represent device roles, and in dimensions of a framework that map a multi-device design space with privacy and sharing on one axis, and multipurpose and specialized roles on the intersecting axis.

Finally, in the **validation step**, we evaluated the McKit in a one-day design workshop with nine members of a product team at a large technology company. Workshop participants had backgrounds in design, engineering, and research. The participants were focused on envisioning designs of a product under development that features multi-device experiences. The results of the workshop demonstrate that the design kit helps designers to consider contexts and constraints of situated use of multiple devices. It also provides a common language and framework to critique one another's designs from the standpoint of ecological validity (i.e., how might this work in the real world?).

In the rest of the paper, we show our approach to creating the McKit in detail and demonstrate its utility for addressing ecological validity early in the multi-device experience design process. This paper makes three contributions to research on multi-device experiences:

1. A reusable design kit that allows designers to consider ecological validity and consume insights derived from our field study and literature review, specifically for multi-device experience design;
2. Insights into six device roles that we found in everyday multi-device use, and the ways in which these roles are influenced by shifts in contexts of use; and
3. A generalizable approach to making field research more accessible and useful to design practitioners.

ANALYTICAL STEP: DRAWING ON RELATED WORK

In this section, we describe related work that influenced our empirical inquiry and codification of design kit materials.

Multi-device Theories and Frameworks

The design space of multi-device experiences is rich in theoretical foundations and frameworks, including works on ecologies of interactive artifacts, a perspective rooted in theories such as information ecology [30]. Understanding people's device ecologies emerged from Jung et al.'s [21] work on how people categorize their artefacts based on relations, and Forlizzi's [11] work on how aesthetic, symbolic, and functional aspects of robots influence their relations within the home. These ideas were expanded upon by Bodker and Klokmose [1] who developed the notion of dynamic device ecologies that change over time. Note that the term "ecology" used in this line of work is not in the same sense of "ecological validity" which speaks to the utility and feasibility of a design in the real world.

Other frameworks are more technical in focus, aimed at guiding concrete design decisions. For example, Sorensen et al [37] describe a framework representing the "4Cs" of multi-device interaction design: communality, collaboration, continuity, and complementarity. The authors show how this framework can guide heuristic evaluation of existing technologies and concrete design ideation of new concepts. Waljas et al [41] proposed an initial framework for cross-platform web services based on their findings from a field study investigating user experiences across PCs and mobile devices. The themes represented in their framework prompt designers to consider: appropriate system composition, fluency in content and task migration, and service consistency. Paterno and Santoro [33] present a logical framework for understanding, analyzing, and comparing features of multi-device user interfaces (UIs) that reveals dimensions of multi-device UI design that are underexplored. One of the underexplored areas of multi-device research that they identified, that we address in our field study, is users' attitudes towards multi-device UIs when the context is shared with other users. A framework by Lundgren et al [26] helps to map this underexplored design space, through consideration of spatial, temporal, social, and technical perspectives of mobile collocated interactions. Our work adds to this literature by offering a framework that helps designers to explore tradeoffs in technical and social considerations (i.e. seamless integration versus privacy needs) that we found to be highly salient in multi-device use in our field study.

Multi-device Interaction Techniques

Design practitioners might be familiar with multi-device interaction patterns that have been widely used in commercial products such as mirroring content between screens, but it is important for them to be aware of the technologies on the horizon and consider how users might adopt them. Many novel interaction techniques have been proposed to seamlessly move content across multiple devices to optimize task flow and information display, such as those exemplified in Pick-and-Drop [29], Conductor [16], and Pass-them-Around [25].

Five typical multi-device interaction patterns emerged from our analysis of the literature, including: (1) *mirroring* information from one display to another (e.g., Chromecast[‡]); (2) providing *overview + detail*, with an overview of information on one device and more detailed information on another device (e.g., Display Stacks [14], United Slates [5] and Conductor [16]), (3) displaying *related information* for a single task on multiple devices, such as writing the response to an email on the tablet while having the email being replied to on a smartphone (e.g.,XDBrowser [31]); (4) *stitching* information across multiple displays to maximize real estate (e.g., Pass-them-around [25] and TableTalk [10]), and (5) providing *alternative views* of information (e.g., the dual map views example in Panelrama [43]). These five patterns are by no means exhaustive, but their technical feasibility has been demonstrated. We believe including these patterns in our design kit, described later in the paper, can inspire designers in their ideation process.

Studies of Multi-device Use

Empirical studies of how people use multiple devices have yielded several insights about device roles, patterns of use, and workarounds. Early work by Oulasvirta and Sumari [32] identified challenges and workarounds of multi-device use experienced by workers at a large IT company. Workers had difficulty synchronizing data across devices and often resorted to carrying around “mobile kits.” Jung et al. [21] found that users group digital artifacts according to purpose of use, context of use, and subjective meanings that motivate different device configurations. In particular, they found that multipurpose devices, like smartphones and tablets, had many interconnections with other devices, making them central in personal device kits. Multipurpose devices are often specialized within parallel multi-device configurations. Dearman and Pierce [9] studied academic and industry professionals, and found that users assign specialized roles to devices to support complex tasks (e.g., writing and testing code), conduct a secondary task (e.g., monitoring email on a device other than the one being used for the primary task), and to cope with hardware and software constraints. Santosa and Wigdor [34] also found that industry professionals assign specific roles to devices in multi-device configurations, especially for performing related tasks in parallel. In addition, Jokela et al. [20] found these types of parallel uses in a diary study of everyday users in Southern Finland: resource lending (of device input/output capabilities), related parallel use, and unrelated parallel use. We add to this prior work new examples of the specialized roles that devices take on, especially during *unrelated* parallel use of many devices for multitasking, in a sample of lay users from four diverse regions in the U.S.

Particularly relevant to findings in our field study are empirical studies focusing on the use of shared devices such as [2,27,28]. These studies yield insight into the privacy and sharing behaviors that characterize everyday use of devices. For example, Matthews et al [27] showed that device sharing in households is common and upsets the private and personal nature of device collections. Ion et al [19] found that people are wary of storing data on the cloud, a major barrier to cross-device integration, and Mazurek et al [28] found that sharing devices in the home led to complex privacy rituals for access control. Suh et al [38] showed that privacy considerations are a core user burden influencing adoption and use of technologies. However, these studies did not have an explicit multi-device focus, lacking implications for designing multi-device experiences across many tasks and settings.

Overall, prior work suggests the importance of device role specialization within device ecologies, device sharing and privacy across different settings, and challenges of managing data across many devices. It also reveals several interaction patterns aimed at relieving multi-device pain points. Our analysis of this prior work led to the codification of multi-device interaction patterns, and user burdens into paper-based design tools that we refer to as “hint” cards. Beyond offering key insights, prior literature also raised several questions about multi-device use that we sought to answer in our “empirical step,” i.e., field study, including: how device sharing influences multi-device configurations in everyday settings, how lay users configure many devices across many settings, and what new patterns of multi-device use may be observed with frequent daily experience sampling. Below, we show our empirical step wherein we investigated multi-device use in the wild, and then detail how we codified insights in the design kit.

EMPIRICAL STEP: INVESTIGATING MULTI-DEVICE USE

We drew data from a large, ongoing field study of people’s everyday technology use. The study method is based on trace ethnography [13], and combines several streams of data about users’ digital interactions and contexts through logging device and app usage, experience sampling method (ESM), and field interviews. This situated approach enabled us to explore the daily routines, habits, and challenges that shape everyday multi-device use. To create the McKit, we used two data sources: experience sampling and field interviews.

Participants

We selected a sample of 25 (17 male; 8 female) participants drawn from the large, ongoing study described above, who exhibited frequent multi-device use in the ESM and/or

‡ Chromecast: https://www.google.com/intl/en_us/chromecast/

	N	P#	Age range	Gender	Education	Household income
Boston	6	P01-P06	18-50	4M; 2F	HS (1); College (4); Masters (1)	$9,999 or less to $249,000
Detroit	6	P07-P12	25-50	3M; 3F	HS (1); College (2); Masters (3)	$9,999 or less to $99,999
Bay Area	7	P13-P19	18-60	6M; 1F	College (5); Masters (1); PhD (1)	$50,000 to $250,000+
Miami	6	P20-P25	25-50	4M; 2F	HS (1); College (3); Masters (1); PhD (1)	$10,000 to $74,999

Table 1. Participants. N=number of participants, P#=participant id, Age range in years, M=male, F=female, HS=high school.

interview data. These participants were from four U.S. regions: Detroit, Miami, Boston, and the Bay Area from a participant database at a large technology company. Potential participants were sent a screener, then selected for diversity on a range of criteria, including: gender, age, employment, education, household income, and device ecosystem (i.e., Apple and Android) (Table 1). Participants were required to be 18 years or older. Each participant received $75 for responding to experience sampling moments, and $100 for the interview conducted in their home or office.

Procedures

Participants were enrolled in the study for 5 days. Each day, participants responded to prompts about their activities 5 times at random times within a fixed time period (8 AM to 9 PM). . These momentary states provide a "dense record of quality of experience at each point" [35]. Participants were asked to report their primary and secondary activities, devices in use, who they were with, and location. Data was collected Wednesday through Sunday to get a picture of their digital habits during weekdays and weekends. After the 5-day period, the third and fourth authors went to each participant's home or office to conduct the interviews. Interviews included questions about daily routines, device use, and digital privacy concerns. Interviews lasted for about one hour, and they were transcribed for analysis.

Analysis

To analyze interview data on multi-device use, we coded responses to two questions: (1) Can you tell me about some typical ways you use your devices together? (2) Do you ever share your devices with anyone? If so, what are some examples?" We coded for instances of parallel, sequential, and shared device use. We also coded for frictions in using many devices, including mentions of privacy burdens and difficulty of use. Using the ESM data, we identified 136 moments with multiple devices reported, and then counted the number and types of devices and digital activities reported in each of those moments. The first author completed the coding, and all authors worked together to synthesize the outcomes of the interview and ESM analyses.

Device role	Description
Notifier	Notifies the user of tasks
Broadcaster	Broadcasts or displays information
Hub	Is a hub of activity for multiple tasks
Remote	Controls or streams content to a display or speakers
Collector	Collects data, like pictures, video, or fitness activity
Gamer	Enables user to play games

Table 2. Six device roles within parallel multi-device use.

Findings

Here, we present the findings from our field study (i.e. the *Empirical step*) that led to the creation of design kit components. We found that (1) participants specialized their devices to perform one of six roles—*notifier, broadcaster, collector, gamer, remote, and hub*—in related and unrelated parallel use, and (2) device privacy and sharing needs influenced the roles that participants wanted to assign to their devices in the moment.

Six device roles during multi-device use

In contrast to previous work, our field study revealed that participants often used many devices in parallel for *unrelated* tasks. In other words, many participants had the experience of multi-tasking with several devices. Over half (52%) of the moments involving more than one device reported in the ESM data involved the use of multiple devices for two or more unrelated tasks. Jokela et al [20] called this type of multi-device use, "unrelated parallel use," but did not find many examples through diary studies. Below, we show how this type of device use was common among our participants. Moreover, we demonstrate that devices can take on *separate but complementary* roles to support multi-tasking in everyday contexts. Specifically, from the ESM data we found six different roles of devices to support multi-tasking: *notifier, broadcaster, hub, remote, collector, and gamer* (Table 2). Overall, we found that laptops were often "hub" devices that our participants typically combined with notifiers and broadcasters to support both related and unrelated parallel use in everyday situations. As an example of paralleled unrelated use of multiple devices, P02 described a typical evening routine: "*I'll watch TV, have the laptop open, and I'll be playing on my phone. So, I'll have Netflix; I'll have like House [TV show] was on. That's background noise. [...] So, I'm cooking, too. But then I'm looking on my phone, making sure I got it going for the right amount of time. And then I'll have my laptop up, and when I have nothing else going on over there, I'll browse around on the Internet.*" In this case, his TV was *broadcasting* media, his phone was *notifying* him of the cooking time, and his laptop was a *hub* for web surfing activity. Five of his sixteen multi-device moments captured in the experience sampling also featured a console for *gaming*, in addition to the phone, TV, and laptop. Having different devices play different roles helped P02 switch attention between activities which were distributed across devices as information became more or less important (e.g., timing of cooking), or interesting (e.g., content on TV).

The role of a device was to some extent constraint by its capabilities. For example, P03 used her phone to view an app, kept the radio on in the background for *broadcasting* media, and her laptop as a *hub* of activity: *"Sometimes I'll have a radio on and be using an iPhone app and be sort of casually monitoring something on my laptop. [On] the laptop itself, I am one of those people with multiple programs, multiple tabs open on a website doing personal e-mail and work e-mail sort of all in one and you know with sort of major projects open and also just killing time tabs [...]"* In this case, the radio was a natural broadcaster and the laptop was a hub because of its capability of handling different tasks.

What was more interesting was that some multi-purposed devices could be artificially limited to specialized roles to separate different types of tasks. For example, P20 temporarily used his smartphone to *broadcast* videos while he used his laptop as a *hub* for work: *"Let's say I'll just be watching a YouTube video, and then I have to do something on my laptop. I would literally have the phone open while I'm doing work."* Some participants exercised such role specialization of multi-purposed devices on a more permanent basis. For example, P19 had very clear separations between his devices for specific tasks on a more permanent basis. He explained: *"If I am in bed, and we have something streaming from the iPad to the TV, through Chromecast, then I will most likely either use my phone or the laptop to do that other task. I want this [iPad] to remain the remote control, so if I need to pause it, I can do it right there with that. I kind of don't like to multi-task on a single device as much as I like to have the availability of two devices or multiple devices to do that. So I can have different apps pulled up in different devices."* P19 used his iPad as a *remote control* and TV to *broadcast* media, and his laptop as a *hub* for, in his words, "*more intense*" activities like email and web surfing.

The role assigned to a device could also be influenced by the personal relationship the user had with the device. For example, P05 said, "*My computer, I don't let it have any notifications, like, they made me mad. My computer is my device. It's not my master. My phone on the other hand, we have a different relationship*." This example points to how the subjective value of a device—an important factor identified by Jung et al [21]—can influence its role in multi-device experiences.

These device roles were important in *related* parallel use of multiple devices as well. P10 gave an example when she described using her phone to "update" her of work to follow through with on her laptop. She was a full-time blogger who used her laptop as a *hub* of digital activity to switch between different social media accounts and photo editing, using the phone to *notify* her of tasks to prioritize in the moment: *"Well I use the phone and the laptop all the time at the same time. [...] My phone alerts me to all those -- you know, whatever, like, little updates. So I'm able to look at whatever, and then go on the laptop and follow through. Like, if somebody sends me a message on that Facebook page, then I'd go on the laptop usually."* In contrast to the examples of unrelated parallel use, P10's routine exemplifies related parallel use for work. Her ad hoc set up of relations between a *notifier* and *hub* was not explicitly supported by technology design, presenting an opportunity to enhance these relations through more seamless integration. Next, we show how context shifts had an important influence on everyday device role specialization.

Shifts in context influence device roles

We found that participants' use of devices were influenced by two types of shifts in context: 1) from using devices in a private setting to a public setting, and 2) from having exclusive control over a device to sharing that device. When such shifts occurred, participants often wanted to specialize their devices into roles that could enable discrete use, enable separation of private and public activities, or protect their data and task state on a device. However, that required effort and was not always successful.

The following two examples demonstrate how shifting the usage setting from private to public can influence device roles within multi-device experiences. P01 explained a situation where he needed to share his laptop to present information to colleagues, which made it necessary to temporarily specialize his phone in the role of notifier in that context: "*Sometimes when we do customer calls, if I'm presenting on my laptop, I will shut off, like, Slack and Gmail and all that stuff, because people will post the craziest things and notifications will slide up. So, I want that stuff off the screen, so I'll just do all that stuff on my phone at the same time.*" Similarly, P18 had begun a new job and used affordances of his phone and smartwatch to be discrete: "*I'm new to the job so I don't want to leave a bad impression of the phone and stuff. [...] If I'm waiting on a call, or a text, I might put my watch to vibrate so that if you have an alert for some reason or another. I try not to, at least now, spend too much personal time on the computer.*"

In P01's case, his laptop was no longer suitable as a hub in a public setting, so he transitioned his laptop to a "broadcaster" role and used his phone as a "notifier." For P18, his need to be discrete at his new job made his work desktop unsuitable for personal messages, so he dedicated his smartwatch as a private notifier for that content.

The second type of context shift—from exclusive to shared device control—was more common within households than work settings among our participants. Participants described situations of device sharing that enabled household members to take advantage of each other's devices. P08 borrowed her husband's phone when she wanted to play karaoke because it had better sound: *"I use his [phone] for the karaoke apps, because I think it sounds better. [...] It makes you feel like you might be slightly in the studio."* P01's wife often borrowed his desktop to take advantage of the large monitor: *"She likes the large monitor. [...] She's an urban planner, so she has to sometimes, like, wrestle with gigantic spreadsheets, and it's nice to have a largescale thing to work on, as opposed to a small little window."* These examples suggest that participants desired the ability to opportunistically use others' devices to temporarily optimize a task, whether for leisure or work. This device sharing was an explicit form of *resource lending* [20] in which a personal device collection was temporarily enhanced by the resources of a shared device to perform a very specific role.

Nonetheless, participants lacked technical means to preserve their privacy and reduce the risk of losing task state and device configuration when they lent their devices to other members of their household. Parents who lent devices to their children felt these challenges most acutely. For example, P14 did not usually allow his daughter to use his phone, but sometimes gave in: *"From time to time I'll let my kid watch a YouTube video if something in the car, if they're crying, but for the most part nobody uses my phone but me."* P10 routinely allowed her children to borrow her laptop with Bluetooth mouse to play certain games for which it was better suited than their small tablets: *"The kids use my laptop for a limited amount [of time] for, like, ABC Mouse and things that it's easier to go on a computer for. Plus, I want them to learn how to use the mouse and not just be stuck learning a tablet."* In such a situation, P10 did not have a convenient mechanism to restrict a multi-purpose device to a specific role such as a gamer. P10 would lend her entire laptop, upon which she relied for her livelihood as a blogger, to her children.

The burden of privacy in sharing devices with children was sometimes motivation to buy a new device and dedicate it for a specific role. For example, P09 valued having the Fire TV in his device collection for his kids, taking the burden off of sharing his personal phone for broadcasting media: *"Actually that is probably what gets used the most at my house, because it comes with a remote control, so the kids can use it. You don't have to, you know, hop on the phone. It would be hard, which they could probably figure out [how to use it], but you don't necessarily want them to."* Being able to share devices on the basis of specific roles, such as *broadcaster* or *remote*, could be valuable for ensuring better privacy and for enabling users to shift device roles to adapt to shifts in context. Overall, we found the interrelationship between context shifts and device role specialization highly salient to multi-device use among our participants across both work and home situations.

CODIFICATION STEP: DISTILLING KEY INSIGHTS

We distilled our insights into the McKit with several components. The Shift framework is the central component that represents a multi-device design space wherein device roles *shift* across private and shared contexts. To support the use of this framework for designing multi-device experiences that hold up under ecologically valid constraints, we created supportive materials based on some familiar design tools: personas and scenarios [3,15], the action-reflection design model [44], and paper-based cards [12,18]. These supportive materials distill insights from our analytical and empirical steps that can help designers to reflect on implications of traversing the multi-device design space represented in the framework.

Overall, we developed a framework, 3 scenarios, 3 personas, 3 types of "hint" cards, and worksheets to put all the materials together in an ideation process. Below, we describe each of these materials as part of a comprehensive multi-device design kit.

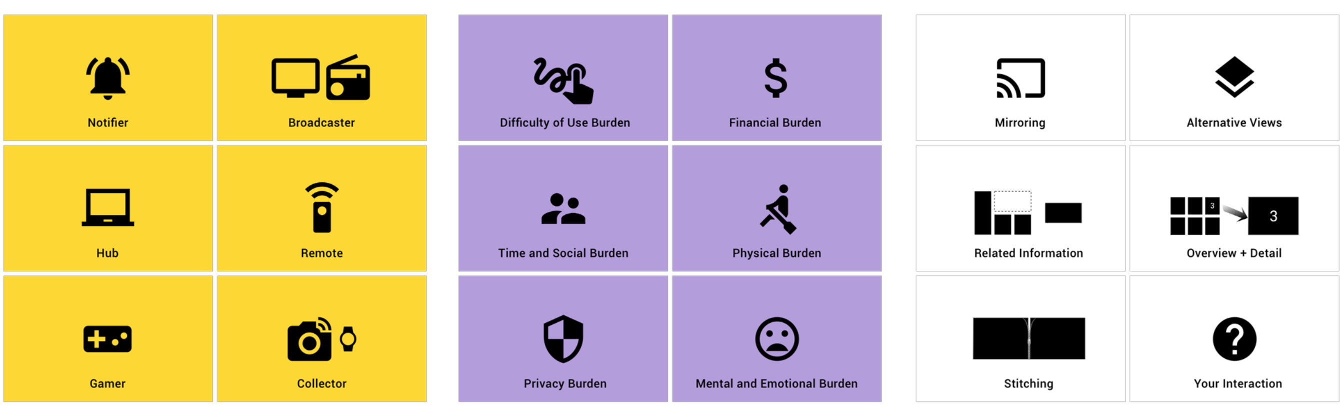

Figure 1. "Hint" cards: (a) Device role cards; (b) User burden cards; (c) Interaction pattern cards.

Hint Cards

There are three sets of "hint" cards (Figure 1) for exploring and reflecting on design ideas: (1) a set of interaction pattern cards for inspiring feasible technical solutions, (2) a set of device role cards for examining role-based relations between devices, and (3) a set of user burden cards for provoking reflection on how different technical solutions relieve and/or introduce burdens for users. Each card has an icon on the front, and description of the pattern on the back with examples. The interaction pattern cards and user burden cards are based on our review of the literature; the device role cards were drawn from our "empirical step," i.e. fieldwork.

Multi-device interaction pattern cards

Our design kit distills five common interaction patterns from existing products and innovations in recent research, described in greater detail in the analytical step earlier in the paper. These five patterns include *mirroring*, *alternative views, related information, overview + detail*, and *stitching.* We also offer a "Your interaction" card to encourage inclusion of additional techniques.

Device role cards

To help designers consider various device roles in multi-device configurations, we included a set of six device roles identified in our empirical study, described in depth above: *notifier, broadcaster, hub, gamer, remote,* and *collector*.

User burden cards

In addition, we include the six types of user burdens identified by Suh et al [38] as another set of cards to sensitize designers to the burdens that users might experience in multi-device use: (1) the *privacy burden* of managing the risk that a system will reveal confidential information, (2) the *difficulty of use burden* of a system that does not fit with the abilities of the user, (3) the *mental and emotional burden* of undue demands on attention or managing anxiety, (4) the *time and social burden* of managing interference with personal time and social relationships, (5) the *financial burden* of paying for costly technology, and (6) the *physical burden* of coping with technologies that are uncomfortable. To our knowledge, this is the first instance of the user burdens from Suh et al [38] being used as design prompts for ideation.

Part 1: Routine event

Marissa needs to be really productive in the evenings. She has several tabs open on her laptop so that she can switch between email, social media accounts, and a photo editor. Her central task is to create a blog post, so she needs to choose pictures, edit them, and create content. She needs her phone to notify her of incoming messages, so that she can follow through with them on her laptop, using the keyboard. She likes having the TV on in the background set to Jeopardy.

Part 2: Context shift

One evening, Marissa's son came into the room because he couldn't sleep. He wanted to play ABC Mouse on her laptop. So, she gave her son full access to her laptop. She tried to work with a bunch of tabs open on her phone while monitoring her son to make sure he didn't mess with any of her work tabs open on her laptop.

Figure 2. Marissa's scenario

Context-shifting Scenarios

We created three scenarios that explicitly feature a *context shift* that provokes changes in privacy needs and device role specializations (see one of them in Figure 2). Each scenario is synthesized from data reported by a single participant referred to by a pseudonym: "Marissa" (P10), "Seth" (P01), or "Alex" (P18). The events did not necessarily occur in the time span in which they appear in the scenarios; however, they are based on actual events reported by participants. Each scenario has two parts. Part 1 is a *"routine event"* in which the character is combining many devices as part of an everyday routine. Part 2 is a *"context shift"* that necessitates the character to adapt the devices she uses and the way she uses those devices in response to sharing needs and/or privacy concerns. Thus, each context shift in the scenarios can be mapped onto the design framework (described below) to aid reflection and ideation (Figure 3). Each scenario is accompanied by a persona of the main character that details their everyday routines and devices.

The Shift Framework

Our finding that context shifts influence device roles, led us to create a framework that represents these two interrelated dimensions: *private* versus *shared* contexts, and *specialized* versus *multipurpose* roles (Figure 3). This framework can be used to map multi-device flows across contexts and to

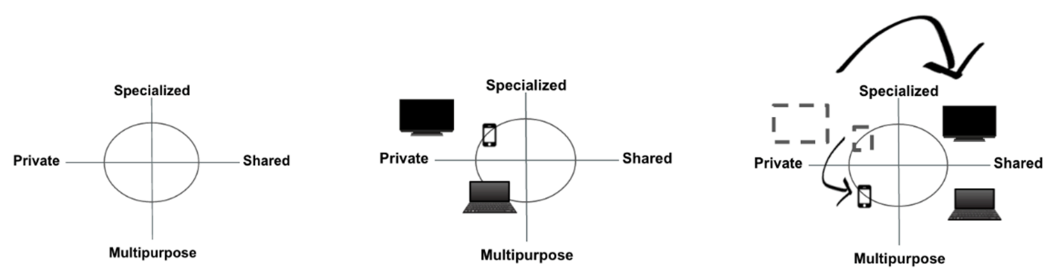

Figure 3. Using the framework to map devices in Marissa's scenario on the dimensions of role specialization and device sharing and then demonstrating how that mapping changes as her context shifts.

reflect on how shifts in context, from private to shared influences device role specialization. In addition, we represent the *relationship* between devices—the extent to which devices are explicitly joined in a related task—as a circle in the middle of the intersecting axes. The framework can be used to analyze scenarios to gain an understanding of how people shift devices across contexts, and in turn, how those shifts might influence multi-device design.

VALIDATION STEP: EVALUATING THE UTILITY OF THE DESIGN KIT

To investigate the usefulness of our multi-device design kit, we conducted a one-day workshop with a product team at a large technology company. From the team, we recruited nine participants (2 females) involved in multi-device product design. Participants from this product team were diverse in terms of expertise (4 designers, 3 engineers, and 2 user experience researchers), and cultural background (Chinese, Canadian, American, Italian, Japanese). After the workshop, we conducted follow-up interviews with the four designer participants about the benefits and drawbacks of using the kit to stimulate their design ideas. We analyzed participants' design work, and video recordings of the workshop, and transcripts of the follow-up interviews.

Action-reflection Process

The worksheets included in the McKit guided the use of the scenarios, cards, and framework in an action-reflection process—a process in which designers use prompts based on empirical field data to aid reflection on design choices [44]. Each worksheet contains prompts for using kit materials to design for one of the three scenarios: "Alex," "Marissa," or "Seth." We divided the participants into three groups, each focusing on one of the three scenarios.

The participants used the worksheets to combine the design kit materials in a three-step action-reflection process. First, participants focused on the "routine event" in the *scenario*, and mapped the devices described onto the *framework* according to privacy, specialization, and relatedness. They used the *user burden cards* to reflect on the burdens the particular user faced when using multiple devices in his or her situation. Second, participants focused on designing a solution for their user. They used the *interaction patterns cards* and *device role* cards to ideate and create a multi-device design that addressed the user burdens they identified in the previous step. Lastly, participants focused on the "context shift" in the scenario and re-mapped, or *shifted*, the devices across the framework to represent changes in the multi-device experience (see Figure 3). They reflected on how the context shift affected device roles and user burdens, and adapted their designs. At the end of the workshop, each participant presented his or her design work. Below, we demonstrate how the design kit sensitized workshop participants to privacy needs, device roles, and user burdens, as they envisioned multi-device features of a product. Due to the proprietary nature of the product, we reserve some details of the designs in our report of findings. We use "WP" as a prefix for workshop participant IDs.

Findings: Towards Ecologically-valid Design

We found that the McKit helped product stakeholders consider a wide range of devices roles, situations of use, and multi-device behaviors that helped address ecological validity in their design work. The focus on context shifts in the semi-structured design process (provided in the kit), triggered critical points of reflection on ecologically valid constraints and opportunities in multi-device experiences.

For example, in explaining his design for Marissa (see Figure 4a), WP01 described how the context shift provoked reflection on his design: *"It evolved into this situation where Marissa had to cede her laptop to somebody else, so then it was like, oh, okay, now we have to think about how the roles of this hub device [laptop] can be re-assigned to these other devices"* Similarly, WP03 found that his initial design was *"not such an ideal of a solution"* for Alex's scenario due to the context shift that Alex routinely experienced: going from a youth center where he volunteers, to an office where he works, that made the designer's initial solution *"a lot less discrete."* WP03 then adapted his design to anticipate his user's privacy needs.

We found the kit's emphasis on privacy burdens and the shared nature of many devices helped participants to explicitly consider those factors in design. WP02 sketched a "device control center" (see Figure 4b) and "user identity

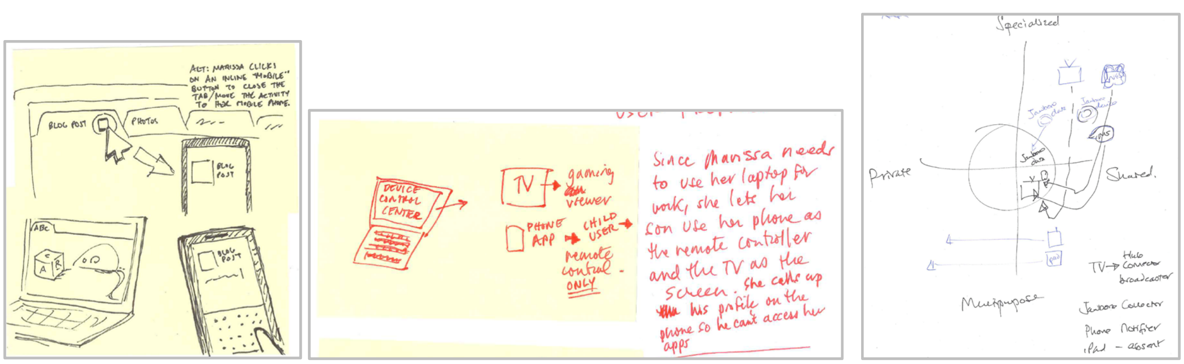

Figure 4. (a) and (b) are two design ideas enabling device role shifts. (c) shows how analyzing scenarios using the framework led to the idea of shifting device data and roles independently.

platform" that enabled Marissa to shift her private device configuration (TV, laptop, phone), to accommodate her son's shared use of her devices to play games: *"From her laptop, from the device control center, she assigns her TV as a gaming viewer, and she puts the phone into the child identity mode, so that her son can use that as a remote control, so he can play a game on the TV while she gets work done on the laptop."* This example shows how this designer engaged extensively with the device roles while considering the influence of privacy burdens.

Participants also showed sensitivity to the relationship between context shifts and device roles. WP04, WP05, and WP06 used the Shift Framework to analyze the roles and relationships of devices in "Seth's" scenario (see Figure 4c). These participants used the kit materials to identify a design requirement that devices should be discovered by services based on the roles they can perform (e.g., *notifier, collector, broadcaster*) without needing to share the data generated when in use by a service. WP06 talked about the value of the role cards especially, and how this design idea was directly tied to them: *"That idea came out exactly because I saw these [role] cards and I thought 'Oh wait a second we can actually take a device and change, temporarily, its role.'"*

In addition to the value participants found in the cards, they felt that the scenarios helped them better understand the problems faced by real users. WP08 commented on the value of the data-driven scenarios for testing a specific product vision: *"This let me exercise in a really meaningful way what that [vision] would feel like to a specific person and that was really useful."* WP01 commented that, overall, the kit helped "*making sure that we're not losing sight of making computing a more human experience."* These comments highlight the importance of developing lightweight and reusable design tools, such as personas and scenarios, specifically to support multi-device product teams to ground their envisioning process.

We found that some scenarios offered better support for ideation than others. For example, Seth's scenario and Marissa's scenario featured complex social relationships that provoked interesting tradeoffs in design. The groups working with these scenarios were highly engaged in developing solutions to resolve the complex privacy and sharing needs across the different social relationships depicted. For example, Marissa's context shifted when her son entered the room and wanted a device to play games, and Seth's context shifted when his mother took on primary use of the iPad and the baby camera when he was absent. In contrast, Alex's scenario contained a context shift from volunteer center to work that did not introduce as much social complexity. Thus, Alex's group had less heterogeneity among their designs than other groups whose scenarios inspired more divergent design thinking.

Participants also told us a few ways to make the kit more effective. One suggestion is to spend more time introducing the content of the cards. WP05 said: *"I feel we could spend a little bit more time to understand what the cards are."* Another suggestion was to provide concrete examples of the burden cards. WP06 had trouble applying the user burden cards: *"I think it was a bit more difficult to use the burdens, mostly because I think the categories, I mean these make sense, but they're still somehow a bit too broad."*

To sum up, the design kit supported a collaborative multi-device design process, across diverse stakeholders on a product team. We have demonstrated some ways that participants utilized the cards, scenarios and the Shift Framework to help formulate and reflect on design ideas, and some ways in which these materials could be improved. We learned that, similar to other types of design cards (e.g., [12,18,24]), designers in our workshop considered the cards useful in building a common ground and getting informed of the technological possibilities. Moreover, the scenarios from our fieldwork helped designers situate their designs in the actual use of devices, and that is an important step towards ecologically valid design.

DISCUSSION

New tools for data-driven ideation can help designers understand the everyday needs and burdens that influence multi-device use. Both sophisticated multi-device *systems* and ad hoc multi-device *collections* will co-exist in users' everyday life. Most of the existing multi-device design tools and frameworks focus on technical aspects of multi-device systems design (e.g., continuity of information across screens) [23,33,37,39–41]. Few frameworks address contextual factors of multi-device experiences in naturalistic settings, with the exception of Lundgren et al.'s [26] framework for designing collocated mobile interactions that account for spatial, temporal, social and technological perspectives. These factors are important, as various HCI theorists have vocally advocated attention to different aspects of human-artifact relationships and contexts [1,11,30]. Our Shift Kit helps designers of multi-device experiences to test design moves using ecologically valid constraints, tasks, and needs.

Our findings from the workshop demonstrate that designers benefitted from the process of using the design kit materials for explicit consideration of context shifts, user burdens, device roles, and privacy needs in multi-device product design. The design insights that emerged from the workshop were clearly derived from our empirical findings (e.g., devices roles should be able to shift flexibly according context), or built upon them (e.g., data should be decoupled from devices that might be shared). Thus, the design kit successfully helped designers to interact with complex data in a relatively short amount of time (*i.e.,* one day). Our design materials supported conscientious and rigorous design ideation based on a shared understanding of core concepts, similar to other techniques for "designing with cards": Lucero et al.'s [24] PLEX cards and Inspiration Card Workshops, IDEO Method Cards [18] for inspiring the use of diverse design methods, and the Envisioning Cards [12] for prompting designers to reflect on the long-term influences of their technologies.

Our process for creating the design framework and supporting materials followed four steps: analytical, empirical, codification, and validation. Our empirical step, detailing a field study of multi-device use across four U.S. regions, yielded novel insights about everyday use of devices. We contribute insight into device roles in multi-device use, especially for multitasking, that adds to existing notions of parallel usage patterns (e.g., Jokela [20]). We found that users in everyday settings compose multi-device experiences that support parallel related and unrelated tasks. We also found that as users change context, they shift their device roles to adapt to different privacy and sharing needs. These findings contrast with previous field studies on multi-device use that have reported little privacy concerns [20,34]. In contrast, we found that, not only do people switch device configurations to suit different tasks and environments [9,20,32], they do so to preserve privacy and sharing.

One reason that our empirical findings differ from previous field studies on multi-device use is that we explicitly focused on practices of device sharing in our data collection and analysis. Another reason, is that we used the experience sampling method to gather in-the-moment reports of using many devices throughout the day, that enabled us to observe patterns of unrelated parallel use that have not been deeply explored in prior work.

Overall, we contribute a reusable design kit that allows design practitioners to consume insights derived from our field study and related work; insights into six device roles that we found prevalent in everyday multi-device use; evidence of the ways in which device roles are influenced by shifts in device sharing and privacy; and a generalizable approach to make field research more accessible and useful to design practitioners. Through sharing our empirical insights and design kit, we hope to support designers to consider ecologically valid constraints when envisioning multi-device experiences.

Limitations
The sample we chose was biased toward people who exhibited a lot of multi-device use in our field study. Non-use or minimal use was not explored in this analysis. Due to time and organizational constraints, the follow-up interviews with the four design participants were conducted by the same person who ran the workshop, potentially biasing designers' reflections on the kit.

FUTURE WORK
The design kit is not definitive; rather it is a version of a kit that can be extended and customized to suit different needs. In fact, as a design tool, the kit should evolve as multi-device interactions become more common and better supported. For example, components of the kit could be replaced with different data and updated as new interaction patterns are developed. We provide a template and process for researchers to distill field research into actionable resources for designers. We hope that future work will build on this design kit as the technological landscape changes. Further validation through use of the kit with different stakeholders and settings is an important next step. We plan to conduct more workshops using the design kit within our organization and offer a printable version of the kit for other researchers and designers to try it.

CONCLUSION
Designers of multi-device experiences need tools to better address situated contexts of use early in their design process through ideation and reflection. To address this need, we created and tested a reusable design kit, called the **M**oving **C**ontext **Kit,** or McKit for short, that contains scenarios, cards, and a framework for understanding tradeoffs of multi-device innovations in realistic contexts of use. In a workshop, we demonstrated that the design kit makes it easier for designers to build on prior work and insights from our field study on everyday multi-device use. The McKit can help designers explore a large design space of sequential, related, and unrelated parallel device use by focusing on the ways in which context shifts force changes in everyday multi-device experiences. Our design kit, and the process of creating it, can support ecological validity in the design of multi-device computing for everyday life.

ACKNOWLEDGMENTS
We thank Peter Hamilton for his help with identifying examples of multi-device interaction patterns, our workshop participants, our colleagues for their feedback and encouragement, and the reviewers for their helpful suggestions for improving this paper.

REFERENCES
1. Susanne Bødker and Clemens Nylandsted Klokmose. 2012. Dynamics in artifact ecologies. *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design*: 448–457. http://doi.org/10.1145/2399016.2399085
2. A.J. Brush and Kori Inkpen. 2007. Yours, Mine and Ours? Sharing and Use of Technology in Domestic Environments. *Proceedings of the 9th international conference on Ubiquitous computing (UbiComp '07)*, 109–126. Retrieved September 20, 2016 from http://dl.acm.org/citation.cfm?id=1771592.1771599
3. John M. Carroll. 1999. Five Reasons for Scenario-Based Design. *Hawaii International Conference on System Sciences*.
4. Scott Carter, Jennifer Mankoff, Scott R. Klemmer, and Tara Matthews. 2008. Exiting the Cleanroom: On Ecological Validity and Ubiquitous Computing. *Human–Computer Interaction* 23, 1: 47–99. http://doi.org/10.1080/07370020701851086
5. Nicholas Chen, Francois Guimbretiere, and Abigail

Sellen. 2012. Designing a multi-slate reading environment to support active reading activities. *ACM Transactions on Computer-Human Interaction* 19, 3: 1–35. http://doi.org/10.1145/2362364.2362366

6. Nicholas Chen, François Guimbretière, and Abigail Sellen. 2013. Graduate student use of a multi-slate reading system. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*, ACM Press, 1799. http://doi.org/10.1145/2470654.2466237
7. Pei-Yu (Peggy) Chi, Yang Li, and Björn Hartmann. 2016. Enhancing Cross-Device Interaction Scripting with Interactive Illustrations. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, ACM Press, 5482–5493. http://doi.org/10.1145/2858036.2858382
8. Pei-Yu Chi and Yang Li. 2015. Weave : Scripting Cross-Device Wearable Interaction. *Proceedings of the 2015 CHI Conference on Human Factors in Computing Systems - CHI '15*, ACM, 3923–3932. https://doi.org/10.1145/2702123.2702451
9. David Dearman and Jeffrey S Pierce. 2008. It's on my other computer!: computing with multiple devices. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*: 767–776. http://doi.org/10.1145/1357054.1357177
10. Hasan Shahid Ferdous, Bernd Ploderer, Hilary Davis, et al. 2016. TableTalk: Integrating personal devices and content for commensal experiences at the family dinner table. *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing - UbiComp '16*, ACM Press, 132–143. http://doi.org/10.1145/2971648.2971715
11. Jodi Forlizzi. 2007. How Robotic Products Become Social Products : An Ethnographic Study of Cleaning in the House. *Proceedings of the ACM/IEEE international conference on Human-robot interaction (HRI '07).*, ACM, 129–136. http://doi.org/http://dx.doi.org/10.1145/1228716.1228734
12. Batya Friedman and David G. Hendry. 2012. The envisioning cards: A toolkit for catalyzing humanistic and technical imaginations. *Proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems - CHI '12*: 1145–1148. http://doi.org/10.1145/2207676.2208562
13. R Stuart Geiger and David Ribes. 2011. Trace Ethnography: Following Coordination through Documentary Practices. *2011 44th Hawaii International Conference on System Sciences*, IEEE, 1–10. http://doi.org/10.1109/HICSS.2011.455
14. Audrey Girouard, Aneesh Tarun, and Roel Vertegaal. 2012. DisplayStacks: Interaction techniques for stacks of flexible thin-film displays. *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*, ACM Press, 2431. http://doi.org/10.1145/2207676.2208406
15. Jonathan Grudin and John Pruitt. 2002. Personas, Participatory Design and Product Development: An Infrastructure for Engagement. *PDC*, 144–152.
16. Peter Hamilton and Daniel J. Wigdor. 2014. Conductor: Enabling and Understanding Cross-Device Interaction. *Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems - CHI '14*: 2773–2782. http://doi.org/10.1145/2556288.2557170
17. Björn Hartmann, Scott R. Klemmer, Michael Bernstein, et al. 2006. Reflective physical prototyping through integrated design, test, and analysis. *Proceedings of the 19th annual ACM symposium on User interface software and technology - UIST '06*, ACM Press, 299. http://doi.org/10.1145/1166253.1166300
18. IDEO. 2003. IDEO Method Cards: 51 Ways to Inspire Design.
19. Iulia Ion, Niharika Sachdeva, Ponnurangam Kumaraguru, and Srdjan Čapkun. 2011. Home is safer than the cloud!: Privacy concerns for consumer cloud storage. *Proceedings of the Seventh Symposium on Usable Privacy and Security - SOUPS '11*, ACM Press, 1. http://doi.org/10.1145/2078827.2078845
20. Tero Jokela, Jarno Ojala, and Thomas Olsson. 2015. A Diary Study on Combining Multiple Information Devices in Everyday Activities and Tasks. *Proceedings of the ACM CHI'15 Conference on Human Factors in Computing Systems* 1: 3903–3912. http://doi.org/10.1145/2702123.2702211
21. Heekyoung Jung, Erik Stolterman, William Ryan, Tonya Thompson, and Marty Martin Siegel. 2008. Toward a framework for ecologies of artifacts: how are digital artifacts interconnected within a personal life? *Proceedings of the 5th Nordic conference on Human-computer interaction: building bridges*: 201–210. http://doi.org/10.1145/1463160.1463182
22. Jake Knapp, John Zeratsky, and Braden Kowitz. 2016. *Sprint: How to solve big problems and test new ideas in just five days*. Simon and Schuster.
23. M Levin. 2014. *Designing Multi-device Experiences: An Ecosystem Approach to User Experiences Across Devices*. O'Reilly.
24. Andrés Lucero, Peter Dalsgaard, Kim Halskov, and Jacob Buur. 2016. Designing with Cards. In *Collaboration in Creative Design*. Springer International Publishing, Cham, 75–95. http://doi.org/10.1007/978-3-319-29155-0_5
25. Andrés Lucero, Jussi Holopainen, and Tero Jokela. 2011. Pass-them-around. *Proceedings of the 2011*

annual conference on Human factors in computing systems - CHI '11, ACM Press, 1787. http://doi.org/10.1145/1978942.1979201

26. Sus Lundgren, Joel E Fischer, Stuart Reeves, and Olof Torgersson. 2015. Designing Mobile Experiences for Collocated Interaction. *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW '15*: 496–507. http://doi.org/10.1145/2675133.2675171
27. Tara Matthews, Kerwell Liao, Anna Turner, Marianne Berkovich, Robert Reeder, and Sunny Consolvo. 2016. "She'll just grab any device that's closer": A Study of Everyday Device and Account Sharing in Households. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, ACM Press, 5921–5932. http://doi.org/10.1145/2858036.2858051
28. Michelle L. Mazurek, Brandon Salmon, Richard Shay, et al. 2010. Access control for home data sharing: Attitudes, needs, and practices. *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*, ACM Press, 645. http://doi.org/10.1145/1753326.1753421
29. Robert C. Miller and Brad A. Myers. 1999. Synchronizing clipboards of multiple computers. *Proceedings of the 12th annual ACM symposium on User interface software and technology - UIST '99*, ACM Press, 65–66. http://doi.org/10.1145/320719.322584
30. Bonnie A. Nardi and Vicki O'Day. 1999. *Information ecologies : using technology with heart*. MIT Press.
31. Michael Nebeling and Anind K. Dey. 2016. XDBrowser: User-defined Cross-device Web Page Designs. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI '16*, ACM Press, 5494–5505. http://doi.org/10.1145/2858036.2858048
32. Antti Oulasvirta and Lauri Sumari. 2007. Mobile kits and laptop trays: managing multiple devices in mobile information work. *Chi '07*: 1127–1136. http://doi.org/10.1145/1240624.1240795
33. Fabio Paternò and Carmen Santoro. 2012. A logical framework for multi-device user interfaces. *Proceedings of the 4th ACM SIGCHI symposium on Engineering interactive computing systems - EICS '12*, ACM Press, 45. http://doi.org/10.1145/2305484.2305494
34. Stephanie Santosa and Daniel Wigdor. 2013. A field study of multi-device workflows in distributed workspaces. *Proc. of UbiComp '13*. http://doi.org/10.1145/2493432.2493476
35. Norbert Schwarz, Ed. Diener, Daniel Kahneman, and Project MUSE. 2013. *Well-being : the foundations of hedonic psychology*. Russell Sage Foundation.
36. Phoebe Sengers, Kirsten Boehner, Shay David, and Joseph "Jofish" Kaye. 2005. Reflective design. *Proceedings of the 4th decennial conference on Critical computing between sense and sensibility - CC '05*, ACM Press, 49. http://doi.org/10.1145/1094562.1094569
37. Henrik Sørensen, Dimitrios Raptis, Jesper Kjeldskov, and Mikael B Skov. 2014. The 4C Framework:Principles of Interaction in Digital Ecosystems . *Proc. Int. Conf. on Ubiquitous Computing*: 87–97. https://doi.org/10.1145/2632048.2636089
38. Hyewon Suh, Nina Shahriaree, Eric B. Hekler, and Julie A. Kientz. 2016. Developing and Validating the User Burden Scale: A Tool for Assessing User Burden in Computing Systems. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI 2016)*: Under Review. http://doi.org/10.1145/2858036.2858448
39. Lucia Terrenghi, Aaron Quigley, and Alan Dix. 2009. A taxonomy for and analysis of multi-person-display ecosystems. *Personal and Ubiquitous Computing* 13, 8: 583–598. http://doi.org/10.1007/s00779-009-0244-5
40. Mejdi Trimeche and Tomi Aarnio. 2005. Enhancing End-User Experience in a Multi-Device Ecosystem. *Design*: 19–25. http://doi.acm.org/10.1145/1149488.1149492
41. Minna Wäljas, Katarina Segerståhl, Kaisa Väänänen-Vainio-Mattila, and Harri Oinas-Kukkonen. 2010. Cross-platform service user experience. *Proceedings of the 12th international conference on Human computer interaction with mobile devices and services - MobileHCI '10*: 219. http://doi.org/10.1145/1851600.1851637
42. Jill Palzkill Woelfer, Amy Iverson, David G. Hendry, Batya Friedman, and Brian T. Gill. 2011. Improving the safety of homeless young people with mobile phones: Values, form, and function. *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*, ACM Press, 1707. http://doi.org/10.1145/1978942.1979191
43. Jishuo Yang and Daniel Wigdor. 2014. Panelrama: Enabling Easy Specification of Cross-Device Web Applications. *Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems - CHI '14*: 2783–2792. http://doi.org/10.1145/2556288.2557199
44. Daisy Yoo, Alina Huldtgren, Jill Palzkill Woelfer, David G. Hendry, and Batya Friedman. 2013. A value sensitive action-reflection model: Evolving a co-design space with stakeholder and designer prompts. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI '13*, ACM Press, 419. http://doi.org/10.1145/2470654.2470715