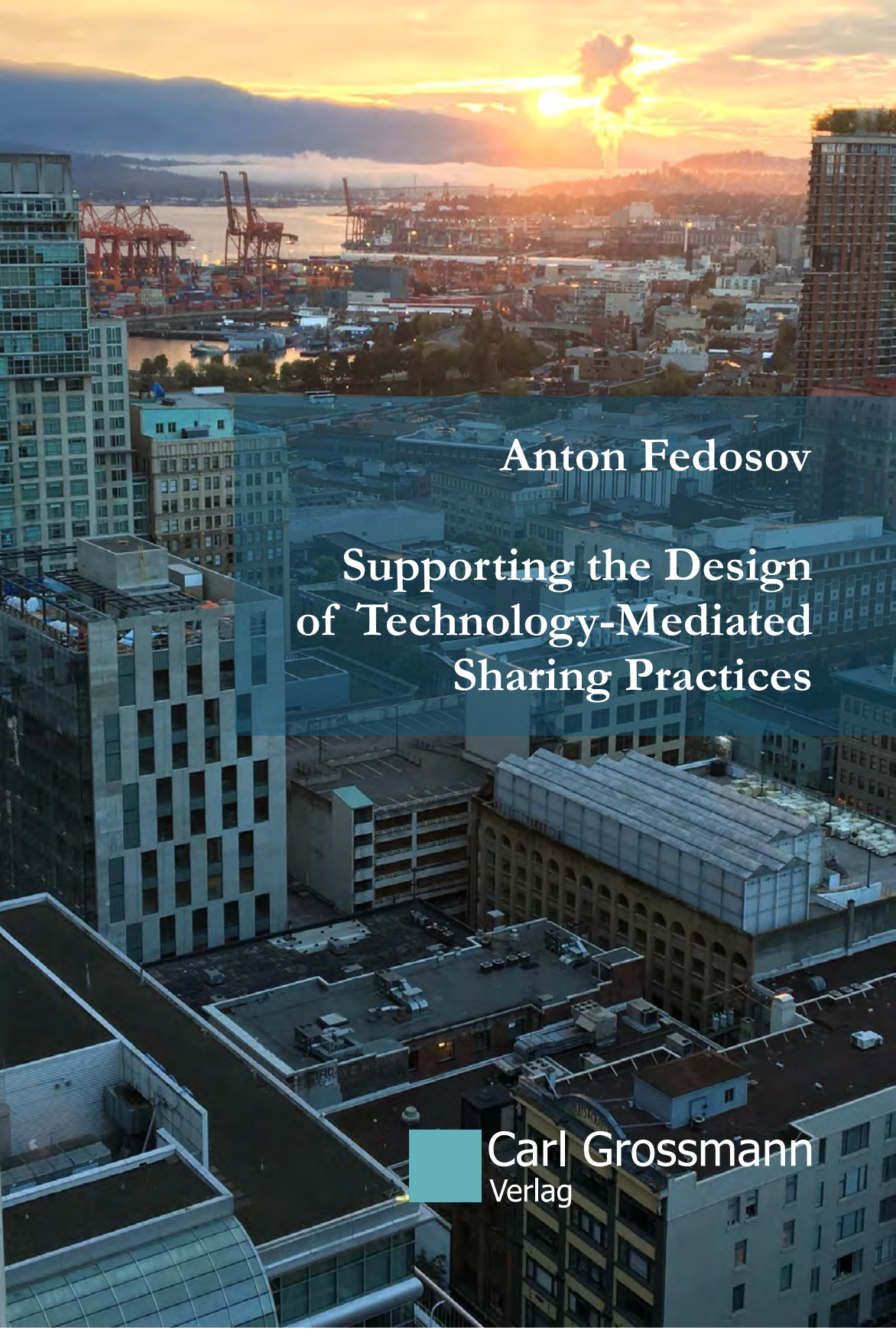

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Author:
Dr. Anton Fedosov, Zürich, Switzerland

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To my beloved family

Abstract

Online social networks have made sharing personal experiences with others – mostly in the form of photos and comments – a common activity. The convergence of social, mobile, cloud and wearable computing has expanded the scope of user-generated and shared content on the net from personal media to individual preferences to physiological details (e.g., in the form of daily workouts) to information about real-world possessions (e.g., apartments, cars). Once everyday things become increasingly networked (i.e., the Internet of Things), future online services and connected devices will only expand the set of "things" to share. Given that a new generation of sharing services is about to emerge, it is of crucial importance to provide service designers with the right insights to adequately support novel sharing practices. This work explores these practices within two emergent sharing domains: (1) personal activity tracking and (2) "sharing economy" services. The goal of this dissertation is to understand current practices of sharing personal digital and physical possessions, and to uncover corresponding end-user needs and concerns across novel sharing practices, in order to map the design space to support emergent and future sharing needs. We address this goal by adopting two research strategies, one using a bottom-up approach, the other following a top-down approach.

In the bottom-up approach, we examine in-depth novel sharing practices within two emergent sharing domains through a set of empirical qualitative studies. We offer a rich and descriptive account of peoples' sharing routines and characterize the specific role of interactive technologies that support or inhibit sharing in those domains. We then design, develop, and deploy several technology prototypes that afford digital and physical sharing with the view to informing the design of future sharing services and tools within two domains, personal activity tracking and sharing economy services.

In the top-down approach, drawing on scholarship in human-computer interaction (HCI) and interaction design, we systematically examine prior work on current technology-mediated sharing practices and identify a set of commonalities and differences among sharing digital and physical artifacts. Based upon these

findings, we further argue that many challenges and issues that are present in digital online sharing are also highly relevant for the physical sharing in the context of the sharing economy, especially when the shared physical objects have digital representations and are mediated by an online platform. To account for these particularities, we develop and field-test an action-driven toolkit for design practitioners to both support the creation of future sharing economy platforms and services, as well as to improve the user experience of existing services.

This dissertation should be of particular interest to HCI and interaction design researchers who are critically exploring technology-mediated sharing practices through fieldwork studies, as well to design practitioners who are building and evaluating sharing economy services.

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Chapter 1

Introduction

Sharing is a ubiquitous phenomenon that is omnipresent in a wide range of everyday activities, and that touches many spheres of our lives. Objects of sharing can be material (e.g., food, apartments, cars, resources), immaterial (e.g., digital music, pictures, links to websites) or even abstract, for instance when sharing beliefs (e.g., through religion), labor (e.g., co-working), or feelings. However, those objects of sharing have different qualities [John, 2017]. For example, when sharing a candy bar with someone, one makes a sacrifice and remains with less of it, a so-called a zero-sum game (e.g., [John, 2013]). Conversely, when one shares a link to a recent New York Times article with a friend using an instant messaging service, there is no less of the article (or the URL for that matter). Here, sharing is a non-zero-sum game. This quality of sharing describes one of the multifaceted sides of sharing [Wittel, 2011] and inherently suggests its contrasting meanings depending on the medium it takes place – the real world or digital ephemera.

While it is evident that sharing is a compound phenomenon that is woven into online and offline fabrics of our everyday lives, scholars seem to agree that all different practices of sharing (from exchanging news to sharing meals) create, support and maintain social relationships [Kennedy, 2015], and often promote pro-social behavior, generosity, openness, and mutuality [John, 2013].

However, there are two main challenges to sharing: one concerns **information oversharing**, the other **"under-sharing" of physical resources**. The convergence of social, mobile and cloud computing has made it easier to communicate, collaborate, and organize our everyday lives, hence opening up vast opportunities for the sharing of personal information (e.g., individual preferences, plans, physiological information) with a wide audience. At the same time, everyday interactions with our smartphones and wearable gadgets can easily lead to digital oversharing. Besides sharing explicitly, users implicitly leave a "trail of

data breadcrumbs" behind, just by virtue of normal activities such as working, eating, sleeping, exercising, and communicating. These tiny bits of data derived from a user's individual digital traces, when put together, may compose a rich corpus of information about the user's habits and activities [Estrin, 2014]. Mobile service providers, social networking sites, search engines, e-commerce websites, and other third-party services actively use those digital traces, and integrate and remix them for specific purposes [Krontiris et al., 2014]. To date, most users have only a vague understanding about the targeted usage of that information and who is a potential receiver of their shared data. Therefore, to address the consequences of oversharing, designers of content sharing services need to account for novel forms of digital content (e.g., enabled by personal activity tracking), outline possible implications of sharing that content online, facilitate decision making, and ultimately put users in control of their data.

In contrast to information oversharing online, real-world resource sharing faces the opposite challenge: there are massive amounts of "under-shared" resources out there. Many household items (e.g., tools), once purchased, may end up barely used and often wind up in garages and yards with the hope that another occasion to use them will come up. Digital technologies offer a major opportunity to enable people to use and re-use existing resources in the service of environmentally sustainable aims [Blevis, 2007]. One solution that leverages technologies to achieve that aim is proposed by non-ownership economic models, known as *collaborative consumption* [Botsman and Rogers, 2010] or more often referred to as "sharing economy". This has enabled people to coordinate, acquire, distribute, and temporarily use many different kinds of resources (e.g., housing, fertile land, vehicles). In addition to the proliferation of commercial sharing economy services, which aim to address latency in housing and vehicles (e.g., Airbnb, BlaBlaCar), an increasing amount of community groups and organizations have established cooperatives (e.g., libraries of things and equipment) that typically prioritize environmental, social, and cultural values within a community above economic benefits while optimizing the use of shared resources. In our work, we aim to explore how the design of interactive systems could approach "the challenge of under-sharing" of physical resources in the context of collaborative consumption.

On the whole, prior research often discusses "the challenge of oversharing" in relation to concerns of privacy [Olson et al., 2005] and disclosures on social media [Lampinen, 2015; Tufekci, 2007], while framing "the challenge of undersharing" within the context of sustainability [Blevis, 2007] e.g., a growing number of underutilized physical assets in the world [Thackara, 2005]. Nonetheless, while these challenges have thus been explored in a range of studies, prior work has not

yet sufficiently examined them within two *emergent sharing domains*. The first domain can be characterized by the wide adoption of **personal activity tracking** devices and services, which, in turn, afforded new kinds of digital items to be shared (e.g., in the form of daily workouts). The second domain can be described by the rapid development of **sharing economy services**, which enabled efficient access to and temporal use of unused physical "things" (e.g., cars, household items).

Collectively, the *novel technology-mediated sharing practices* that appeared in these two domains further reveal the consequences of oversharing and emphasize the importance of sharing for maximal use through collaborative consumption to meet social, economic and environmental sustainability goals. In the future, the role of sharing will be even more important in our everyday lives once research and development forges ahead in augmenting human capabilities (e.g., exoskeleton, augmented vision technologies) and augmenting physical things (e.g., the Internet of Things, augmented reality systems). These technological shifts will produce new forms and volumes of content, which will further amplify concerns of digital oversharing. Furthermore, the creation of new "smart" devices will intensify environmental sustainability efforts to maximize the use of existing physical artifacts (thus minimizing the consequences and effects of manufacturing new things).

Correspondingly, there is an overarching problem of understanding how the design of networked and interactive technologies could adequately address the challenge of information oversharing and the challenge of under-sharing physical resources. Given that a new generation of sharing services is about to emerge, it is of utmost importance to provide service designers with the right insights to adequately support novel sharing practices in our two sharing domains. This challenge marks a salient motivation for our work.

1.1 Problem Statement

Despite prior research efforts that discussed current challenges associated with sharing in individual domains, for example, file sharing (e.g., [Voida et al., 2006; Sleeper et al., 2016]) or photo sharing (e.g., [Voida et al., 2005]), little work has explored the design space to accommodate the broad spectrum of novel technology-mediated sharing practices of sharing digital information and personal physical artifacts. This thesis addresses this gap and focuses on two emergent sharing domains (1) the domain of **personal activity tracking**, which includes associated content sharing practices (e.g., sharing individual preferences in food

and music, workout activities) enabled by the recent advent of personal mobile and wearable technologies (e.g., quantified-self initiatives); and (2) the domain of **sharing economy services**, which incorporates practices of sharing physical possessions within the broad context of collaborative consumption fueled by the recent development of interactive networked technologies. Subsequently, we formulate one research problem for each domain.

(P1) **With the absence of a comprehensive account of novel content sharing practices, it is difficult to characterize the specific role of mobile and wearable technologies in supporting *digital sharing enabled by the advent of personal activity tracking*.**
In other words, this means that we need (a) to develop a sufficient understanding of novel digital sharing practices within the context of personal activity tracking; (b) to identify specific peoples' needs, challenges and concerns within these practices; (c) to understand how personal mobile and wearable technologies can adequately address those concerns. Going forward, as lifestyle-tracking companion devices and everyday personal things become increasingly networked (i.e., the Internet of Things), not only the volume of information being shared will increase, but also its variety. Future online services and connected devices will make user-generated content easier to produce albeit harder to maintain.

(P2) **It remains difficult to describe nuanced design characteristics for interactive technologies to support *physical sharing practices in the context of sharing economy services*.**
Despite the fact that the sharing economy phenomenon attracted researchers from many disciplines, the particular role of technology and design there is yet to be clearly pronounced [Bae et al., 2017; Fagerstrøm et al., 2017]. Specifically, this means that we need (a) to map the largely unchartered and unstructured sharing economy design space; (b) to describe the attendant challenges in physical sharing practices of involved individuals and communities; (c) to formulate the design implications for mobile technologies in order to address those challenges taking into account needs and desires of their users.

In this thesis, we explore this emergent space and provide prospective opportunities for design to build meaningful user experiences (UX). To the best of our knowledge, no prior research has comprehensively described these two sharing domains.

What is more, we argue that many of the challenges and issues that are present in digital online sharing are also highly relevant for the physical sharing

in the context of the sharing economy, especially when shared physical objects (e.g., tools, apartments) have digital representations (e.g., a listing, classifieds) and/or are mediated by an online platform. Prior research on sharing economies demonstrated that the design of online platforms may have a profound effect on the endurance and growth of resource sharing communities [Lampinen et al., 2015; Mosconi et al., 2017], play an important role in establishing peers' interaction [Raval and Dourish, 2016], affect users' behavior [Lutz et al., 2018], and influence their decision-making [Edelman and Luca, 2014; Ert et al., 2016].

Nonetheless, design practitioners do not often adapt this type of design research knowledge since they consider it too abstract, too difficult to use, and it is too hard to look for when it comes to the needs and constraints of professional design practice [Norman, 2010; Roedl and Stolterman, 2013; Goodman et al., 2011]. Owing to the growing body of knowledge in this area [Dillahunt et al., 2017], we additionally formulate the third research problem:

(P3) **We do not know how designers of online sharing platforms and services can support physical sharing practices in the context of the sharing economy.**
While HCI and design research offers a wealth of methods to inform and inspire the design process, there is a lack of domain-specific knowledge to adequately support designers to devise future sharing economy services and platforms without jeopardizing users' expectations, needs and concerns. In particular, we need (a) to outline the commonalities and differences among the digital and the physical sharing; (b) to elicit a set of design guidelines highlighting particular characteristics of physical sharing practices; (c) to understand how this added knowledge can be applied within designers' creative processes in the context of the sharing economy.

1.2 Thesis Goals

The main goal of our research is twofold. Firstly, we aim to understand novel practices of sharing personal digital and physical possessions within two sharing domains, personal activity tracking and sharing economy services. Secondly, we aim to uncover corresponding end-user needs and concerns across these technology-mediated sharing practices, in order to map the design space for user experience design to support emergent and future sharing needs.

Particularly, in this thesis, we will address the three aforementioned problems with the corresponding research goals:

(G1) **We will provide a comprehensive account of common digital sharing practices stemming from the advent of personal activity tracking.**
At the outset, we will conduct an online survey to identify the needs, practices and tools of sharing various novel types of digital content (e.g., personal workout details, preferences in music and food) enabled by the advent of mobile and wearable technologies (see Chapter 4). Next, we will employ a qualitative research methodology (e.g., technology probes [Hutchinson et al., 2003]) and will conduct several ethnographically-inspired empirical inquiries in the context of outdoor sports (see Chapter 5). Outdoor physical activities represent a broad design space for novel digital sharing practices within various social contexts. We will reflect on how mobile and wearable technologies can support and inhibit sharing practices for co-located amateur skiers. Lastly, in order to address the needs of remotely-located sharers, we will engage in a related project and develop an interactive prototype with a view towards exploring the social effects of sharing biophysical and emotional data during distance-separated movie-viewing activities (see Section 5.3).

(G2) **We will describe nuanced design characteristics for interactive technologies to support physical sharing practices in the context of the sharing economy.**
To begin our understanding of the sharing economy design space, we will conduct an empirical study to outline the tools, needs, and concerns around sharing everyday purchases (See Section 6.1). Furthermore, to evaluate the specific role of mobile technologies, we will design, develop, and deploy an interactive system to support physical sharing practices within a tool sharing cooperative (see Section 6.2). In this study, we will adopt a research-through-design methodology [Zimmerman et al., 2007], which allows us to elicit current needs and desires of users, as well as provides the design sensibility for devising new interactive systems that can address those needs. To conclude, we will discuss the value of nascent smart-contracting technologies to address some of the challenges of resource-sharing communities (see Section 6.3).

(G3) **We will investigate how designers can specifically support technology-mediated physical sharing practices in the context of the sharing economy.**
Through a systematic literature review of technology-mediated sharing practices and prior research in HCI that looked into bridging personal physical and "virtual possessions" (e.g., collections of personal photos, music, etc.) in the domestic environment [Odom et al., 2011; Petrelli and Whit-

taker, 2010; Nunes et al., 2008], we will first illustrate how digital sharing relates to physical sharing practices in the context of the sharing economy and discuss the commonalities and differences between the digital and physical sharing spheres (see Section 3.3). Second, we will further engage a set of designers and sharing economy domain experts in qualitative interviews to elicit particular characteristics of sharing economy services in order to map this largely unchartered design space (see Section 3.3.3). Third, based on these insights, we will draw a set of design guidelines targeted to researchers in HCI and interaction design who are interested in exploring the physical sharing domain further (see Section 7.1). Finally, using our guidelines, we will develop and partially validate a design toolkit to aid designers in both evaluating existing sharing economy platforms and creating new value-added services in that space (see Section 7.2).

The outcome of the thesis will be a rich and descriptive account of sharing phenomena within two emergent sharing domains and their chartered design spaces. Our results will inform user experience design for technology-mediated sharing practices and will offer a design toolkit for the sharing economy, which will also serve as a formative evaluation tool for design practitioners to assess and improve current and future sharing services in order to maximize the utility of such systems. On the whole, taking a cross-disciplinary perspective, this dissertation contributes new empirical knowledge on how the design of interactive mobile and wearable technologies could approach two growing challenges to *sharing*, (1) the challenge of information oversharing and (2) the challenge of under-sharing of physical resources. Ultimately, this dissertation discusses new avenues in design research that aim to examine novel technology-mediated sharing practices within collaborative consumption. As a consequence, this thesis will be especially of interest to HCI and interaction design researchers who are critically exploring physical sharing practices through fieldwork studies and design-oriented projects.

1.3 Organizational Overview

This dissertation is divided into eight chapters. In Chapter 2, we discuss related work. First of all, we introduce the theoretical underpinnings of *sharing* based on scholarship in consumer behavior research, communication sciences, and media studies. Then, we provide a synopsis on the theories of practice and describe their role in our research. Next, we outline relevant studies in HCI and related disciplines that have looked into technology-mediated sharing practices.

In Chapter 3, we propose a conceptual framing for digital and physical sharing practices adapting two contrasting logics of sharing introduced by John [2017]. We then describe the mixed-methods research approach that we employ in our empirical studies in two emergent sharing domains. Furthermore, we offer five key design themes that constitute technology-mediated sharing practices (see Section 3.3), stemming from (i) a systematic literature review partially described in Chapter 2 and (ii) a set of findings from qualitative interviews with design practitioners and sharing economy domain experts. To conclude, we identify the commonalities and differences between technology-mediated physical and digital sharing practices spanning from file sharing to sharing physical artifacts in the context of the sharing economy. We specifically focus on *what* is being shared, *with whom*, *why*, and *how* this sharing takes place. Collectively, these insights lay an important foundation to address our research goal **G3**.

Chapters 4 and 5 address our research goal **G1** and discuss two empirical undertakings of digital sharing in the domain of personal activity tracking. The first study describes the common practices of sharing novel forms of personal content (see Chapter 4). A second set of studies (see Chapter 5) provides an in-depth inquiry into digital sharing practices of leisure skiers (see Section 5.1) and discusses design implications of how to support their practices (see Section 5.2). In particular, we describe our findings based on a data corpus collected from various sources: ethnographic observations from two skiing sites, interviews and focus groups with skiers, a co-design workshop, a lab, and a field deployment of an interactive mobile and wearable prototype. Next, with reference to these findings, in order to cover a wider breadth of shared content stemming from personal activity tracking, we take a step back and discuss a related project (see Section 5.3), where we prototyped a mobile application that facilitates the digital sharing of one's emotions in the context of movie-viewing.

Chapter 6 addresses research goal **G2** and assesses the specific role of design and technology in physical sharing practices in the context of the sharing economy. In particular, we describe the results of two field studies. The first outlines the current practices of sharing peoples' everyday purchases (i.e., the actual items bought, not spreading information about the purchase, see Section 6.1). The second examines sharing practices of one tool-sharing cooperative in Canada (see Section 6.2). We then reflect on how interactive technologies could support individuals and groups of people in their activities. We conclude this chapter by outlining the design and implementation of a resource sharing platform in the form of a smartphone application (see Section 6.3) that we developed to address the challenges that surfaced during the field study in the tool-sharing community.

In Chapter 7, we focus on our research goal **G3**. We first identify a set of implications for design of sharing economy services (see Section 7.1) drawing on the findings of our empirical study of technology-mediated sharing practices described in Section 3.3. Based on these design considerations, we then present a design toolkit for sharing economy services (see Section 7.2) and discuss its use within designers' creative processes in both individual and group settings.

Chapter 8 summarizes the contribution of our research in the domain of HCI. There, we synthesize the findings from our empirical studies, discuss the limitations of our approach, argue how we achieved our research goals, and outline avenues for future research beyond this thesis.

Chapter 2

Related Work

The work in this thesis draws on scholarship in several domains, including consumer behavior research, communication and media sciences, sociology, human-computer interaction, and interaction design.

2.1 Conceptual Framing of Sharing

Sharing is not a well-defined concept. As we established in Chapter 1, sharing today is ubiquitously present in our daily interactions in a wide range of digital and non-digital contexts (e.g., to share feelings, to share posts on social media, to share a house), and therefore inherently has different meanings. A number of research efforts in the social sciences have attempted to find a common theoretical ground to describe the sharing phenomenon. These efforts can be divided into two approaches – one is prescriptivist, the other is pragmatic. The prescriptivist approach concerns to determine whether something *really counts* as sharing, while the pragmatic one stands for situatedness and malleability of sharing in diverse contexts. Both are useful when delving into this complex phenomenon by revealing how different notions of sharing have crystallized to date as common knowledge. Below we present three seminal works that helped frame our inquiry into technology-mediated sharing practices.

Consumer theorist Belk [2010] pointed out the lack of theoretical conceptualization of the sharing phenomenon and defined "sharing-in" and "sharing-out" as two types of interpersonal interactions, based on the relationship with, and attitude towards, the counterpart of a sharing transaction. He characterized a "sharing-in" behavior as an inclusive act of sharing within the *extended-self* (i.e., intimate circles and immediate family) that dissolves interpersonal boundaries and creates social ties, while a "sharing-out" behavior (e.g., providing spare

change, directions or even "time-sharing" a condo) creates no social bonds [Belk, 2010, 2014a]. His scrupulous approach to answer the question "What practices should we call sharing?" resulted in a new concept *pseudo-sharing* – "business relationships masquerading as sharing" [Belk, 2014b].

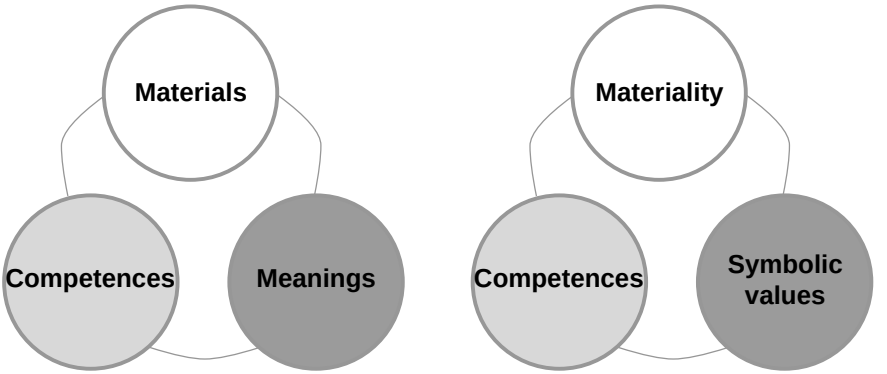
In contrast to Belk, Kennedy [2015] adopted a more pragmatic practice-based approach and studied the "everydayness and ubiquity" of sharing in relation to networked cultures. She illustrated that both the modern meaning and interpretation of sharing are guided by complex social, economic, cultural and political norms. She concluded that despite the multifaceted nature of the sharing practices exercised in both the sharing economy and on social media, all share a common ground with respect to their pro-social attitude toward community, and associated with a set of mutual values such as cooperation and participation [Kennedy, 2015].

In the same way as Kennedy, media scholar Nicholas A. John in his recent book "The Age of Sharing" [2017] extensively discussed everyday interpretations of sharing. There, he critically interrogated the real and metaphorical meaning of the word "sharing" in our daily lives, and distinguished two logics behind the term – distributive and communicative. In *distributive sharing*, the shared item is a limited resource, e.g., an apartment that is rented to another person for some time. There, sharing is an act of distribution, which means to divide something with someone. In *communicative sharing* on the other hand, the shared item is not a limited resource, e.g., when sharing a memorable photo online, or when talking about our feelings and emotions online or offline. However, despite these differences, both types of sharing behavior not only create and regulate social relationships [John, 2013], but also promote openness, trust, commonality, and understanding between people [John, 2017].

In this thesis, building on Belk's [2010] early theoretical conceptualization of sharing, we follow Kennedy's [2018] pragmatic approach to study it, and apply John's [2013] communicative and distributive framing to emergent sharing domains.

2.2 Theories of Social Practice

Without an agreed upon definition of sharing, researchers found it useful to frame it as *a practice*, that is, to answer the question "What practices do we call sharing?" (e.g., [John, 2017; Kennedy, 2018]). According to Reckwitz [2002] practice is "a routinized type of behavior which consists of several elements interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their



(a) Shove et al. [2012] **(b) Kennedy [2018]**

Figure 2.1. The elements of (sharing) practice

use, a background knowledge in the form of understanding, know-how, states of emotions and motivational knowledge".

Shove et al. [2012] examined everyday practices within the context of science and technology studies, and proposed an understanding of the practice as a composition of three related elements (see Figure 2.1a):

- *materials*, including things, technologies (hardware and software), "tangible physical entities" and things they are made of;
- *competences*, which "encompass skill[s], know-how and technique[s]"; and
- *meanings*, which include symbolic meanings and motivations.

Drawing on Shove's framework, Kennedy [2018] developed a theory of sharing practice in "network culture" (i.e., a new socio-economic phenomenon emerged with the advent of digital computing and mobile networking technology [Varnelis, 2008]). There, she distinguished (i) *materiality* that addresses the type and modalities of sharing objects; (ii) *competences* through which the practice is recognizable to practitioners and observers; and (iii) *symbolic values* that encompass the motivation of sharing. These three elements of sharing practice are fully aligned with Shove's interpretation of practice (see Figure 2.1b).

In particular, under *materiality* Kennedy [2018] distinguished material objects, immaterial objects, as well as object of affect (e.g., emotions and thoughts). She offered three distinct ways how objects can be shared. Namely, (1) objects

can be duplicated (e.g., sharing digital images); (2) objects can be divided and apportioned (e.g., sharing a candy bar); and (3) access to the objects can be shared (e.g., collaborative consumption). With regard to *competences* she argued that constitutive elements include ways of doing sharing (e.g., face-to-face, phone calls, social media platforms) through tacit knowledge, bodily actions and 'know-hows' traversing a range of spatial, temporal and material arrangements. The key contribution of her work concerned with explaining the ways of doing sharing. She argued that a sharing activity involves an extension of control of an object, rather than transferral of its ownership from one participant to another. When it comes to *symbolic values*, she explained that they capture the motivations and aspirations of sharing practice, often with a view towards community-building.

While Kennedy's work is rather comprehensive in terms of conceptualizing and developing a holistic understanding of sharing as a practice, her work focused on social media and communication practices online, leaving the topic of design of interactive technologies that supported these practices largely unexplored. Building upon Kennedy's work, we examine sharing practices in the context of personal activity tracking and the sharing economy services, and unpack particular design characteristics and how to support them within these emergent sharing domains.

The reader should notice that in contrast to generative practice-oriented approaches to design (e.g., [Kuijer et al., 2008; Kuijer and Jong, 2012]), where a practice is considered as the unit of design, and people have only a peripheral role as the carriers of practice [Shove et al., 2012], we have chosen to follow a user-centered design approach [Holtzblatt et al., 2004]. This not only ensures that people remain at the center of a design process but also allows us to understand the design space (e.g., users' needs and concerns) descriptively.

Collectively, the body of work described in this section (1) informed our understanding of practice elements in order to create ethnographic accounts of digital and physical sharing practices in two emergent sharing domains; (2) helped develop the research questions and the interviews scripts for our empirical studies; and (3) provided guidance on how to use practice theories as a lens for data analysis [Wakkary et al., 2013].

2.3 Studies of Digital Sharing Practices in HCI

At the outset, studies of digital sharing in the HCI community focused on needs, practices, and concerns around the sharing of personal digital data. For instance, researchers discussed sharing of files [Voida et al., 2006], photos [Miller and

Edwards, 2007], collections of music [Voida et al., 2005], videos [Lange, 2007], as well as textual information [Acquisti and Gross, 2006], like status updates on social networking services (SNS), and personal information at large [Olson et al., 2005]. However, most prior research only partially addresses the set of core questions [Kennedy, 2018] that allow one to create a comprehensive account of sharing practices, such as "What is being shared?", "Who is it being shared with?", "How it is being shared?", and "Why it is being shared?". The benefit of focusing on "practice" as the unit of analysis (see Section 2.2) is that it provides a holistic view of sharing behaviors and requires a nuanced understanding of the context where sharing takes place. Ultimately, by further reviewing related work and conducting empirical studies, we will not only build a comprehensive account of sharing practices in our two emergent sharing domains but also assess the commonalities and differences between digital and physical sharing (see Section 3.3.3).

2.3.1 Sharing Multimedia Content

Early work on digital sharing phenomena started with the practice of file sharing, mainly for supporting group work [Voida et al., 2006; Whalen et al., 2006; Dalal et al., 2008; Smetters and Good, 2009]. Whalen et al. [2006] described the heterogeneity of various file-sharing methods (e.g., E-Mail, instant messaging, blogs), Smetters and Good [2009] classified motivations to share files around efficiency and productivity at work, and Mannak et al. [2004] outlined social factors characterizing peer-to-peer sharing. We summarize the insights from this prior work on file sharing based on the aforementioned core sharing questions in Table 2.1.

What to share?	Documents, Personal media collections, Notes, Schedules, Contacts, Preferences (TV shows, places)
With whom to share?	Colleagues (individual and groups), Friends, Family members, Publicly
How to share?	Remote sharing, Rarely showing on display
Why to share?	Collaboration, Reporting, Social visibility, Convenience, Reciprocity, Utilitarian, Legal issues

Table 2.1. Insights from prior work on file sharing practice

What is more, Voida et al. [2006] made an important contribution with regard to the design of new file sharing tools. They identified that (1) users select which

tools to use based on how well the affordances and features of those tools fit to the sharing situation at hand; (2) there is a need to design and develop tools that capture the broadest possible set of affordances that can reduce the amount of compromise required to effect sharing. These insights informed our empirical research and design explorations (see Chapter 5).

Later, with the boom of online photo sharing services [Frohlich et al., 2002; Miller and Edwards, 2007], researchers started to look at the actual experiences surrounding sharing practices. Self-representation, self-expression and emotional aspects (see Table 2.2) became important factors to motivate digital personal photo sharing [Goh et al., 2009; Van House et al., 2005] and music sharing [Brown et al., 2001]. Sharing started to be considered not only as an asynchronous distributed activity (e.g., file sharing to support work-related tasks) where media objects do not have any inherent meaning, but rather as sense-making that supports communication and group interaction [Salovaara et al., 2006]. More generally, Bødker [2015] challenged the value of technologies that only provide utility at work, but rather embraced experience and meaning-making in everyday lives. Finally, from prior research on photo sharing it became apparent that personal devices should minimize interruption and disruption in users' established processes, allowing the maximum flexibility to share at any convenient time [Ames et al., 2010] to targeted audiences [Ojala and Malinen, 2012].

What to share?	Photography (memories, ordinary pictures, spontaneous, news-like)
With whom to share?	Selective group (friends, family), Publicly
How to share?	Co-located (storytelling), Remote sharing
Why to share?	Connectedness, Reminding, Self-representation, Self-expression, Functional, Emotional

Table 2.2. Insights from prior work on photo sharing practice

With the rapid adoption of GPS sensors on smartphones, people started to share their locations [Wagner et al., 2010] not only with family members (e.g., through specialized apps) but also publicly (e.g., on SNS), which naturally prompted issues of privacy and security [Consolvo et al., 2005; Beldad and Citra Kusumadewi, 2015]. Furthermore, Brown et al. [2007] pointed out that people can infer one's activity from a shared location and, subsequently, make judgmental conclusions about one's behavior. Location-sharing research revealed the importance of *context* in sharing practices, which we address in our own studies.

2.3.2 Sharing Biophysical Data

Prior research on sharing personal activity data sheds some light onto emergent sharing practices. Mobile consumer devices (e.g., smartphones, smart watches, sensing textiles) are being increasingly used as sensing instruments to record personal habits, to keep track of one's physical exercises or sport activities, and to monitor users' own health [Krontiris et al., 2014]. We synthesized the motivations for sharing details of training routines and physical exercises from prior research in Table 2.3. The most frequent reasons to share are (1) to get feedback and guidance [Ojala, 2013]; (2) to create and maintain social ties (e.g., through finding a running partner) [Consolvo et al., 2005; Mueller et al., 2010]; (3) to build an attractive social profile [Ojala, 2013]; and (4) to compete among peers [Ahtinen et al., 2008]. Prior work also confirmed that sharing these data not only contributes to the overall user experience and enjoyment of workouts for both, the sharer [Munson and Consolvo, 2012] and their target audience [Curmi et al., 2013], but can also be a powerful motivator for health activities at large [Toscos et al., 2006].

What to share?	Personal statistics, Location data, Supplementary information (e.g., mood, weather, media)
With whom to share?	Selective groups (family, friends, peers, a trainer), Publicly, Third-parties
How to share?	Mostly remote sharing using the same medium as sensed data
Why to share?	Get feedback, Self-monitoring, Competitiveness, Create and maintain social ties, Self-expression, Ease of adding data

Table 2.3. Insights from prior work on sharing biophysical data

However, as sharing personal workout data has become more automated owing to the wide penetration of tracking apps and wearable devices, the control over such information became harder to maintain [Krontiris et al., 2014]. Researchers emphasized the importance to design usable, expressive, intuitive, and transparent user interfaces to support sharing personal physiological data with privacy in mind [Raij et al., 2011; Prasad et al., 2012].

Epstein et al. [2015] proposed a social sharing design framework for personal activity data, which is composed of six dimensions: (i) the type of data collected and shared; (ii) the transformations applied to the data prior to sharing; (iii) events that causes the data to be shared; (iv) persistence of shared content; (v) the presentation of the shared data; and (vi) the audience as a recipient of the shared data. Their framework effectively summarized the core sharing

questions: *what* is being shared, *to whom*, *how* and *why*. What is more, Epstein and colleagues emphasized the importance of audience and content selection strategies and techniques for designing services to allow users effectively manage the personal data generated during sport activities. In this thesis, we aim to extend their framework by taking into account technology-mediated physical sharing practices in the broader context of sharing economy.

2.3.3 Sharing on Social Media

A large number of studies in HCI and, particularly, the Computer–Supported Cooperative Work (CSCW) research sub-community, explored sharing on social media. Prior research comprehensively discussed shared content (e.g., [Acquisti and Gross, 2006; Boyd and Ellison, 2007]), target audiences (e.g., [Litt and Hargittai, 2016b; Wiese et al., 2011]) and motivations that drives social media users to share their personal information (e.g., [Acquisti and Gross, 2006; Lange, 2007]). Table 2.4 presents a synthesized snapshot addressing the core sharing questions.

What to share?	Textual information (posts, personal data, preferences), Media (images, videos, audio), Links to another resources
With whom to share?	Selective groups (friends, family, interest groups), Publicly
How to share?	Always remote sharing
Why to share?	Create and maintain social ties, Connectedness Self-expression, Self-representation, Social Visibility, Emotional/Fun, Get feedback

Table 2.4. Insights from prior work on sharing on social media

This strand of research particularly made substantial advancements in developing and unpacking the concept of *target audiences*, as well as reflected on associated users' challenges when it comes to sharing content to these audiences. In the era of asynchronous computer-mediated communication (e.g., SNS, instant messaging apps), users often utilize multiple online services as communication channels [Sleeper et al., 2016] to reach out to heterogeneous audiences, which may lead to unexpected privacy problems [Vitak, 2012]. Social network research demonstrated the importance of understanding users' sharing attitudes and their mental models for privacy management with respect to personal content [Acquisti and Gross, 2006], and suggested new methods of dealing with privacy issues, emphasizing the need of audience control mechanisms that can govern access to

shared content [Ahern et al., 2007]. Ellison et al. [2011] confirmed that managing the audience that has access to the shared content is one of the key factors in service usage.

Previous research has explained how people perceive their target audiences while posting content on social media: they think of more general abstract audiences or imagine specific audiences [Litt and Hargittai, 2016b]. In fact, these ambiguous audiences in SNS raised the issue of what Vitak [2012] identified as *context collapse*, where the self-presentation and the distribution of information to distinct social groups (e.g., friends, family, professional) becomes difficult, that is, "people from different context become part of a singular group of message recipients" within a single SNS. Social media scholars proposed various coping mechanisms to address the context collapse. For example, Wisniewski et al. [2012] suggested boundary regulation, an act of optimizing the level of openness [Altman, 1975] to control who sees their content.

Nonetheless, despite the privacy concerns, Litt and Hargittai [2016a] found that social network users typically tried to enlarge the reach of their posts, rather than limiting it. This became known as *privacy paradox* [Acquisti and Gross, 2006]. Furthermore, Tufekci [2007] empirically illustrated that students, in order to manage unwanted audiences, adjust the visibility of their profiles on Facebook, but did not regulate their level of disclosure. Vihavainen et al. [2014] described the effect of automation in content sharing with respect to privacy perception. Their work suggested that while automated options require less effort from the users, the downside is that users may feel disempowered and unable to perform boundary regulation.

Collectively, this strand of research identified challenges and opportunities of contemporary digital sharing practices through systematic examinations of audiences *to whom* sharing takes place. What is more, it proposes *privacy* as a new thematic category [Lampinen, 2015], which is tightly woven into any online sharing practice. We will build upon these results to understand how the insights from social media research are situated within technology-mediated physical sharing in the context of sharing economy.

2.4 Studies of Physical Sharing Practices in the Sharing Economy

The recent development and proliferation of sharing economy platforms and services has enabled people to temporarily share, access and exchange underutilized

physical resources, such as housing [Ikkala and Lampinen, 2014], vehicles [Bardhi and Eckhardt, 2012], household objects [Ozanne and Ballantine, 2010], and spaces [Taylor et al., 2016]. Users (both peer-producers and peer-consumers) that participate in popular commercial sharing services (e.g., Airbnb, Uber) are largely driven by practical needs (e.g., get a service, increase convenience, receive monetary benefits) [Bellotti et al., 2015; Ikkala and Lampinen, 2014]. However, beyond these commercial enterprises, prior research studied grassroots sharing initiatives and member-owned collectives, such as maker spaces [Taylor et al., 2016], libraries of things [Ozanne and Ballantine, 2010], and community gardens [Light and Miskelly, 2015], which often prioritize social, cultural, and environmental values over economic gain. Scholz [2016] called this phenomenon, fueled by networked technologies, "platform cooperativism".

Prior work examined numerous issues that commercial sharing economy services face (e.g., transience among and anonymity of membership) [Bardhi and Eckhardt, 2012], outlined technical limitations (e.g., account sharing) of existing sharing economy platforms [Lampinen, 2014], discussed challenges related to disintermediation (e.g., out-of-platform transactions) [Bellotti et al., 2017], and argued for a significant role of emotional labor (i.e. the management of feelings) in the experience sharing services [Lutz et al., 2018].

Researchers also identified attendant challenges of platform co-ops, such as lack public profile and long-term funding, compared with multinational corporations [Scholz, 2016]; discussed emergent issues of trust and reciprocity within membership and supporting online exchange platforms [Lampinen et al., 2013]; emphasized the value of social ties in sustaining online sharing communities [Lampinen et al., 2015]; outlined considerable challenges that can occur in terms of creating [Luckner et al., 2015] and nurturing new instances of local communities [Lampinen et al., 2015] if social ties and trust are weak; and discussed challenges to clearly convey social and personal benefits of participation [Bellotti et al., 2014]. We envision that the designers of sharing economy platforms would require an adequate set of tools in order to address those growing organizational and interpersonal challenges. This marks a salient motivation for our work.

Dillahunt et al. [2017] conducted an extensive survey of the sharing economy in computing literature and identified several underexplored areas and directions for future research. In particular, they revealed a lack of studies that engage in informal economies of underutilized physical resources. They also called to explore different sharing contexts, such as "shared spaces and couches, etc." as the sharing economy platforms enter the new markets beyond housing, transportation, and timebanking. In addition to that, they pointed out to a significant bias towards the US context in the studies of the sharing economy. What is more, recent field

studies of cooperatives as a non-profit form of the sharing economy (e.g., [Bødker et al., 2016; Lampinen et al., 2018]) illustrated the piecemeal use of technologies to support co-ops day-to-day activities. This highlights the increasing need to understand the intricate nuances of use (or non-use) of technologies within actual resource sharing communities and organizations in order to formulate design strategies that adequately support endurance and growth of those organizations.

In sum, a key contribution of this body of prior work has been a number of qualitative accounts of various physical sharing practices within (local) sharing economy communities and collectives. However, more research is needed to outline the differences and commonalities of digital and physical sharing practices in order to inform the design of novel sharing services and platforms. In this thesis, we will bridge this gap by (i) mapping the design space between physical and digital sharing and (ii) synthesizing a set of user experience design considerations in order to support future physical sharing practices. To facilitate this, in what immediately follows, we first review prior work that looks at the design for physical and virtual possessions within domestic environments and second outline key building blocks that constitute user experience.

2.5 Studies of Physical and Virtual Possessions in Interaction Design

In order to understand the commonalities and differences between physical and digital sharing, we looked into research in interaction design that examines the use of the personal physical and virtual possessions in domestic environments [Odom et al., 2011; Gruning and Lindley, 2016], through personal mementoes [Petrelli and Whittaker, 2010], souvenirs, and keepsakes [Nunes et al., 2008]. For instance, studies of personal photography [Brown et al., 2001; Frohlich et al., 2002; Lobinger, 2015; Nunes et al., 2008] demonstrated that artifacts created around material forms of media (e.g., family photo albums) are still present in digital ephemera (e.g., on a photo sharing service). This digital content along with supporting metadata (e.g., face and location tags) constitutes our "virtual possessions" e.g., collections of personal photos, music, etc. [Odom et al., 2011].

Odom conducted a set of ethnographic studies to explore personal "virtual possessions" [2011; 2012; 2013; 2014]. He contrasted them to personal physical possessions and proposed three distinctive qualities [Odom et al., 2014]: (i) placelessness – an absence of place where digital things can be found; (ii) spacelessness – they do not intrude into people's physical space and can thus grow

invisibly; and (iii) formlessness – the fact that there is no clear sense of how virtual possessions can become unique personal artifacts. Furthermore, he argued that the accrual of metadata is another defining aspect of virtual possessions [Odom et al., 2011]: it allows for personalization, linking multiple types of virtual possessions together, and creating social stories [Odom et al., 2013].

Sharing virtual possessions in domestic environments comes with a number of challenges in comparison to their physical counterparts. Firstly, the virtual possessions are fragmented across different services (e.g., desktop, cloud storages, smartphones), which complicates users' sense of ownership [Odom et al., 2013] and control over them [Odom et al., 2012]. Secondly, a study of family heirlooms [Petrelli and Whittaker, 2010] revealed that digital belongings are often lacking symbolic associations and lasting value in comparison to their physical counterparts. Thirdly, the effortful access to digital possessions [Petrelli and Whittaker, 2010] inhibits the serendipitous opportunities for social engagement [Nunes et al., 2008] that are enabled by physical possessions (e.g., displayed souvenirs and framed photographs). Finally, digital possessions play a lesser role in identity construction in comparison to personal physical things [Kaye et al., 2006; Lee et al., 2015].

Collectively, this strand of research outlined several differences between physical and virtual possessions within domestic environments, and suggested several design strategies to build new interactive technologies that account for those differences. However, we note the lack of a common frame of reference to describe both differences and commonalities of such cross-domain sharing practices, in order to inform the design of new physical sharing services and platforms. While these studies represent an important point of departure for our work, in this thesis we will look at sharing in a broader social context beyond domestic environments.

2.6 Towards a Social User Experience

Hassenzahl and Tractinsky [2006] defined *user experience* (UX) as "a consequence of a user's internal state, the characteristics of the designated system and the context within which the interaction occurs". Following the philosophical traditions of pragmatism, McCarthy and Wright [2004] illustrated how technology can be seen in terms of experience with technological artifacts, and developed a framework for analyzing *felt* experience with technology. UX became a central subject of the interaction design research and practice agendas [Forlizzi and Battarbee, 2004; Law et al., 2009] owing to the growing interest of researchers and designers of interactive systems to examine hedonic and eudaimonic [Mekler and Hornbæk,

2016] qualities of experience and meaning-making in everyday life [Bødker, 2015]. Forlizzi and Ford [2000] suggested three ways to talk about experience: (i) *experience* as a stream that happens during the moments of conciseness; (ii) *an experience* as an event with a beginning and an end that shapes the user and the context; and (iii) *experience as story* – "the vehicles that we use to condense and remember experiences, and to communicate them in a variety of situations to certain audiences".

Battarbee and Koskinen [2005] leveraged the social dimension of the user experience and introduced the term "co-experience", i.e., the experience that is collaboratively created or perceived while using interactive technologies. Väänänen-Vainio-Mattila et al. [2010] defined *social user experience* as "a type of user experience that primarily occurs as a result of social activity enabled by distinct service functionality" and proposed pragmatic (e.g., learning, functionality) and hedonic (namely: self-expression, reciprocity, curiosity) factors of the social UX.

Collectively, researchers emphasized that interactive technologies play a large role in supporting social UX through providing mediated communication channels that enable the creation, editing, reviewing and sharing digital content with others [Forlizzi and Battarbee, 2004; Battarbee and Koskinen, 2005]. In this thesis, when it comes to communicative and distributed practices of sharing, social UX can reveal how an individual's experiences and their interpretations are influenced and shaped by the physical or virtual presence of others. Even though the concept of social UX was fundamental in informing our thinking and the foci of our empirical studies (e.g., see Section 6.1), as well as helped us uncover experiential blocks within technology-mediated sharing (see Section 3.3), future research should examine this promising avenue in greater detail.

We envision future-looking research opportunities to develop the nuances of the UX when it comes to supporting physical sharing practices within the context of sharing economy. For instance, one important direction is to re-examine the role of UX in the value proposition of platform co-ops. Whereas well-known services in the sharing economy, such as Airbnb, go to great lengths to deliver effective and efficient UX to match peer-producers and peer-consumers, how can social UX better serve platform co-ops in their challenges to further engage and retain their communities?

2.7 Summary

Prior research described in this chapter has made important contributions in terms of understanding the semantic meaning and underlying concepts of sharing, as

well as suggested framing sharing as a practice to explore its constitutive elements. Furthermore, the work reviewed in this chapter described digital and physical sharing practices individually in the various application domains and settings. However, more research is required in order to provide further insights into whether and how technology-mediated sharing practices from two emergent sharing domains, that is of personal activity tracking and the sharing economy services, are intertwined and related to each other. This dissertation not only discusses situated and contextualized insights from empirical studies *within* each sharing domain separately, but also compares and contrasts the design themes *between* those domains. In other words, we aim to understand how commonalities and differences between the digital and physical sharing spheres can inform and inspire the design of future technology-mediated sharing services.

Chapter 3

Decoding Technology-Mediated Sharing Practices

First of all, we describe the conceptual framing that we have employed to map the "polysemic homonymity" [John, 2017] (i.e., diversity of uses and logics) of sharing based on the work of media and communication scholarship. This step not only outlines the conceptual boundaries of sharing, but also defines the scope of our work. Next, we briefly elaborate on the mixed research methods that we use in our field deployments. We then present the key design themes that constitute technology-mediated sharing practices. We sythesized those themes from both the systematic literature review (a subset of which we discussed in the prior chapter) and in-depth qualitative interviews with 16 designers and sharing economy domain experts. Ultimately, we offer a comparative analysis of the commonalities and differences between digital and physical sharing practices.

3.1 Proposition for Conceptual Framing of Sharing Practices

Drawing on Kennedy's non-prescriptivist (i.e., pragmatic) approach in examining the sharing phenomenon [Kennedy, 2015], we propose to classify various practices of sharing using the two-dimensional Cartesian plane (Figure 3.1). On the horizontal axis, we position John's distributive and communicative logic of sharing [John, 2013]. For instance, as we previously described in Section 2.1, communicative sharing can be found in the plethora of contemporary sharing practices both online (e.g., digital photo sharing) and offline (e.g., sharing news with a family member). What is more, John [2017] argues that sharing can

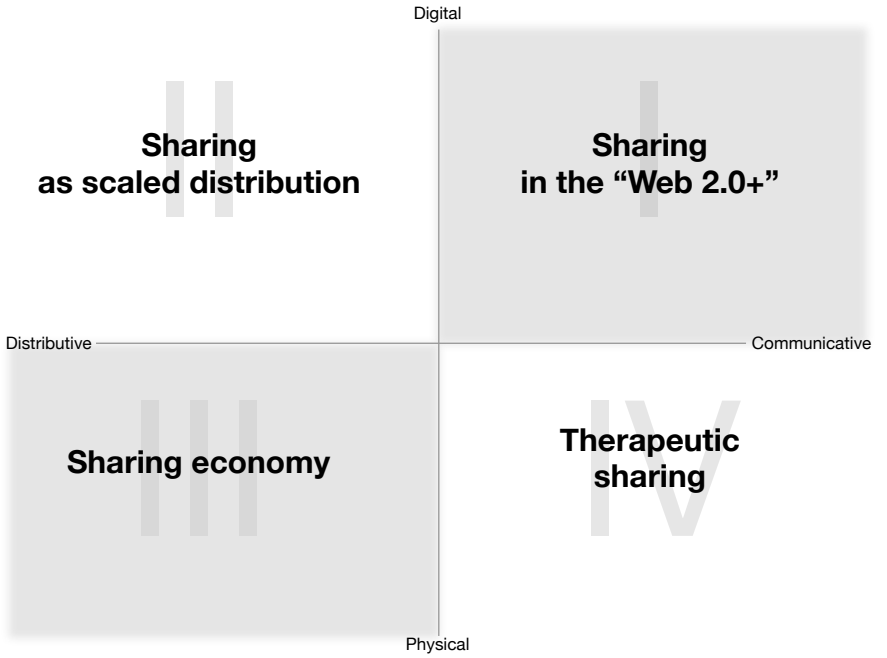


Figure 3.1. Conceptual framing of sharing and main sharing discourses from the literature. Following the Cartesian plane notation, the numbering of sharing domains goes counter-clockwise starting from the upper right (“northeast”) quadrant. The focus of this thesis is on quadrants `I` and `III`, as highlighted in grey.

be seen as a constitutive activity on social media, where it represents an act of participation in networked culture. In turn, he explains that distributive sharing often evokes a sense of community and is driven by aspirations for distribution and redistribution of (unused) resources. On the vertical axis (see Figure 3.1), we position the medium where sharing practices occur. Specifically, sharing practices can take place in digital ephemera (e.g., sharing a file) or in the real world (e.g., sharing a candy bar). This conceptual framing helps us to organize various research efforts that study sharing not only in the communication and media scholarship but also in the domain of human-computer interaction.

Figure 3.1 presents four discursive threads from prior research in communication and media studies that critically interrogated sharing phenomena. This framing, albeit simple, accommodates contemporary and novel sharing practices.

Furthermore, it allows us to examine these practices from different analytical perspectives, e.g., the context where sharing takes place or the motivational factors that drive sharing. Ultimately, this distinction encompasses a wide range of content (material or immaterial) in digital and physical realms.

On Figure 3.1, quadrant `I`, labeled as "Sharing in the 'Web 2.0+'", includes contemporary and novel content sharing practices, which occur with the help of digital technologies, with the purpose of "letting someone know" [John, 2012]. The most common examples of "traditional" sharing practices are sharing pictures, videos, or text messages through SNS or dedicated smartphone apps (e.g., instant messaging). The rapid adoption of mobile and wearable computing decreased a barrier to produce more user-generated information that describes our personal preferences (e.g., of music and food) and daily activities (e.g., workouts). As proposed earlier in Chapter 1, we label such personal digital information as *novel content* and we will discuss it in detail in Chapter 4.

In quadrant `II`, we include sharing practices of "collaborative production" [Benkler, 2006] of digital content, labeled as "Sharing as scaled distribution". The technological shifts accelerated opportunities to create new digital content (e.g., Wikipedia) and to scale sharing digital ephemera (i.e., music, videos) for the purpose of content distribution to a massive volume using distributed peer-to-peer technologies and dedicated online services such as personal podcasts (e.g., Soundcloud), video clip hosting platforms (e.g., YouTube, Vimeo), and music streaming services (e.g., Spotify). Naturally, sharing as a form of scaled distribution [Kennedy, 2015] enabled by digital technologies brought the issues of piracy and oversharing to the attention of researchers from many disciplines. Although those challenges help problematize the need and urgency of our work, we will not extensively focus on this area in this dissertation. Political theorists Benkler [2006] and Wittel [2011] paved the way to examine this area further.

Quadrant `III` shows novel practices of sharing created with the rapid development of sharing economy services fueled by networked technologies. Note that the object of sharing in these practices is not necessarily physical, but can also be virtual when people share computing resources (e.g., blockchain technologies, peer-to-peer computing) or abstract (e.g., sharing time). This domain opens up many opportunities in exploring sharing from the user experience design point of view, as everyday things become increasingly networked and will have their own digital presence and identity (i.e., the Internet of Things). What is more, given that the central role of a digital platform in mediating transactions among peers in a sharing economy service, we argue that this domain should be compared and contrasted with quadrant `I` in order to unpack nuanced design characteristics of technology-mediated physical sharing. Following prior work in sharing economy

that highlighted the interrelated nature of physical and digital sharing, we discuss fluid boundaries that exist between these two emergent sharing domains (see Section 3.3.3). In particular, recent work in the area emphasized the importance of online platforms to support offline sharing communities [Lampinen et al., 2015; Mosconi et al., 2017], critiqued unfair design choices of reputation review systems, which may lead to poor decision-making [Raval and Dourish, 2016], discussed the role of platforms in negotiating emotional labor [Lutz et al., 2018], and explained the effects of digital discrimination based on specific design features (e.g., peer profiles) in well-known sharing economy services [Edelman and Luca, 2014; Ert et al., 2016]. This thesis contributes with a critical exploration of this quadrant, in particular, we examine how designers can develop a sensibility to take into account the wealth of research in digital sharing to inform and inspire the creation of future technology-mediated physical sharing services and platforms (see Chapter 7).

Finally, quadrant `IV` contains what John [2013] calls "therapeutic sharing". This is a further area of research that looks at sharing as a form of communication, which includes sharing our emotions and feelings (e.g., support groups). Here, sharing is a constitutive activity of the intimate relationships in contemporary Western societies. The reader should note that therapeutic sharing is seen by researchers (e.g., John [2017]) as a special form of speech that occurs in the real world (in contrast to sharing on social media), that is why we position this type of sharing in the physical medium cluster in Figure 3.1. This strand of research relies on a psychological interpretation of everyday life and marks a salient direction for future research beyond the scope of emergent sharing domains that we aim to explore in this thesis.

In our thesis, we employ the conceptual framing presented here as a lens to charter the related work in HCI on sharing (see Section 3.3). What is more, in Chapters 4 and 5, we examine quadrant `I` in detail through a set of qualitative and quantitative studies of digital sharing practices, while in Chapters 6 and 7, we unpack quadrant `III` through a set of fieldwork studies of (technology-mediated) physical sharing practices. In what immediately follows, we describe the research methods that we adopted throughout our empirical studies.

3.2 The Adopted Empirical Research Methods

There are two dominant approaches to research methods in HCI: positivism and interpretivism. While positivism stresses the importance of doing quantitative research, such as large-scale surveys in order to get an overview of society to

understand and to model the natural world, the interpretivist school of research philosophy [Miles and Huberman, 1994] involves an explanatory, contextualized approach to the world [Creswell, 2007], and adopts qualitative research methods to build a detailed understanding of it. Given that emergent sharing domains are still a largely unexplored area, qualitative research methodology is the most appropriate approach to build a rich and comprehensive account of sharing practices within those domains, and to understand nuanced design characteristics of technology-mediated sharing. Furthermore, with mobile and tangible interfaces, it has become harder to abstract technology away from the context of use. This is why qualitative research is an appropriate instrument to study complex interaction between technologies and ways of life [Adams et al., 2008].

Due to the empirical nature of our research, we employ various data collection methods [Berg and Lune, 2004] including interviews, focus groups, observations, and open-ended questionnaires to reach the desired audience in their context. To design a research study, we use established theoretical framings and approaches such as grounded theory [Glaser and Strauss, 2009], ethnography [LeCompte and Schensul, 1999] and case studies [Yin, 2013]. To interpret the collected data, we often employ content and thematic analysis [Berg and Lune, 2004] and the affinity diagramming method [Holtzblatt et al., 2004] in order to surface emergent empirical categories that describe observed phenomena using participants' responses, behaviors, and observations. The data analysis process is always iterative and involves traveling back and forth between the literature, the raw data, and researchers' notes to reach what is called a "theoretical saturation" [Glaser and Strauss, 2009].

Our research methodology draws on contextual [Holtzblatt et al., 2004] and research through design approaches [Fallman, 2003; Zimmerman et al., 2007]. These approaches not only can help in understanding current needs and desires of users in real-world settings, but also illustrate how designing new interactive systems and artifacts can address those needs. In particular, we broadly apply the *technology probes* method [Hutchinson et al., 2003] to conduct field deployments. Typically, the probes we develop to study contemporary sharing practices use mobile and wearable application prototypes that act as a proxy to gather information through diary studies [Sharp et al., 2007] and empirical sampling methods [Sharp et al., 2007], and facilitate a critical dialog with participants about a sharing practice in question. The insights created within such constructive design research inquiries often generate new design knowledge in the form of design methods, implications and guidelines, and an intermediate-level knowledge between design theory and practice, (e.g., strong concepts [Höök

and Löwgren, 2012] and bridging concepts [Dalsgaard and Dindler, 2014]). Both have been considered as a specific, lasting contribution of design research to interaction design discipline [Höök and Löwgren, 2012; Zimmerman et al., 2007].

Moreover, following participatory design approaches [Simonsen and Robertson, 2012], we incorporate various stakeholders within our empirical studies as active partners in the design process to develop technologies and tools that support or inhibit contemporary sharing practices (e.g., see Section 5.1.5). This allows us to collect nuanced input from (and generate specific insights for) perspective users of our prototypes.

Finally, in addition to qualitatively-oriented empirical research, we complement our findings using quantitative research methods. We design and conduct online surveys, lab studies, and field experiments involving users. With the help of software packages (e.g., IBM SPSS [Field, 2013]), we utilize an extensive statistical toolbox: analysis of frequency, inference (e.g., ANOVA), correlation, and regression, as well as statistical modeling techniques. In some studies that we conducted (e.g., see Section 5.1), we have used SUS [Brooke, 1996] and NASA-TLX [Hart, 2006] questionnaires to understand the usability and cognitive load of the designed system.

Collectively, the combination of qualitative and quantitative research methods provided us with the necessary tools to address our thesis goals **(G1–G3)**. In particular, quantitative methods enabled us *to explore* the wide range of novel content sharing practices stemming from the advent of personal activity tracking **(G1)** (see Chapter 4), as well as contemporary physical sharing practices in the context of the sharing economy **(G2)** (see Chapter 6). What is more, quantitative research approaches allowed us not only to perform a formative evaluation of our research prototypes (e.g., see Section 5.2), but also to computationally model sharing behavior within the context of collaborative consumption (see Section 6.1). In turn, the wealth of qualitative research methods we employed in our empirical studies enabled us *to develop a rich and descriptive understanding* of the particular design characteristics that support the sharing phenomena across digital **(G1)** and physical realms **(G2)**, and to provide a nuanced account of how this knowledge could be translated for design practitioners **(G3)**.

3.3 Key Design Themes of Technology-Mediated Sharing Practices

To this end, in Sections 2.3 – 2.5, we comprehensively described prior work in HCI that investigates online content sharing practices, related studies of sharing economy services, as well as intersecting research in interaction design and domestic computing that looks into bridging digital and physical artifacts.

This section[1] further attempts to consolidate the existing body of work on both sharing personal digital content (e.g., social networking) and personal physical artifacts (e.g., apartment, car sharing) by asking a question: "How does the sharing of physical artifacts differ from online sharing practices of photos and status updates?" In particular, we aim in this section to unpack how the wealth of prior research in HCI on digital sharing can inform and inspire the creation of future sharing economy services and platforms. In order to do so, we attempt to map the design space between digital and physical sharing practices by comparing and contrasting their respective sharing spheres, i.e., digital and physical. Consequently, we formulated the two following research questions:

1. What are the key design themes that constitute technology-mediated sharing practices?
2. What are the commonalities and differences between sharing digital and physical artifacts?

We address these questions by surveying previous studies of digital and physical sharing. We systematically reviewed 87 papers published in major HCI-related venues throughout the last 15 years (a subset of which are described in Chapter 2). We additionally conducted 16 semi-structured interviews with design practitioners and domain experts in the sharing economy to develop a deeper understanding of specific design challenges of sharing economy services. We offer two main contributions: (1) a mapping of the design space between physical and digital sharing and (2) a descriptive account of the commonalities and differences between sharing digital and physical artifacts.

3.3.1 Background

Prior research identified peoples' socio-technical requirements across respective sharing spheres and outline attendant interpersonal and technological challenges

[1]The parts of this section is adapted from a paper published at NordiCHI'18 [Fedosov, Albano and Langheinrich, 2018].

(see Sections 2.3 through 2.5). In short, despite the fact that online sharing is a widespread practice nowadays, there are a number of issues end-users face, such as (a) managing access to shared content [Voida et al., 2006]; (b) self-presentation to multiple audiences [Voida et al., 2005; Vitak, 2012]; (c) larger concerns of privacy [Ahern et al., 2007; Raij et al., 2011]; (d) trust in a sharing service [Beldad and Citra Kusumadewi, 2015]; (e) security [Consolvo et al., 2005; Lange, 2007]; and (f) avoiding information oversharing [Dalal et al., 2008]. A number of research efforts suggested different ways to address those challenges. Namely, to reduce user interface complexity, to introduce granular access controls mechanisms over shared content, and to target selective audiences [Lange, 2007; Smetters and Good, 2009; Voida et al., 2005; Whalen et al., 2006].

We argue that many of the challenges and issues that are inherent to digital online sharing (e.g., intricacies of access control, ramifications of self-presentation, and privacy burdens) are also highly relevant for the sharing of real world artifacts in the context of sharing economy owing to the fact that their digital representations are mediated by an online platform. What is more, prior research on sharing economies demonstrated that the design of online platforms play an important role in establishing interaction among peers [Raval and Dourish, 2016], affect end-users' behavior [Lutz et al., 2018], influence their decision-making [Edelman and Luca, 2014; Ert et al., 2016], and may have a profound effect on the endurance and growth of resource sharing communities at large [Lampinen et al., 2015; Mosconi et al., 2017]. Nevertheless, due to the lack of comprehensive and descriptive mapping between digital and physical sharing, we see the value to establish a common frame of references for designers. This creates an opportunity to charter the design space for technology-mediated sharing practices.

3.3.2 Study Design

In order to understand the key design themes that constitute technology-mediated sharing, we performed a systematic literature survey across eight broad sharing practices identified in prior work: (1) file sharing; (2) photo sharing; (3) sharing videos; (4) music sharing; (5) sharing in social media; (6) sharing locations; (7) sharing personal biophysical information; and (8) sharing physical artifacts in the context of sharing economy services. Even though the different practices of sharing that we selected might seem to be categorically at different levels, they broadly cover digital and physical sharing spheres. Hence, exploring those eight practices helped us to understand their constitutive activities and their relations among each other. In our study, we aimed to include both seminal and recent

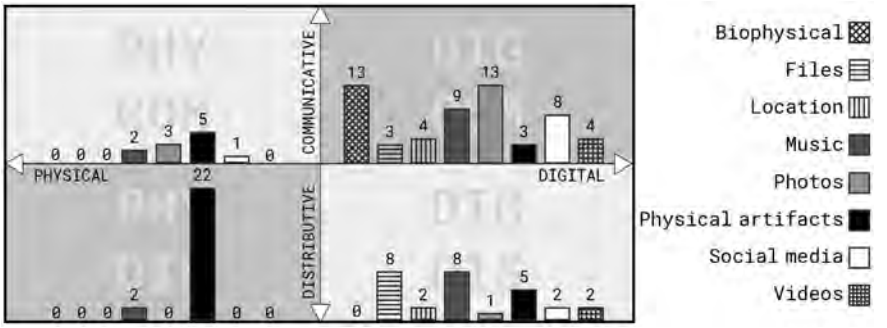


Figure 3.2. The overview of our data corpus. Each paper is classified within digital and physical medium where sharing occurs, and communicative and distributive logics of sharing. The detailed list is maintained at `https://doi.org/10.6084/m9.figshare.6960509.v1`

works on sharing (a subset of which we discussed in Chapter 2) within the HCI and CSCW communities and beyond.

Following a methodology suggested by Dillahunt et al. [2017], we built a data corpus of studies that examined various contemporary sharing practices of both digital and physical artifacts. Initially, we identified the most cited papers on "sharing" using both the ACM digital library (`http://dl.acm.org`) within key conference proceedings (e.g., CHI, CSCW, Ubicomp) and journals, as well as Google Scholar (`http://scholar.google.com`). Subsequently, by reading the papers' abstracts, we excluded articles that were not aligned to our goal of identifying the key design themes, or which had no clear methodology or data collection process described. For the remaining articles, we additionally looked into studies that cited those works and applied our above-mentioned selection criteria. The final amount of papers that we included in our data corpus was 87. We then classified articles along two dimensions (see Figure 3.1): the principal medium of sharing (physical vs. digital) and the logics of sharing (*communicative* vs. *distributive*) [John, 2013]. It is important to note that after performing this process iteratively, the studies of digital sharing practices were dominant in our data corpus. Figure 3.2 presents an overview of the included publications in our data corpus. Note that some articles cover multiple dimensions, hence the final count is greater than 87.

Next, following Epstein et al.'s [2015] design framework, we reviewed each paper from the corpus focusing on *what* people share, *to whom*, *why*, and *how* sharing takes place. Two researchers on the team employed open-coding and

axial-coding techniques from grounded theory [Glaser and Strauss, 2009] to analyze the data thematically. At the inception, we coded 10% of the data set independently across our core sharing questions. Subsequently, in two code-adjustment meetings, we iteratively reached agreement on the final coding tree that was later used to code the entire data set. The team met every week going back and forth between the data, the researchers' notes, and the emerging structure of empirical sharing dimensions, which we developed through the recurrent reading of the material [Miles and Huberman, 1994]. We also held meetings with researchers outside of the project to challenge our assumptions and to corroborate our empirical categories. Subsequently, we identified five top-tier themes and eights sub-themes (see Figure 3.3) that we used as a point of comparison to find similarities and differences between sharing digital data and sharing physical things. For this purpose, drawing on content analysis methodology [Glaser and Strauss, 2009], we revisited our set of papers and counted occurrences that corresponded to our coding tree.

To further our understanding of these numerical findings, and to develop a richer account of physical sharing practices (which has received less attention from HCI research, see Figure 3.2), we engaged with 5 sharing economy domain experts and 11 design practitioners (16 people in total, 11 were female, all used sharing economy services actively) in semi-structured interviews. The average age of the participants was 31.3 years old ($SD = 3.6$). We were particularly interested in recruiting designers and domain experts not only to elicit their personal experiential accounts of participating in popular sharing economy services, but also to collect their professional reflections on developing and running such services. The goals of the interviews were twofold: (1) to better understand nuanced characteristics of contemporary sharing economy services within the previously identified five top-tier themes and (2) to identify challenges end-users face while interacting with such sharing services to, ultimately, inform the design of future sharing economy services (see Section 7.1).

We recruited participants through our extended professional network. After having collected participants' demographic information and established a common frame of reference around the sharing economy phenomena, we then inquired about one sharing economy service that participants had the most experience with. We first wanted to elicit their personal experience with this service, therefore we asked for instance "Can you describe what have you shared in this platform? Have you had any concerns about sharing this?". Consequently, we collected their professional feedback about that service. For example, we challenged designers: "According to you, what are the key user experience requirements in this platform? How have designers tried to meet them?". For sharing economy experts, we

asked: "Can you describe the main motivations to participate in this sharing economy service for both peer-producers and peer-consumers?" For those who had experience running a service we further inquired about the biggest challenges they had faced to establish a new service. The interviews were conducted using Skype, lasted about one hour each, and were transcribed verbatim. We adopted a deductive coding approach [Miles and Huberman, 1994] in order to corroborate our insights from the content analysis.

The results reported below, firstly, describe five main themes and eight sub-themes that emerged from the analysis, and secondly, outline similarities and differences between digital and physical sharing practices. For each (sub-)theme, we present illustrative examples that help capture detailed characteristics of contemporary sharing economy services and illustrate their ongoing design challenges using participants' quotes from the interviews. We use pseudonyms to describe study participants.

3.3.3 Comparative Analysis of Technology-Mediated Sharing Practices

Our literature survey identified five key themes within our data corpus: (1) shared content; (2) audience management; (3) motivations to share; (4) privacy and trust issues; and (5) user experience requirements. In spite of their simplicity, we argue that these themes can serve as a point of departure to understand similarities and differences between sharing digital and physical artifacts. Drawing on Epstein et al.'s work on social sharing in personal informatics [2015], we identified several sub-themes within both the **Content** and the **User Experience** theme. Collectively, our themes and sub-themes constitute 13 dimensions of sharing (see Figure 3.3).

To arrive at these dimensions, we clustered a total of 1212 codes into 68 groups that uniquely describe one aspect of sharing, for example "sharing for self-expression". For each sharing dimension, we report the most representative groups with its relative values counts (in percentages within their respected sharing sphere, i.e., digital or physical). Relative values were calculated as the sum of the code-occurrences of one sharing group within a sharing sphere (i.e., digital or physical), over the number of groups in the category. The detailed results (per each distinctive group) of the analysis are included in Annex A.

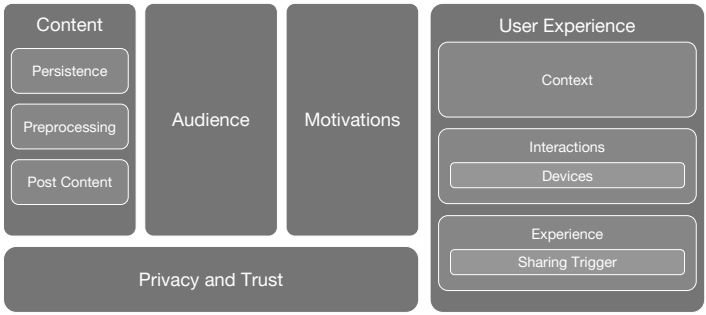


Figure 3.3. Sharing dimensions emerged from the data analysis. Five key design themes represented in the darker shades.

Content

The **Content** theme refers to the type of the shared artifact. It addresses the question: "What is being shared?"

Sharing practices for digital and physical artifacts may involve content of diverse nature. We distinguish three levels of materiality for shared artifacts: (i) material with a physical presence; (ii) immaterial with defined representation or form (e.g., digital files); (iii) immaterial and abstract types of artifacts with no defined physical form (e.g., knowledge). Sharing digital information involves only immaterial content with defined representation, usually files in the form of digital imagery (50% of all digital shares in our data corpus) and status updates in social media or in instant messaging apps (50%). In physical instances of sharing, material artifacts are the most frequently shared (60% of all physical shares). These include houses, cars, personal goods, electronic devices, and their digital representations. Worden, 32, explained the diversity of content shared using Airbnb:

> *"On the one hand, it is a physical space that is being shared that is makes flat or house accessible or the room within a flat, on the other hand, it is the whole data layer about the users themselves and the byproduct of their interaction with the platform."*

Julie, 27, pointed out that Airbnb since extended their offerings to different types of services (23% of all physical shares):

> *"Airbnb launched other kind of products besides accommodation, they are expanding the things they offer. It's a new category called 'experiences' where you can find other stuff, not houses, you can book tours, excursions, dinners, maybe even a yoga class at the Himalaya, it's a different type of content."*

Persistence The *Persistence* sub-theme refers to the lifetime of an artifact. It addresses the question: "For how long is a shared artifact visible or available?"

While both sharing practices can be time constrained, the enforcement mechanisms can be different. For instance, 80% of the digital instances of sharing can be regulated by a system's capabilities, such as the maximal display time of a piece of content on top of the personal timeline in a social media platform. In contrast, the practice of sharing physical artifacts is frequently determined by a sharer (62%), such as in the case of renting apartments through Airbnb, as illustrated by Julie, 27:

> *"Some [flats] are available for immediate booking, but on others you have to indicate you are interested in booking the place and the host evaluates it, and you exchange comments or messages with each other [to reach an agreement]".*

Preprocessing The *Preprocessing* sub-theme describes the amount and the type of work done on the content prior sharing it, and outlines how much a platform assists in performing these tasks. It addresses the question: "Which transformations are being applied to the content before sharing it, and have they been carried out automatically by a system or manually by its users?"

In our data corpus, there is a large amount of manual preprocessing work involved in sharing physical artifacts and services (e.g., rides), suggesting lack of automatic tools to accomplish the most frequent tasks (92% of all physical sharing). Pierre, 37, listed few manual tasks to find a companion for a ride:

> *"App is not the main communication tool after you establish a contact with your passenger, I used SMS, phone or another messenger to sync on certain details. The service did a great job to find a travel buddy. Basic conditions were agreed within the app: I tried to get people who speak [the] same language, but small details were arranged on the phone... at 5am I prefer to call [the] person directly to confirm the pick-up".*

In our data corpus, we observed a prominent difference in the type of manual preprocessing that takes place in physical and digital sharing. For example, the

main form of manual processing in the context of photo-sharing is related to naming, tagging and captioning pictures (55%). With physical artifacts, common tasks are instead related to their maintenance (25%), grouping and linking supporting digital content (e.g., making announcements or creating albums) (50%), as well as editing it (17%). Danny, 31, recalled his recent experience with Airbnb:

> *"Sometimes the owners do a good job in describing the place with text and pictures. Sometimes those pictures are too good, I think this [indicates that] something could be wrong with the property, if the pictures have being photoshopped or they used wide-angle camera... if the text is too well-written."*

This observation suggests that an overly polished description may be interpreted as suspicious or non-reliable.

Post Content The *Post Content* sub-theme refers to the format of the shared information. It addresses the question: "What form or shape does the content take in order to be shared?"

In our data, this sub-theme illustrates a similar characteristic among the sharing of digital and physical artifacts. In the digital sphere, people not only share digital "things" such as images or music (51%), but also digital information about real-world events, such as free-form status updates (29%) and contextual activity information e.g., workout summaries, or GPS tracks (20%). Sharing of physical artifacts or services, e.g., home repairs, IT support, or tutoring, always involves such digital descriptions about an object (e.g., an address where it is located) or a service. Note that while in some popular platforms, including Airbnb, the content of those listings are carefully curated, Jehanna, 31, mentioned that information does not even need to be explicitly advertised at all in order to get a service, like a city tour:

> *"I got in touch with another Couchsurfing user who didn't offer his house, instead he offered a tour of the city. That's another way to use Couchsurfing, users don't necessarily need to offer their houses, they may offer social encounters. I met this guy who paints, I was interested because I paint as well, it was a good experience, he took me to dance salsa, he showed me his studio, and told me facts about the city, we shared a one day experience".*

Audience

The **Audience** theme describes the recipients of the shared content. It addresses questions like "To whom is the content being shared and how is it being communicated?"

In our data, we found a visible difference between digital and physical sharing: most instances of digital sharing are targeted towards friends and family (43%) or with their extended circles, which include co-workers and classmates (25%). Conversely, physical sharing practices in the sharing economy typically target unknown people (43%). While sharing physical artifacts (e.g., tools) sometimes happens within interest groups such as makers (32%), Morten, 33, criticized the lack of community when interacting with a typical sharing economy platform:

> *"Airbnb somehow seems like making a strong connection between an owner of the apartment and the user, but currently it misses the community dimension between users who rent those apartments."*

Unlike in the digital environment where sharing is usually targeted to multiple users at once (73%), most of the time people share physical artifacts or services to one individual at a time (73%). However, there are examples of physical sharing with more than one receiver (such as the sharing of tools, or spaces).

When it comes to communicating the information about the shared artifact or service, Dacie, 35, emphasized the importance to involve multiple stakeholders to support a transaction on a sharing economy platform, especially when their involvement is crucial to the outcome of that transaction:

> *"I had an excellent experience communicating with our host (Lilly). However, since she is not fluent in English, she has to ask her daughter to reply [to our messages], so there was some waiting involved in the process (half day or a day). [The platform] may also CC our conversation to her daughter [in order] to get her involved directly."*

What is more, Delora, 32, reaffirmed the importance of community-building by maintaining multiple communication channels based on her own experience running a sharing economy service:

> *"[In our platform] a user buys meals that someone else is cooking. We have different communication channels, one of them is [a] chat with a cook, Q&A . . . We're trying to create a cooking community and let users to create new discussions through our platform."*

Danny, 31, reflected on the aspect of temporality regarding post-transaction communication:

> *"The owner was trying to identify who had smoked in the unit, by sending messages through Airbnb. The property was checked-out ok, nothing was broken. I don't think that's OK to send messages after our departure. There should be something like a [departure] contract: as soon as you sign it, we are done. I should not take responsibility for someone else."*

This quote illustrates the potential of ephemerality of the shared data to play an important role in managing online disclosures at large.

Motivations

The **Motivations** theme describes what drives people to share. It addresses the question: "Why is the content being shared?"

One of the most notable differences between digital and physical sharing practices lies in its motivations. Motivations for sharing physical artifacts are highly instrumental, such as to earn money or to get things done (41%). Thus, economic and practical needs are the most common reasons to engage in this type of sharing, which is usually not the case in the purely digital context (7%). Worden, 32, elaborated on reasons to engage with Airbnb from a supplier and a consumer side:

> *"For those hosts that are doing it full-time professionally it is clear – monetary incentives are the most important motivations, especially if they are renting an entire apartment. If they are renting a room within a place, it may be more about the community and experience. On the guests' side, it can be more diverse."*

Purely digital instances of sharing are largely motivated by self-expression and enjoyment needs (24%). Sharing for the purpose of social connection is a strong motivating factor in digital sharing (23%), yet it has a limited presence when it comes to sharing physical artifacts and services (10%). Despite that, Rebecca, 26, used ride-sharing as an example of a physical sharing practice that may create new social ties:

> *"There's also the social bond that one is able to build in these practices, I believe it's a different idea, another culture of transportation, you may meet really interesting people, not the usual taxi driver."*

In addition to that, both physical and digital sharing practices are motivated by aspirations of self-development. However, these pursuits often have different meanings. In digital sharing, they are largely related to identity construction

(21%), whilst in physical sharing they relate to personal and community development (28%). Gladys, 30, reflected on the importance of both based on her own experience using a bike sharing service:

> *"I want to be a user and personally I would like to participate in their organization from some other angles as well: for example to clean the bike and to protect it a bit [from being stolen]... also to say 'Look, that's a bike I use, it is my bike', not really mine but you know... I would feel much happier... somehow this aspect of community[-making] around bikes is missing there [for me]."*

Privacy and Trust

The **Privacy and Trust** theme relates to people's desire to control information dissemination. It addresses questions such as: "How do users feel about privacy and trust issues when deciding to share, and how does it affect their choices?"

People have a number of privacy concerns regarding the sharing of their personal information, most of them can be drawn around people's self-presentation online (43% of all digital sharing) and disclosures to the undesired audiences that could get access to the shared content as a result of sharing personal details too widely (28%).

Within our data corpus, people that participate in sharing economy services were not broadly concerned about these issues (40%). In the same way, Worden, 32, suggested that convenience outweighed his privacy concerns when he decided to sign up to Airbnb:

> *"My biggest concern was when I had to scan my passport for verification purposes. I wanted to be a verified user, so I would have easier time finding a place if I needed one. That's a very personal document, it was the moment when I was quite skeptical... but in the end I just signed up and hoped for the best."*

What seems to be more relevant in sharing economy services is a trust in the recipient or the community where sharing takes place (40%). Bobby, 33, discussed the use of reputation review systems to improve the trust within a platform and its participants:

> *"I believe all these tools to build and show a reputation are there to mitigate potential issues of trust. If I see 300 people stayed in this house and everyone says 'it's OK' and they are all happy with the experience, well... if nothing bad happened to them, why would it happen to me?"*

Furthermore, Aubrey, 30, reflected on the privacy trade-offs that users have to make when deciding to participate in a sharing economy service:

> *"Considering that you can link [your profile] to the Facebook account, some people may not like it, but it is a way to make a person accountable and to be secure that you are that person... you can't be anonymous in this regard: one has to accept that the name and the age will be visible to others. You are part of the service. You have to be a part of the [online] community. It's hard to protect this kind of information in sharing economy. You're part of the transaction."*

User Experience

The **User Experience** theme concerns aspects of a user's internal state, the characteristics of the interaction, and the context where interaction between the user and the system occurs. In addition to those upper-level categories, we also explore two sub-themes: devices that support sharing, and sharing triggers that initiate an interaction.

Context, Interactions and Experience The *Context, Interactions* and *Experience* sub-themes examine how users share, and how they experience the activity. They address questions such as: "What are the circumstances in which they are involved?" and "What is the state of a user before, throughout, and after using a sharing service?"

While user experience is a complex phenomenon, our participants (i) evaluated the role of positive and negative experiences with a sharing service; (ii) argued for the value of contextual feedback; and (iii) emphasized the importance of addressing users' information needs. Jehanna, 31, illustrated that by simply reading reviews of a host on a room-sharing platform could save her a lot of time and effort:

> *"I created my Couchsurfing account during a trip, so I didn't look too much. I was heading to Amsterdam and I saw someone offered a place to stay, I got in touch with him and ended up staying at his place, but then I noticed he had a lot of bad reviews, I saw it at the end of my stay. My experience was not good."*

Furthermore, our participants valued effective and efficient interactions with a platform when actual sharing takes place. For instance, Worden, 32, outlined the importance of the instant in-situ feedback feature:

> *"I think hotels.com, they send out these surveys immediately after you checked-in, asking how was it, how was the location – a very quick user survey. Airbnb does not provide that immediate feedback that you can give during the transaction while you are staying at the host's place, especially when he or she is physically not present [there]... like problems with electricity or noise."*

Danny, 31, while reflecting on the Airbnb web interface, brought up the benefit of concierge-like personalized recommendations that is currently absent from commercial sharing economy services:

> *"The designers could leverage the available information on amenities and transportation through existing services out there: Google Maps and Yelp. Pull that and use it in a platform interface. [One can show] the most important aspects of this information and prioritize that for users, if there is a way to tailor it – better... like 90% of users care about transportation, 10% of users care about restaurants, can we give them that tailored experience?"*

Devices The *Devices* sub-theme refers to the type of an electronic device that supports sharing. It addresses the question: "What devices are used to collect and to share the information or artifact?"

Digital content often needs to be collected and/or created, and this process requires an electronic device (e.g., fitness trackers or mobile phones to collect personal workout data, or, simply, a digital camera to take pictures of a shared room). In digital sharing practices smartphones and tablets are the most used companion devices for both collecting digital content (49%) and sharing it (56%). However, to facilitate sharing of physical artifacts and services the rapid adoption of mobile phones (35%) did not overcome the use of personal computers (39%). Dacie, 35, contemplated on the use of multiple channels when she had to book an apartment on her trip to Iceland:

> *"We started to communicate through the mobile [app]. However, when we were about to leave the place, we used email to agree about how to hand back the keys."*

Sharing Trigger The *Sharing Trigger* theme describes the event that initiates sharing. It addresses questions like: "What causes the information to be shared?" and "Is it automatically or manually shared?"

Users engaged in sharing digital content and physical artifacts behave similarly with respect to the triggers that drive them to share. Sharers often initiate the sharing activity and determine its conditions by themselves. One interesting difference between two contexts of sharing is a number of shares that are requested by a sharee. For instance, the aforementioned case of Jehanna (see the Post Content subsection above), when she has proactively reached out to a "non-sharing" Couchsurfing user to give her a city tour. On the whole, "share-on-request" behavior is much more present in practices of sharing physical artifacts and services (32% versus 10% in digital sharing). Blanca, 30, explained the nature of the request mechanism in Airbnb and outlined potential challenges related to reliability and authenticity that can be associated with immediate responses:

> *"If you are the person who is looking for a flat, a host needs to approve [your] request... there are some hints [in the interface of a platform] like 'this person normally answers within a range of 6 hours... or even instantly'. However, this does not tell you if this 'person' [is] just a bot or not."*

Automatic triggers are common in digital sharing (21%). For example, work-out tracking apps can determine the exact time when a user finished her run and immediately after share detailed statistics (12%). Usually, sharing triggers in physical sharing are driven manually by the user (87%). Nevertheless, Morten, 33, suggested to consider some elements of automation in sharing economy platforms:

> *"One nice option would be, for example, when I am renting an apartment abroad, [the platform] could make me a reciprocal offer: 'Why would not you rent your apartment when you are away?' This [approach] can be used as enrolling process for new hosts."*

Collectively, these reflections not only outline the intricate boundaries of physical and digital sharing by mapping out the space for researchers in the area, but also establish frames of reference for designers who are working on sharing economy services.

3.4 Summary

This chapter described the conceptual boundaries of sharing and defined the scope of our research. We then introduced the research methodology that we

employed throughout this dissertation. What is more, this chapter outlined the results from our empirical study of technology-mediated sharing practices. In particular, drawing on the wealth of research on peoples' digital sharing routines (e.g., photo sharing, sharing on social media), we illustrated how this body of knowledge can be relevant to designers of future sharing economy services. We incorporated this knowledge by mapping the design space between digital and physical sharing practices. Consequently, this mapping sets an important foundation *for investigating how designers can specifically support technology-mediated physical sharing practices in the context of the sharing economy* **(G3)**.

To this end, we systematically analyzed prior work that broadly covered various technology-mediated sharing practices spanning from file sharing to sharing physical artifacts in the context of the sharing economy. Using qualitative research approaches, we synthesized 13 sharing dimensions that can be used for comparing and contrasting contemporary technology-mediated sharing practices. We aggregated those dimensions in five key design themes, namely (1) the diversity of shared content; (2) audience management; (3) motivations to share; (4) privacy and trust issues; and (5) user experience requirements. We additionally recruited 16 design practitioners and sharing economy domain experts for qualitative interviews to critically examine our key design themes. Based on both experts' reflections and reactions, and the synthesis form our empirical review of the literature, we elicited and discussed in-depth the commonalities and differences between the digital and physical sharing spheres. The five main differences are: (1) the shared content: sharing physical artifacts often encompasses not only the shared material object itself, but also the accompanying layers of (meta)data; in digital sharing, content is exclusively immaterial; (2) the recipients of a shared artifact: unknown audiences in physical sharing vs. family members and friends in digital sharing; (3) the motivations for sharing: physical sharing is often driven by economic and practical needs (e.g., getting monetary benefits), while digital sharing is largely guided by self-expression; (4) the substantial concerns of trust in physical vs. digital sharing; and (5) the sharing triggers: in physical sharing, a borrower proactively needs to express an interest in a shared artifact, while sharing digital artifacts is often initiated by a sharer.

The findings described in this chapter influenced our work in the following ways. The framing of sharing dimensions guided the design of our empirical studies to understand specific challenges in two emergent sharing domains, namely, the domain of personal activity tracking and the domain of sharing economy services. Through a systematic examination of the **Content**, **Audience**, **Motivations**, **Privacy** and **User Experience** themes in this thesis we, firstly, create in-depth

descriptive accounts of sharing practices within each emergent sharing domain (see Chapters 4 through 6), secondly, formulate a set of design considerations for design practitioners who aim to devise future sharing economy services (see Section 7.1) and, thirdly, partially validate those design considerations within designers' creative practices (see Section 7.2).

Chapter 4

Novel Content Sharing Practices Online

Following the conceptual framing introduced in the previous chapter (see Section 3.1), we first looked at communicative sharing practices in the digital realm. Today, a vast amount of user-generated and user-mediated content populates social networks. Prior research (see Section 2.3) has focused extensively on needs, practices, and concerns surrounding the sharing of photos and videos, textual information (e.g., status updates), and documents. However, in recent years, with the rapid adoption of wearable devices and specialized online personal tracking services, the scope of what is "shareable" has greatly increased. It comprises not only audio-visual content, but also preferences and tastes (e.g., playlists, food), physiological data (e.g., workouts), trips, and even information about and access to real-world artifacts (e.g., "couchsurfing").

The goal of this chapter[1] is *to provide a comprehensive account of common digital sharing practices stemming from the advent of personal activity tracking* (**G1**). In order to achieve our goal, we conducted a large-scale online survey study to understand challenges and requirements, and to elicit tools that support these novel sharing practices in the Web. The study was conducted in collaboration with the Unit of Human–Centered Technology (IHTE) at Tampere University of Technology (Finland).

We focused our investigation on six novel types of content: (1) music preferences and playlists; (2) travel plans and trip details; (3) details of physical exercises and sports activity; (4) digital representation and contextual metadata about real-world items such as rooms and vehicles (note for the purpose of this

[1]This chapter is adapted from papers published at MindTrek'16 [Fedosov, Ojala, Niforatos, Olsson and Langheinrich, 2016] and ECSCW'17 [Fedosov et al., 2017].

chapter we label this content category as "sharing economy"); (5) virtual artifacts in video games and virtual social worlds and (6) personal culinary and dietary preferences. The particular choice of content types is based on an initial literature review (see "Background" section below) and covers the wide range of online sharing services beyond traditional messaging and social media platforms. We deliberately left out popular content items such as videos, photos, documents and audio files, as sharing them has been studied widely (see Section 2.3). To the best of our knowledge, no study so far has extensively investigated and compared such novel types of shared content. For each type, we systematically asked participants what content they share, with whom, and whether they would like to share some content that a sharing service at hand does not provide.

We also wanted to understand what personal devices are currently being used to capture, record, and share those novel types of digital content. The question of device preference is particularly relevant in activities where the shared data is often created while being mobile (e.g., run logs or images). Contemporary mobile apps and online services broadly employ "social" buttons (e.g. "Tweet", "Post on Facebook"), which makes user-generated content easier to produce albeit harder to maintain. As a result, users may (a) develop a fear of oversharing, since many mobile sharing apps – after an initial setup – often share a user's activity automatically (e.g., workout statistics); and (b) lose control over information dissemination, as obscure access control and audience management mechanisms make it difficult to understand who can read what.

In sum, this exploratory study had three goals:

1. To unveil common practices regarding the sharing of novel types of content.
2. To identify common privacy concerns that frame the sharing of novel types of content.
3. To understand participants device preferences to support the sharing of novel types of content.

Drawing on research that looked at device preferences for everyday activities and tasks (see Section 4.1.3), we specifically detailed the third goal to understand the three following aspects when it comes to novel content sharing practices: (a) our participants' device usage; (b) their device selection criteria; and (c) perceived efficiency and ease-of-use of mobile devices compared to their desktop counterparts for a sharing service at hand.

After briefly discussing related work below, we describe our study design in detail. We then present our participants' practices of sharing different types of content, followed by our findings regarding privacy concerns and device prefer-

ences across the six content categories listed above. Finally, we conclude with design reflections on user control for novel content sharing services.

4.1 Background

A large number of studies on sharing in HCI focus on personal digital data, e.g., files, photos, and videos. We reviewed these research efforts in Section 2.3.1. Equally, wide attention is given to sharing textual information through social networking sites (see Section 2.3.3). Therefore, in this particular study, we extended our research area to the novel types of shared content. Our related work lies at the intersection of three specific research areas, which we briefly present next: (1) a set of nascent studies in HCI that looked at the novel types of content; (2) research on privacy concerns when sharing personal information online; and (3) studies of device usage for everyday activities.

4.1.1 Studies of Novel Types of Content

The content categories that we examined have been studied individually with different levels of attention. However, no study has of yet attempted to compare sharing across those different practices.

Sharing music preferences (i.e., not actual files, but things like playlists) has been studied extensively. Long before music streaming services became popular, Voida et al. [2005] studied how users share their listening preferences using iTunes. Silfverberg et al. [2011] studied how users employ "profile work" to shape their online profile in a service that automatically shares their played music with others. Expanding upon this earlier work, we focus on music preference sharing services that allow the sharing of self-made playlists with followers (e.g., Spotify).

Sharing travel information has seen somewhat less research. Aizenbud-Reshef et al. [2012] studied the sharing of travel information by interviewing employees regarding their willingness to share their past and future travel plans. Gretzel and Yoo [2008] studied how online reviews affect user travel decisions. We further examine this content category with the view towards privacy.

Sharing one's biophysical data (e.g., workouts) is probably one of the most explored categories among those we looked at. We summarize here the selected works, for a greater review of this research area, see Section 2.3.2. Of particular relevance to our research is the work by Ojala [2013] on motivations for tracking and sharing details of training routines and physical exercises in online sports

communities. Prior work confirmed that social sharing contributes to the overall user experience and enjoyment of workouts [Mueller et al., 2010; Munson and Consolvo, 2012]. A range of work also looked at privacy concerns [Klasnja et al., 2009], associated risks [Raij et al., 2011] and preferences [Prasad et al., 2012] regarding the tracking (and potentially sharing) of personal health data. Epstein and colleagues developed a social sharing design framework in personal informatics [Epstein et al., 2015]. Their work informed our categorization of biophysical and contextual metadata of users' workout routines.

A very recent trend is the sharing of physical possessions, initially rooms and apartments (e.g., Airbnb), but more recently also rides (Uber), cars (Getaround), and household items (Snapgoods). Several researchers studied such sharing economy services, in particular motivations to participate [Bellotti et al., 2015; Ikkala and Lampinen, 2015]. Lampinen [2014] studied users on couchsurfing.com, focusing on reputations problems among users of shared accounts. For a more in-depth overview of this research space, see Section 2.4. In this study, we examine peoples' experiences toward and extent of sharing digital representation of their physical items.

Somewhat more on the fringes lies the sharing of virtual goods in virtual social worlds (e.g. Second Life) and video games (e.g., World of Warcraft). Bakshy et al. [2009] examined an interplay of social networks and social influence in the adoption and transfer of user-generated content among friends and strangers in a massively multiplayer virtual world. Neustaedter and Fedorovskaya [2009] explored capturing and sharing memories through the medium of photos, conversation logs, diaries and landmarks in a virtual social world. Odom et al. [2014] investigated the emotional attachment to virtual possessions, including online game avatars. In turn, our study explore how users' share their virtual possessions.

Sharing information about food and dietary preferences has grown in popularity ever since Grimes and Harper [2008] described design opportunities in the spaces. Davis et al. [2014] investigated the design space for recipe sharing practices. We aim to expand upon these works by investigating users' concerns and needs when sharing their culinary preferences.

While the six different content categories we described here have thus individually been investigated with various degree of attention to sharing, user preferences and concerns were usually not the primary subjects of inquiry, perhaps due to the complexity and ambiguity of the phenomenon itself [Kennedy, 2015]. Our exploratory study suggests a possible direction to start a deeper discussion on sharing novel types of content.

4.1.2 Selected Works on Privacy on Social Media and Beyond

Olson et al. [2005] studied a person's "willingness to share" for various intimate information items – from personal statistics to health-related data – and indicated the importance of specifying correspondent privacy and access control preferences across different sharing groups. We adopted a similar methodology and asked our participants about their practices with respect to privacy settings for novel shared content. Wiese et al. [2011] added that "willingness to share" is also dependent on the frequency of collocation, communication, and the overall closeness of the sharing participants. While these studies informed our initial classification of personal content that people share, they nevertheless only inquired on participants' willingness to share a particular piece of information. In contrast, we focused on actual (self-reported) experiences of sharing individual types of content.

Our empirical categorization on privacy draws on a number of prior publications. Palen and Dourish [2003] described disclosure, identity and temporal boundaries as central characteristics of privacy management. Stuart et al. [2012] presented a "transparency framework" that articulates a continuum of identity from anonymous to a real name, which informed our selection of target audiences. As previous studies suggested, managing the audience to shared content is one of the key factors in service usage. In the era of asynchronous computer-mediated communication, users were able to express themselves in a carefully constructed manner [Vitak, 2012]. Currently users utilize various online services as communication channels to reach heterogeneous audiences, which may lead to unexpected privacy problems. These strategies to reach composite audiences have been described in the recent work by Sleeper et al. [2016]. For further details of the privacy challenges when it comes to audience management on social media (e.g., context collapse) and subsequent mitigation strategies (e.g., boundary regulations) see Section 2.3.3.

Our results indicate that designers of novel sharing services need to account for audience control, i.e., allowing a user to determine who sees what content. Our study unpacks this problem by eliciting the privacy needs and concerns for novel types of data, ranging from metadata about physical artifacts (e.g., apartments) to personal digital data (e.g., music preferences). Furthermore, we present four design themes stemming from privacy concerns across six novel sharing categories. These include findings around the strategies for both "audience limiting" (to prevent unwanted access) as well as "audience reaching" (to approach the wanted audience in its entirety) [Litt and Hargittai, 2016a,b]. To this end, our survey gathered responses on how users perceived the possibilities to control the audience of a shared content item with different devices.

4.1.3 Studies of Device Usage for Everyday Activities

Prior work has looked at internet use on smartphones [Tossell et al., 2012] and tablets [Müller et al., 2012], as well as cross-device and multi-device use for everyday activities and tasks [Jokela et al., 2015; Santosa and Wigdor, 2013; Kawsar and Brush, 2013]. Our research extends this work by focusing on device selection for sharing content, especially when it comes to novel content types.

Research on mobile internet use listed many problems and factors that challenge the use of mobile devices. Tossell et al. [2012] compared native apps and web applications on mobile, and observed a much wider use of native apps. Böhmer et al. [2011] described a large dataset on application use with mobile devices, also listing the most likely transitions between applications. Studies made during the time of early generations of smartphones listed convenience, mobility, input efficiency and readability as the main factors that affect their use [Karlson et al., 2009]. Karlson and others also found that mobile devices were often seen as a stopgap solution for situations when no PC was available. Kawsar and Brush [2013] conducted a mixed methods study on the use of different devices at home. They identified five key selection factors: screen size, portability, interaction available, always on, and usability. Their findings suggested that easiness to initiate interaction on the device often overcomes form factor drawbacks, especially in the context of social media use. Their work also argued that activity comes first and device next: a device selection is made to match the planned activity, and devices are changed even throughout a task in a home environment. That might not be the case outside a home, where device availability plays a bigger role. Our study further clarifies the reasons for device selection for content sharing activities.

A comparative study on the online use of PC's and mobile devices by Kane et al. [2009] suggested that similar services were used on both devices, but mobile devices limited service use because they had insufficient input and output capabilities. Bao et al. [2011] studied the use of mobile devices for content production. Their work discussed problems especially in text production, comparing subjective perception and real performance on text creation tasks with mobile devices. Today's devices, however, have more developed interface capabilities, and our work discover the current state of their usage for sharing novel types of content.

Müller et al. [2012] demonstrated the frequent the use of tablets in content production activities, and suggested that tablet devices are preferable to PCs and laptops due to their easy initiation and their convenient form factors. A

study by Santosa and Wigdor [2013] identified specialized use cases for different devices in a multi-device setting, and showed how multiple devices changed the workflows of users. Our study broadens knowledge on identifying the tasks that users perceive laborious with a certain device and discusses the device selections to access a certain sharing service.

4.2 Study Design

The selection of content types is based on our initial literature review and a pilot study. Drawing on the conceptual framing introduced in the previous Chapter (see Section 3.1), in this study we looked at communicative sharing practices in the digital realm. We initially followed John's descriptive account of sharing for Web 2.0 [2012] to determine what novel sharing practices represent communicative logic of sharing. We thus included such content types as food and music preferences, as well as travel plans or physical exercise data. However, in contrast to John's study, we purposefully excluded popular content sharing platforms such as social networking sites (e.g., Facebook) or instant messaging services (e.g., WhatsApp), as these are already well-covered by prior research. Furthermore, with the help of an initial benchmarking and a pilot study, we included two additional sharing categories, that is, virtual artifacts and digital representations of real-world artifacts, which we label "sharing economy". Please note that virtual artifacts, and even more so sharing economy services, may represent sharing as an act of distribution, although their digital representations (i.e., actual content) on the supporting platforms (e.g., Second Life, Airbnb) represent sharing as an act of letting people know (i.e. communicative logic).

The categories that we selected cover a large area of personal content and differ in several sharing dimensions. For example:

- type of audience or level of disclosed details (e.g., on one hand personal travel plans, and on the other hand often impersonal virtual artifacts in virtual social worlds);
- the medium to capture content (e.g., workout details are often captured using an app on a smartphone or a wearable device, in contrast to virtual possessions in videogames, which are often created on desktop platforms);
- mechanics of sharing. Some content items have to be manually selected in order to be shared (e.g., content related to travel plans or preferences of food), others can be continuously streamed online throughout a user

activity (e.g. activity tracking from workouts apps or music tracks played with music streaming services like Spotify etc).

Even though the different forms of sharing we selected might seem to be categorically at different levels, exploring sharing in different spheres helps us to unfold its "polysemic homonymity", i.e., its diversity of uses and logics (John, 2017), as well as better understand the novel sharing practices and their relations among each other.

4.2.1 Data Analysis and Methodology

For each of the six content types we selected, we created a set of survey questions to explore personal sharing practices, asked about privacy concerns that inhibit sharing, and inquired about device selection and usage throughout novel sharing practices. In other words, we explored the four following key design themes identified in Section 3.3: **Content**, **Audience**, **Privacy**, and **User Experience**.

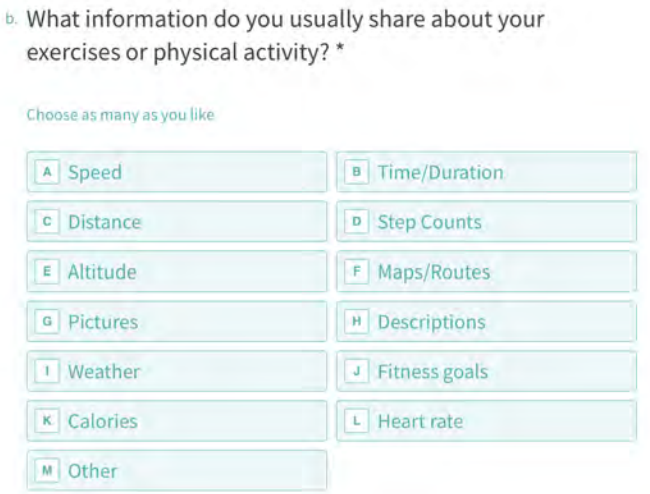


Figure 4.1. Examples of the content items for sharing workouts

In particular, to unpack the **Content** and **Audience** themes we followed the approach in Olson et al. [2005]: we first examined *what* content people share

per category, and *with whom* such sharing takes place. Participants selected several content items from a comprehensive list (e.g., see Figure 4.1 on page 54), which we extracted for each category from modern online sharing platforms and services. For sharing workout statistics, we examined popular smartphone apps like Endomondo, Runtastic and Sports Tracker; for food preferences sharing, we used the content from dish-finding apps such as Foodspotting and Yelp; for sharing music preferences, we evaluated music streaming (e.g. Spotify) and hosting services (e.g. Bandcamp); for sharing travel details with others, we looked at TripIt; for the "sharing economy" category, we used services such as Airbnb and Uber to build content items; and for the "virtual possessions" category, we looked at several examples of virtual social words and game platforms that afford sharing digital artifacts. Participants were also able to provide their own examples in an "Other" text field. Finally, we asked participants to choose those content sharing categories that they were most experienced with and specify the names of the corresponding services they were most familiar with.

After identifying the content items participants have experience with, we explored the **Privacy** theme. We subsequently asked more detailed questions about sharing these content items with a view to eliciting participants' corresponding needs and concerns. For example, for a participant that had shared their travel plans with others, we asked: "What are your main privacy concerns about sharing these personal details, such as travel itineraries?". We additionally asked participants to describe any positive or negative experiences sharing this information in a free-form text field. For *non-shares* we asked: "Why did you (so far) decide not to share that type of information?"

As for the **User Experience** theme, we aim to identify reasons for device preference across different novel sharing service categories. We collected their self-reported values of experience with each sharing service, as well as the frequency of access to the service using either a desktop/laptop computer, a smartphone, or a tablet device. In our analysis, we decided to combine smartphones and tablets into a single category (we label them as *mobile* devices) since their user interfaces are often rather similar. Furthermore, we asked the respondents to explain why they use a particular device(s) to access a sharing service. We also wanted to determine whether mobile platforms afforded an easier and more efficient sharing experience across different novel content types in comparison to desktop counterparts. Following Olson et al.'s [2005] study of preferences for sharing and privacy, we additionally asked participants how easy and efficient their experiences were with configuring privacy settings for a shared content item using a mobile and a desktop device. We only asked participants about sharing services that they had actually used before.

Qualitative analysis process

To analyze all open-ended survey questions, we use the thematic analysis technique [Berg and Lune, 2004]. At first, three researchers on the team independently coded answers using content analysis from grounded theory [Glaser and Strauss, 2009] searching for emergent patterns (e.g., factors for device selection to access a sharing service or common privacy concerns across our categories). In addition to counting instances of each factor, we also collected participants' quotes to support each factor of a given theme. Our analysis followed an iterative process that repeatedly revisited the data, the researchers' notes, and the emerging structure of empirical categories (which we developed through the recurrent reading of the material). Regular meetings were set to interpret the findings and discuss differences and overlaps of the identified content categories until we reach consensus for each aggregated dimensions. We invited researchers external to the project to several of these meetings in order to receive a critical review of our assumptions and the themes categorization. Finally, two researchers created affinity diagrams [Holtzblatt et al., 2004] to reveal connection among themes and elicit privacy- and device-related design and research opportunities in this emergent space.

Quantitative measures

When it came to the quantitative analysis, we applied correlation analysis and non-parametric statistical tests to analyze the reported device usage practices and level of experience with a sharing service. We established the following quantitative measures in our study:

- **Level of Experience with a Service.** We asked participants to self-assess their level of expertise with a sharing service and choose the most appropriate category: "Novice", "Advanced beginner", "Intermediate user", "Advanced user", and "Expert user". We adapted the Dreyfus model of skill acquisition [Dreyfus and Dreyfus, 1980] to assess a participant's level of expertise with a service.

- **Device Usage to Access a Service.** We asked participants to estimate their device usage to access a content sharing service on the scale from 0 ("Never used") to 10 ("Always use/used") for a desktop or laptop computer, a smartphone, and a tablet, respectively. Additionally, participants could indicate whether they use any other device with a sharing service and provide a correspondent score.

- **Usability Scores.** We measured subjective efficiency and ease-of-use of a device, since perceived criteria are often relevant to the users' decision whether or not to use a service [Davis, 1989]. To measure perceived ease-of-use and efficiency of a device to access a particular sharing service, and to change correspondent privacy and access settings for a shared content item, we used 7-point Likert scales, e.g., "It is easy to change privacy settings for a shared item in this service using this device" for ease-of-use, and "It is fast to change privacy settings for a shared item in this service using this device" – for efficiency, respectively. We asked participants to indicate their level of agreement on the scale from 1 ("Very hard/slow") to 7 ("Very easy/fast") for both mobile and desktop devices. Each participant in our sample reported prior experience with at least one of the two platforms to access a content sharing service. Therefore, we asked these questions about their actual experience.

4.2.2 Pilot Study

We recruited 14 participants for an initial survey pilot using a snowball sampling strategy. We initially reached out to colleagues from our respective universities, we then asked for their recommendations whom to approach next. Each pilot survey variant focused on only one category, and each participant possessed some previous expertise in sharing content within the category assigned to him or her. Nine participants took part in a face-to-face feedback session after completing the survey; the other five participants provided feedback via E-mail. General feedback included suggestions about optimizing the flow of the survey, to create a comprehensible narrative for an interviewee, and to keep a participant reminded about the section in question. After the pilot feedback, we decided to simplify the initial categories selection, arriving at our final set of six content types: (1) music preferences and playlists; (2) travel plans and trip details; (3) details of physical exercises and sports activity; (4) digital representation and contextual metadata about real-world items such as rooms and vehicles (note for the purpose of this chapter we label this content category as "sharing economy"); (5) virtual artifacts in video games and virtual social worlds and (6) personal culinary and dietary preferences.

4.2.3 Study Participants

We launched our online survey in spring 2015 and collected data for three months. We particularly wanted to use an online survey as a method for collecting data

since it can cover a diverse sample of sharing and non-sharing populations. We used Typeform (`http://typeform.com`) to administer the survey, as it featured a modern design and a responsive (i.e., cross-device) interface. We distributed the survey URL through social media channels, mailing lists and forums, personal contacts, and by distributing printed flyers in our respective universities. The response rate was 26%. Participants who completed the survey were able to win one of 10 Amazon 40-Euro vouchers or one 100-Euro voucher. Our data cleaning process included the following strategies: removal of incomplete responses and duplicates, identification of "straightliners" (i.e., respondents who consistently choose the same answer in order to more quickly complete the questionnaire), identification of inconsistent responses (we specifically asked some questions more than once), and removal of senseless responses (e.g., gibberish, cursing) for the open-ended questions.

Consequently, we collected 256 responses from 246 participants in our online survey. Note that multiple responses were possible per participant if a respondent had prior experience with more than one sharing category. Exactly 200 responses described participants' previous experience on sharing content in one (180 participants) or with exactly two (10 participants) of the six categories we listed (see Table 4.1), while 56 participants did not have any such experience. For those without any experience, our online survey form branched to a single free-form text field, asking them why they did not yet use such services. All 56 provided this information, which helped us understand the privacy concerns and needs of non-sharers. Table 4.1 describes the survey demographics on all six content sharing categories, as well as for the 56 non-sharers. Of the 190 respondents who indicated prior experience, 63% were male and 37% were female, with the largest age group being adults of 25–34 years. Their occupations spanned a wide spectrum, including ICT jobs, researchers, educators, marketing professionals, and students; 84% of them have academic degrees (Bachelor, Master, or PhD). Participants were actively engaged in use of digital technologies, highly valued usefulness of technology in their lives and considered themselves skilled users of digital media and online communication tools. Note that 10 participants who completed the survey more than once are listed in Table 4.1 as an independent instance in a respective sharing category.

4.3 Findings

We first report statistics and other general findings for each content category, while outlining differences and similarities of target audiences across the categories.

	Music Preferences	Travel Details	Physical Activity	Sharing Economy	Virtual Possessions	Culinary Habits	Non-sharers
Avg. age	25.9	28.4	31.4	28.6	35.3	26.6	31.3
Nr. males	47	22	22	11	14	9	31
Nr. females	20	25	11	10	4	5	25
Total Nr.	**67**	**47**	**33**	**21**	**18**	**14**	**56**

Table 4.1. Participant demographics for our novel content sharing study

We then report our participants' privacy needs and concerns. Ultimately, we identify device usage and selection criteria across the categories, and statistically determine whether mobile and desktop platforms significantly differ in relation to ease-of-use and efficiency in supporting sharing tasks. We use pseudonyms to describe study participants.

4.3.1 Reported Experience with Sharing Novel Content Types

After collecting participants' demographic information we identified the content items they have sharing experience with. Figure 4.2 presents the aggregated data of 1263 sharing instances from our 200 "sharing" responses, across all six categories. In this figure, each inner cell in a table gives the number of participants that reported to share a given content item with the respective recipients. Multiple selections were possible. In addition, a participant could add items not covered in our set of choices using the "Other" text field (see Figure 4.1). To facilitate visualization, we clustered similar content items in categories: descriptive information, metadata, contextual data etc. Then we ordered the clusters (columns) from most to least shared, and color-coded them in darker shades for higher item counts. Participants indicated a variety of specific apps and services they use to access sharing services. Below, we report the number of participants who had experience with a particular service in brackets (we asked participants to pick the one service in which they had the most experience).

In the *music preference* category, most of the sharing happens with friends, followed by public sharing and sharing with other individuals. The most shared information was descriptive details, such as song title, record, and artist name. To share music preferences participants used frequently music streaming services, most often Spotify (23 participants) and YouTube (20). Some participants shared music preferences through Last.fm (8), Soundcloud (6), Deezer (1), and Shazam (1).

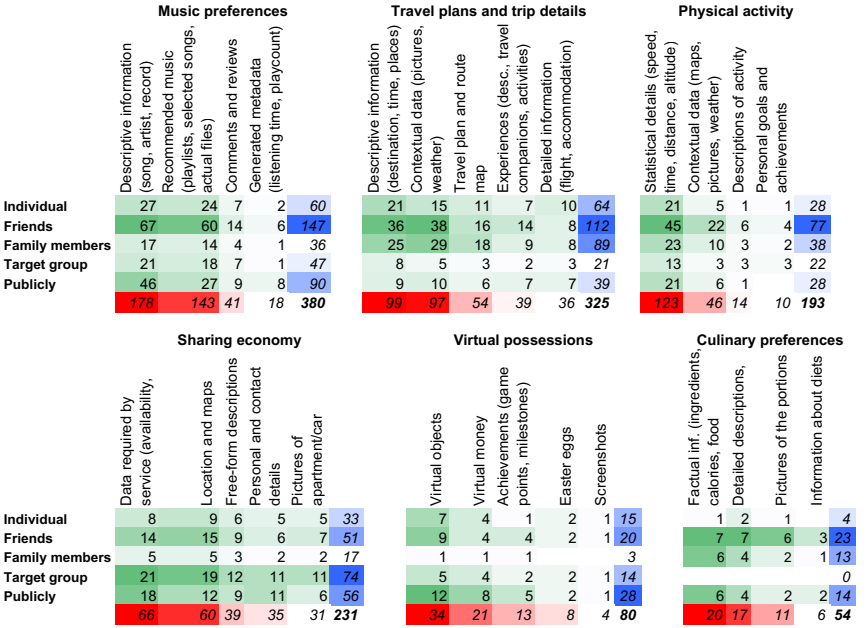


Figure 4.2. Aggregated table of novel types of content shared across different sharing categories

The most shared content in the category *travel plans and trip details* was pictures and names of destinations, followed by travel plans and descriptions of destinations. Recipients were mostly friends and family. Respondents preferred to share specific accommodation information mostly with individual recipients, though also sometimes disclosed this publicly. Targeted sharing to a certain interest group or community was the least selected option. To share trip details and travel plans, communication channels span from dedicated travel apps such as Trip Advisor (18 participants) or TripIt (2), to online social networks (13) and blogs (1), to Google Maps (9) and E-Mail (1). Participants also suggested creating tools to share other kinds of trip details, such as trip calendars, real-time HD videos, requests for locations, and consolidated trip journals.

Participants shared information about *physical exercises* (i.e., workouts) mostly in the form of duration, distance covered, and routes. Information such as heart rate, altitude drop or step counts was less frequently shared. Occasionally participants shared pictures, exercise descriptions, or general fitness goals. Physical

exercises are primarily shared with friends, than with family members. In some cases, people opted to share data both with individual people and publicly. Sharing with target groups with a common interest was rare. To share information about their physical exercises (i.e., workouts), our participants used Sportstracker (9 participants), Endomondo (5), Runtastic (2) and Strava (2), and other services (15 participants). When asked if they would like to share some information that is currently not shareable with current tools, few named the ability to share detailed analytics, statistics, videos, or pictures of the exercises as missing from current tools.

Our *"sharing economy"* questions primarily asked about accommodation and car sharing experiences. Figure 4.2 on page 60 shows that a description of the item to be shared, its availability, as well as its location are among the most shared content, though the distribution among items is fairly even, including pictures, descriptions of conditions, maps, and contact details. Airbnb (6) and couchsurfing.com (7) were among the most mentioned services for sharing accommodation information. For car sharing services, most used BlaBlaCar (3) and Uber (1). Unsurprisingly, participants shared such details with targeted groups and/or publicly, rather than with friends or family members. This might also be because these services usually enable only sharing with all other service members, in order to give a wider exposure. Participants complained about certain artificial constraints imposed by these services in order to anonymize listings, such as not being able to share an external URL that would describe the item in more detail, not being allowed to embed video, or not being able to provide personal contact details to directly follow-up with interested parties.

The most shared items in *videogames and online worlds* were virtual objects and virtual money, both actively shared with specific target groups and publicly. The fact that family members are the least frequent sharing audience may stem from the fact that few of these games are played within a family context. Furthermore, participants would like to share videos and replays, as well as being able to export content from other services and virtual worlds. To share virtual possessions and objects in videogames participants reported the use of many online communities and games, most often Second Life (5), Steam (4), and Minecraft (2). Participants would furthermore like to share videos and replays, as well as being able to export content from other services and virtual worlds.

The least used category of information being shared among our participants was *food-related information*. Most participants reported sharing food-related descriptions and comments in this category, followed by pictures of portions and ingredients. Similar to music preferences, content in this category was most frequently shared with friends. This suggests that such information is considered

less private, but instead is used for self-representation and to actively engage with others. Foodspotting (3) and GialloZafferano (4) were the most frequently used service for food information sharing. Alternatively, participants preferred to share information about personal food and culinary preferences via social networking platforms (9).

In Figure 4.2 on page 60, we can see that information about trips and physical exercises are primarily shared with friends and family members, followed by individual recipients. They are only rarely shared publicly or with a specific target audience. Content from sharing economy services and virtual possessions from videogames and virtual worlds instead is shared with target audiences or publicly, less often with friends and individuals. This might also be owing to the fact that these services usually enable only sharing with all other service members, in order to give a wider exposure. Our respondents shared content from music and food preferences widely, both with friends as well as broadly to the public. This suggests that such information is considered less private, but instead is used for self-representation and to actively engage with others. Music-related preference data was only rarely shared with family members. None of our participants shared culinary and dietary preferences with specific target audiences.

Across all sharing categories, respondents most often shared factual and descriptive information around an artifact, an event or an experience, with an exception of online games, where the most shared item were virtual possessions. Contextual details such as maps, pictures and supplemental information are being shared moderately. Personal details are being shared less frequently, and the sharing of such details are usually dedicated only to some selected audiences.

Figure 4.3 describes the participants' level of expertise in the reported services. The majority of participants within each category rated themselves as "advanced"

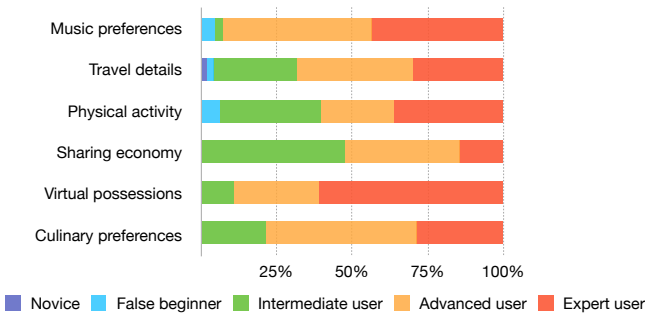


Figure 4.3. Participants' levels of expertise with a sharing service

or "expert" users. In the physical activity, travel details, and sharing economy categories, over 25% of participants rated themselves as "intermediates".

We conducted a quantitative analysis to find whether participants reported equal experience levels across all sharing types categories. A Kolmogorov-Smirnov test of normality did not confirm the assumption of normality for the independent variable "sharing category type". Non-parametric Levene's tests did not confirm the homogeneity of variance assumption among sharing categories ($p = .003$). Mood's median tests were performed with the reported "level of experience" – on a scale from 1 ("Novice") to 5 ("Expert") – as the dependent variable and "sharing type" as the independent variable. However, the analysis displayed no significant results ($\chi^2(6) = 11.853$, $p = .065$). This indicates that there were no significant differences across all categories for the reported experience level. In other words, participants reported similar levels of experience for all sharing categories independently, hence we can include all of them in the statistical analysis in the upcoming sections. This suggests that our observed population sample is representative with regard to experience with sharing services.

4.3.2 Privacy Concerns and Needs

The privacy concerns and needs that our 200 "sharers" articulated were mostly formulated around the concept of "content that is shared with a particular audience". However, some of our participants also mentioned privacy issues with respect to the actual service provider, in particular concerns about a less established provider (i.e., a startup) being acquired, or not being able to protect stored data to the same extent as a large company would. Please note that we neither engaged with nor explicitly offered a particular definition of privacy in our questionnaire, and thus our participants were free to interpret what privacy means to them.

When it came to concerns about the actual content being shared, our respondents were quite conscious about sharing information revealing their identity (such as phone number, email address, pictures):

> "*[Concerns?] None, as long as the game prevents real identity and "real world" financial data from connecting to the actual sharing/transaction with other individuals and vice versa.*" (Benny, 50, about sharing virtual possessions in a virtual world)

Additionally, participants also considered information that has embedded location in it to be critical (e.g., a home address, a map with a current location, a travel route). Some concerns related to a fear of being stalked, especially

from respondents that shared data about physical exercises, travel details, and accommodation listings:

> *"I realized that I had been inadvertently and unknowingly providing maps and times of day of my regular walking tracks and that I could not delete this information from the world. It showed my house and I felt vulnerable."* (Lillian, 35, sharing physical exercise data).

With respect to concerns about the recipient (audience) of a particular piece of information, our respondents stated three main issues: (1) that a particular individual or an unwelcomed group would gain access to the shared data:

> *"I don't like some specific persons [to] know about my ads."* (Steven, 32, sharing accommodation listing)

(2) concerns about misuse and violation of personal data as a result of fraud or safety issues (e.g., identity theft); (3) and acquisitions by a third party:

> *"This is why I no longer use a fitness tracker. I don't like wondering about who will get to use my data and why – one of the companies that had access to the data was purchased by another company I don't trust."* (Victoria, 49, sharing physical exercise data).

We also found that self-representation to the wider audience and disclosing personal details too broadly also contributed to privacy concerns of being misjudged or laughed at:

> *"There have been some cases when I've shared too intimate information to too wide an audience. I slightly regretted after sharing."* (Naomi, 28, sharing travels plans and details).

Olson et al. [2005] pointed out the need for various controls over content that would enable anonymous, coarse- and fine-grained sharing of details. Our findings confirm that this need also holds for novel types of shared content:

> *"I try to eliminate information that makes me concerned about privacy beforehand."* (Dianne, 23, sharing accommodation listing).

As anticipated, participants mentioned that audience control mechanisms should allow them to decide which audience can access shared content within a service. For example, having the ability to easily remove professional contacts from the list of recipients of a post would help with the following concern:

> *"Main concern is posting pictures of food during working hours, which may imply that I am not at work."* (Randolph, 34, sharing culinary preferences).

On the other hand, participants also mentioned their willingness to share openly information that would be beneficial to certain individuals and interest-based communities:

> *"[I'd share] information about a production of [certain] foods, and important [ingredients] that substitute meat and fish."* (Bertha, 26, sharing dietary habits).

Finally, users mentioned an issue with overly flexible privacy policies and mechanisms to protect their sharing choices:

> *"[I fear a] change of privacy policy that would allow a wider circle of people to see what I have shared without my consent."* (Jenna, 32, sharing travel plans and details).

Some of the aforementioned privacy needs and concerns were more present in one sharing category than another. Figure 4.4 describes privacy needs and

	Music preferences	Travel plans and trip details	Physical activity	Sharing economy	Virtual possessions	Culinary preferences	
Privacy concerns							
Misuse and violation of the shared data	1	10	2	1			*14*
Revealing identity and location	1	7	10	3		3	*24*
Unwanted access and unwelcome crowd		12	4	7			*23*
Acquisitions by a third party	2	1	1	1			*5*
Disclosure of personal details broadly	5	2		2	6		*15*
Self-representation to the wider audience	5	3					*8*
	14	35	17	14	6	3	**89**
Privacy needs							
Controls over the content	14	3	2	4	4	1	*28*
Access control mechanisms	4	10	1		1		*16*
Flexible privacy policies and mechanisms		1			1		*2*
Willingness to share openly	3				2	1	*6*
	21	14	3	4	8	2	**52**

Figure 4.4. Privacy concerns and needs of active sharers that inhibit sharing novel types of content

concerns on a per-content category basis. Each cell in the table gives the number of instances we encountered during our content analysis. Darker shades represent higher counts. We conducted a two-way contingency table analysis to test the dependency of these privacy concerns across different sharing categories, and found that there was a significant association – Pearson $\chi^2(25) = 84.661$, $N = 89$ and $p < 0.001$. Similarly, we found a significant association among privacy needs and sharing categories – Pearson $\chi^2(15) = 25.743$, $N = 52$ and $p = 0.041$.

Looking further into this, we found that concerns related to revealing one's own identity and location, as well as a need to control the distribution of shared content, were most crucial across all novel sharing practices online. Preventing unwanted access is most important for services that share travel plans, physical possessions, and biometrical data. Looking at the detailed list of content categories presented in Figure 4.2 on page 60, we can speculate about how specific content types prompt the needs and concerns listed in Figure 4.4. For instance, sharing pictures, location, and descriptive information could prompt privacy concerns about the misuse and violation of the shared data in "travel plans", while triggering fear of unwanted access in the "sharing economy" category. Sharing descriptive information about songs or self-made playlists ("music preferences") may entail concerns about being misjudged by others, while information about personal workouts may lead to concerns related to revealing one's identity.

We also prompted the 56 respondents that did not report any experience of sharing emerging content to explain the reasons why they decided not to do so (information in this paragraph is not shown in Figure 4.4). For 16 of them, this behavior related to personal safety and their preference for limiting the spread of private information. These reasons match our above findings on privacy concerns related to the misuse of the shared data and fear of revealing one's own identity or location.

> *"I don't share those [details] anywhere. I like to keep most of my things private, even when it requires some work. I share some stuff to my friends, but even that is really limited."* (Viola, 30, not an active sharer).

20 out of 56 "non-sharers" reported that they only share impersonal information (e.g. news, educational materials, useful tips), resonating with our findings on concerns over revealing identity and self-representation to a wider audience. Few participants found that sharing personal information offers no benefits to their community:

> *"It's information that none of my friends should have a practical use for. At times, I use such online services to keep track on my own, for myself. I*

> *don't consider my exercising private, just info no-one is interested in and thus I should not bother others with it."* (Javier, 27, not active sharer).

Furthermore, several participants were concerned about their data being acquired by a third party and required adequate control tools over their personal information to even consider sharing these novel types of content. Other reasons not to share such content items were related to their unoriginality. In other words, certain participants found that sharing their mundane workout routines or food preferences would not be of any interest to anyone within their social circles. Ultimately, some participants saw no personal gain in sharing their content at all. This finding indicates that within different circumstances those "non-sharers" may change their attitude towards sharing, hence it suggests a salient opportunity for designers of novel content sharing services to explore this space further.

4.3.3 Device Preferences

To illustrate participants' device preferences to support the sharing of novel types of content, we, first of all, report their device usage practices to access online services that facilitate the sharing of our six content sharing categories. We then identify device selection criteria across the categories. Finally, we examine differences among mobile and desktop platforms in relation to ease-of-use and efficiency in supporting participants' sharing tasks.

Device Usage Practices

Figure 4.5 describes the self-reported frequencies (mean values) of device usage for each sharing category. The reader can observe that services that support sharing physical activities are being primarily accessed using smartphones. Services that enable sharing travel plans and culinary preferences were equally used on desktop and smartphones, with a slight bias towards desktop for the former, and to smartphones for the latter. Sharing economy services and services for sharing music preferences were more often accessed using desktop interfaces than using a smartphone, and only rarely through a tablet. Nevertheless, combined *mobile* (smartphone and tablet) usage exceeds *desktop* usage in all sharing categories, except sharing virtual possessions (see Figure 4.5). Videogames and virtual social worlds services suggest that sharing is done primarily using desktop platforms, which offer more gaming performance.

In addition to smartphones, several participants who share information about their physical exercises reported the use of a complementary sports gear, such as

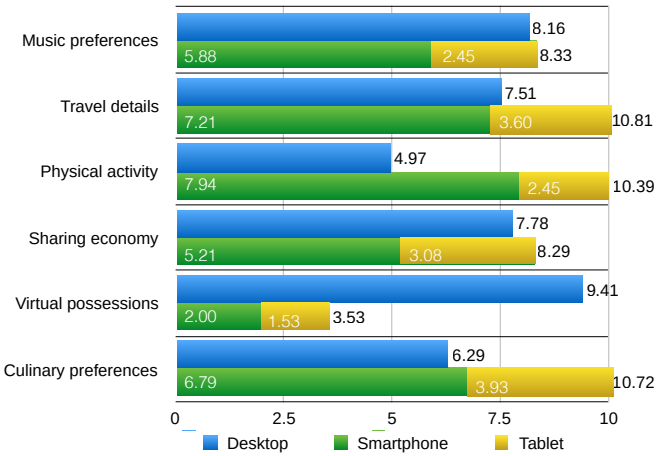


Figure 4.5. Reported device usage for each sharing category on the scale from 0 ("Never used") to 10 ("Always use/used").

smart watches and heart-beat monitors to collect, and, subsequently, share their personal experiences. A number of participants used smart TVs and game consoles (e.g., PlayStation) to share their music preferences. However, the reported usage was marginal and we consequently excluded them from our analysis.

Device Selection Criteria

To identify device selection criteria, we conducted a thematic analysis (for a more detailed discussion on how the analysis was performed see subsection 4.2.1). Two main themes emerged: *properties of a device* to access a sharing service and *user experience* with a sharing service itself.

Considering the *properties of a device* to access a service, we established three larger categories: (1) enabling hardware; (2) primary device for a service, and (3) availability and portability of a device used for sharing.

Enabling Hardware Firstly, participants indicated the importance of having significant screen real estate and a full-sized keyboard that is present in every desktop setup. This was particularly emphasized by participants who shared travel details and music preferences:

> *"It is easier to put photos from the camera on the laptop and have a bigger display (than with a smartphone) to write about your experiences"* (Sara, 26, sharing travel plans and details).

Our participants also preferred a desktop due to the lack of "battery drainage" problems, which often exists for mobile devices. Lastly, participants indicated hardware advancement as an influential factor to choose a sharing platform. Desktop or laptop computers often provide sufficient storage space for personal content, or simply have better computational capacity to run a software:

> *"It has [the] better capability with the graphics than a portable device"* (Ruby, 57, sharing virtual possessions in a virtual world).

On the other hand, smartphones were an attractive sharing platform for reporting physical exercises. Mobile and wearable devices are equipped with many sensors that support capturing various biophysical parameters, e.g., to share one's heart rate during workouts.

Key Device for a Service Some participants told us that they possess a single device to access the Internet; therefore, this sole device was their gateway to all sharing services. For others, desktop and mobile devices were used out of habit. As long as a device serves the sharing purpose, participants did not see a need for an alternative platform:

> *"I make updates mostly on my phone, and I also check new stuff usually while waiting [for] a bus or a train"* (Darrel, 28, sharing culinary preferences).

Participants who possess several devices often chose a primary device for a sharing task:

> *"I need to write messages, check profiles, etc. It is something that I do carefully, with attention. I don't do it on the fly with my smartphone"* (Bernice, 29, sharing an accommodation listing).

Some sharing services, such as activity tracking apps, are designed to be used on a wearable or a mobile device:

> *"The phone is always with [me] and it is the key device to use and [get] data from [an] application."* (Todd, 24, sharing physical exercise data).

Availability and Portability Often, at the time of a sharing task, users chose any device available at hand:

> *"I have my phone's [data] turned on most of the time [I travel], so gathering and sharing information is fast."* (Naomi, 28, sharing travel plans and details).

For example, when sharing is not a primary activity (e.g., while gaming, or using a desktop device for work), participants mentioned the importance of multitasking, conveniently attainable using a desktop interface:

> *"It allows me multitasking, as I like to have music in [the] background while doing other things on the computer."* (Gretchen, 24, sharing music preferences).

Smartphones, in turn, attract sharers on-the-go because of their portability:

> *"I carry my phone during the activity. I share the activity as soon as I am available using my phone."* (Vicky, 25, sharing physical exercise data).

However, when one would like to create a personal story with rich descriptive details about one's experience, portability is not of immediate importance.

> *"I like to take my time for logging the exercises so I always do it when arrived home. And I prefer working with my computer, to make logs as descriptive as possible."* (Richard, 24, sharing physical exercise data).

With respect to the *user experience* with a sharing service, participants mentioned two key factors that ensured adequate experience: (1) importance of efficiency and ease-of-use of a sharing service at hand, as well as (2) features that a service affords and restrictions imposed by a service.

User Experience with a Service Ease of use in the form of a dedicated app or a platform-optimized user interface influenced the choice of a device:

> *"The service is optimized for that [mobile] device"* (Lana, 17, sharing music preferences).

Immediate and fast capturing and sharing capabilities make a mobile platform the obvious choice to share novel content:

> *"My phone is always with me and always on, so it's easy and fast to share with it."* (Margaret, 28, sharing travel plans and details).

Surprisingly, on several occasions, users found a desktop interface simpler to use in order to share personal content:

> *"The interface to share [on desktop] is simpler, and, actually, I don't use the others devices at all to share stuff in general."* (Aaron, 27, sharing music preferences).

Service Features and Limitations Rich service features, such as connectivity with a supporting device or social outreach, also often influenced the choice of a device:

> *"[T]here is an application for it and you can connect it with Facebook to see friends' activities".* (Kelly, 26, sharing music preferences).

Several participants reported that artificial software restrictions on one platform made them switch to another one that better supports the sharing activity:

> *"I use my laptop more than my smartphone because there are more restrictions regarding the free use of [the service] with a smartphone"* (Corey, 24, sharing music preferences).

Some of the aforementioned criteria for device selection were represented better in one sharing category than another. Figure 4.6 describes how factors that influence a choice of selecting a desktop (D) or a mobile platform (M) on a per-category basis. Each inner cell in a table gives the number of findings

	Music preferences		Travel plans		Physical exercises		Sharing economy		Virtual possessions		Culinary preferences		
	D	M	D	M	D	M	D	M	D	M	D	M	
Enabling hardware	5	1	8	1	3	6	4		5				*33*
Key device for a service	6	2	8	4		5			1		1		*27*
Availability and Portability	23	21	1	7		13	2	1	7		3	2	*80*
User experience with a service	14	8	14	21	2	4	10	6		1		5	*85*
Service features and limitations	4	2	1	1	2	4	1		7			1	*23*

Figure 4.6. Device selection factors for sharing novel types of content

encountered during the analysis of the open-coded answers regarding device selection practices. We color-coded cells in darker shades for higher hit counts – in blue for a desktop platform and in green for mobile. We performed a two-way contingency table analysis to test the dependency of these device selection factors across different sharing categories for both mobile and desktop platforms. We found that there is a significant association – Pearson for mobile ($\chi^2(20) = 43.882$, $N = 116$, $p < .05$, $V = .308$) and desktop ($\chi^2(20) = 63.692$, $N = 132$, $p < .001$, $V = .347$). This means that device selection factors vary significantly across six sharing categories.

We now discuss each of the device selection factors listed in Figure 4.6, in descending order of total findings. The *user experience with a service* is the most represented category of factors that influence the choice of a sharing device (85 findings). Our participants reported that mobile platforms provide adequate support for services that enable sharing workouts, travel plans, and culinary preferences. We speculate that this is due to the immediate capturing and sharing capabilities that a mobile platform affords. For music preferences and sharing economy services, user experience with a desktop interface seems to be more suitable.

The *availability and portability* category is the second most represented group of factors (80 findings) that influence device selection across all novel content sharing categories. These factors are predominantly available in mobile platforms for services that support sharing travel plans and physical exercises. Availability factors play an important role for desktops when sharing is not a primary activity (e.g., playing videogames). For the remaining services (music preferences, culinary preferences, sharing economy) mobile and desktop devices are more or less equally balanced.

The *enabling hardware* group of factors (33 findings) is important for services supporting the sharing of travel information and music preferences, as well as for sharing economy services and videogames. We find many instances of desktop interfaces in this group, where many tasks require bigger screen estate, a full-size keyboard, and/or advanced capabilities to store and share content.

The *key device for a service* group of factors (27 findings) illustrates how mobile devices (smartphones) are a key enabler for sharing workouts, due to their portability and sensing capabilities. For travel plans, the picture is less clear: some users prefer the mobile device due to its in-situ sharing capabilities, while others rely on the ability of a desktop system to support in-depth reporting.

Service features and limitations (23 findings) are especially important when it comes to sharing virtual possessions, as most mobile systems simply are not able to run resource-intensive virtual environments or games.

Finally, we evaluated the association of extracted factors across our six sharing categories with respect to device preference. First, we calculated Pearson chi-square tests for factors that influence a device preference, to assess whether there is a significant association between device choice with the factors. The analysis showed a significant association between factors and device selection ($\chi^2(4) = 11.925$, $N = 248$, $p < .05$, $V = .219$). In other words, this indicates that the device selection factors extracted from qualitative data play a significant role in deciding on a device to access a sharing service. We then conducted a two-way contingency table analysis to test the dependency between device selection and sharing categories. Pearson chi-square tests revealed a significant association between device usage and sharing categories ($\chi^2(5) = 41.685$, $N = 248$, $p < .001$, $V = .41$). This finding is in line with our prior findings that certain sharing categories are preferred to be shared with certain devices (see Figure 4.5); for example, services that support sharing workouts are often accessed through smartphones.

Ease-of-use and Efficiency of Device Usage

Next, we wanted to statistically determine whether personal mobile devices provide a more satisfactory and efficient user experience in supporting sharing tasks than their desktop counterparts. We asked our participants to report the experienced ease and speed to share content in a given service on both a mobile and a desktop platform. Additionally, following Olson et al.'s 2005 study, we inquired how easily or efficiently the task of changing privacy settings for a shared content item could be performed on a respective platform. Finally, we hypothesize that experience with a sharing service influenced efficiency and ease of sharing, as well as the ability to change privacy settings. In the following analysis, the scale ranges from 1 ("very hard/slow") to 7 ("very easy/fast").

We investigate with which device it is easier to share content based on our participants' responses. We present our findings for all sharing categories overall. A Wilcoxon signed-rank test showed that it is significantly easier for participants to share content using desktop platform than it is using mobile ($Z = -5.703$, $p < .001$). Furthermore, the median ease of sharing score with mobile platforms is 5 and with desktop platforms is 6.

We then investigated with which device it is faster to share content based on participants' responses. A Wilcoxon signed-rank test showed that it is significantly faster for participants to share content using desktop environments than it is using mobile one ($Z = -4.908$, $p < .001$). In addition, the median speed of sharing score with mobile devices was 5 and with desktop computers/laptops was 6.

In order to investigate with which device it is easier to change privacy settings for a shared content item, we again performed a Wilcoxon signed-rank test, which showed that it is significantly easier for participants to change the privacy and access settings using desktop devices than it is with mobile ($Z = -6.663$, $p < .001$). The median score of ease for changing privacy settings with mobile platforms was 4, while for desktop platforms it was 6.

In order to investigate with which device it is faster to change privacy settings, we performed another Wilcoxon signed-rank test, which showed that it is significantly faster for participants to change their privacy settings using desktop interfaces than it is using mobile ($Z = -7.11$, $p < .001$). The median score of speed for changing privacy settings with a mobile device was 4, while for a desktop device it was 6.

All aforementioned findings suggest that, in general, participants found it easier and faster to share and, subsequently, to change privacy and access settings for a shared content item by using a desktop platform across all six novel content sharing categories. Despite the fact that the services that afford sharing physical exercise and culinary preferences indicated more frequent usage on mobile devices, we found no significant difference in reported efficiency and easiness to share than using desktop platforms within those categories.

Finally, we investigated how one's reported level of experience with a sharing service affects one's self-reported measures of ease and speed of sharing, as well as one's self-reported measures of ease and speed of change privacy settings for that particular type of shared content. We computed Spearman correlation coefficients for assessing the relationship between the overall reported level of experience with the ease and speed of sharing with desktop devices and mobile, as well as ease and speed of changing privacy settings with desktop platforms and mobile. We found a significant positive correlation between "reported experience level with sharing type" and "ease to share content on desktop" ($r_s = .186$, $p < .05$, $N = 141$) and with "speed of sharing on desktop" ($r_s = .213$, $p < .05$, $N = 166$). No other significant correlations were found between "reported experience level with a sharing type" and "ease of sharing with mobile" ($r_s = -.055$, $p = .477$, $N = 170$), or with "speed of sharing with mobile" ($r_s = -.038$, $p = .619$, $N = 173$). This indicates that the more experienced a participant is with a service, the easier and faster it is for him/her to share in desktop environments. From a privacy perspective, we found no significant correlations. In particular, we found no significant correlation between "reported experience level with a sharing service" and "ease of change of privacy settings" on desktops ($r_s = .119$, $p = .162$, $N = 140$) or for mobile ($r_s = -.008$, $p = .917$, $N = 166$), and no correlation between "reported experience level with a sharing service" and "speed of change

of privacy settings" for desktops ($r_s = .08$, $p = .354$, $N = 138$) or for mobile ($r_s = -.013$, $p = .354$, $N = 138$). This indicates that increased experience with a sharing service does not necessarily imply increased ease and speed in changing privacy settings for a shared content through this service.

4.4 Considerations for User Control

Based on a qualitative analysis of our survey's open-ended answers across different content categories, we distilled four initial design themes for designers and developers that are interested in building novel content sharing services. Our design themes address the privacy concerns and needs identified in Section 4.3.2. In particular, we review (1) different angles of access control; (2) privacy mechanisms; and (3) quality of controls; and (4) open sharing. We additionally reflect upon the insights from the device selection criteria, which we discussed in Section 4.3.3, with respect to access control.

Different angles of access control Firstly, our survey results show that people tend to share different personal content with various levels of details. Mechanisms that enable anonymization or vagueness can be useful in this context. For content related to sports, this could be an aggregated overview of physical activity over a certain period [Epstein et al., 2015], with generic information that cannot be traced back to an individual. This idea is well-illustrated in a quote of our sharing participant:

> *"[Service] allows to remove any training as you want and to provide a border area."* (Chester, 30, sharing physical exercise data).

Furthermore, similarly to unwanted audience concerns in social media [Tufekci, 2007], users of novel content services should be able to easily select the right target audience for a given piece of content, in order to prevent unwanted audience access. Gradually unfolding shared content upon gained trust is another strategy to consider when sharing sensitive data. Some sharing economy services, such as Airbnb, are using this strategy already during their matching phase. This was brought up by a participant in the open-ended answers as an example of good practice:

> *"Couch surfers. If they are interested in staying and I with them, more details are shared"* (Fredrick, 26, sharing accommodation listing).

Privacy Mechanisms Secondly, services should maintain easily comprehensible privacy policies. Information that articulates where and how content will be used, and whether and to whom collected data is sold, traded or exchanged should be provided. One non-sharer further elaborated this:

> *"I do not wish to become a free agent for advertisers. Almost all services we use to share stuff use the data for companies to improve their advertising. If I wish to be utilized as a subject for marketing studies, I wish to control the data I share and get some kind of compensation for it. So I use social media to update quite vague stuff, however I'm aware I'm still sharing more to companies than I actually would like to."* (Jodi, 40, not an active sharer).

Recent research has explored wheter short, standardized privacy notices [Kelley et al., 2009] can simplify this process [Cranor, 2012], as standard free-form policies are typically difficult to read and comprehend [McDonald and Cranor, 2008]. In addition, obtaining explicit user consent is a good practice to follow when updating or making changes in the existing privacy policy, even if local laws do not require this. Note, however, that many scholars have started to question whether consumers are actually able to take meaningful decisions based on privacy policies [Solove, 2012; Acquisti et al., 2016]. Nevertheless, some level of transparency is expected from a service as illustrated by one of our participants:

> *"[If] I understand [service's] nature, functions, and policies, I can choose how to use the service"* (Bradford, 52, sharing virtual possessions in a virtual world).

Quality of Controls We found a need for providing adequate sharing controls for content sharing services. Our participants became easily frustrated when data was being automatically shared without their consent.

> *"I want to be in control of what I share to who. None of it should be [shared] automatic as such without my explicit consent."* (Glenn, 30, sharing music preferences)

To prevent such behavior, services periodically could help users review their automatic sharing settings. Furthermore, our respondents were cautious about being marked as "spammers" if they would share too often or to the wrong audience. A service could offer certain policies that would allow only a limited amount of content to be shared within a certain period, protecting both posters (from oversharing) and recipients (from being spammed).

Open Sharing Lastly, in order to amplify engagement with – and increase the attractiveness of – a service, designers should consider presenting certain shared content within the service to non-users. Potentially this technique will convert them into users of the service. Users would also benefit from sharing data openly for public use, e.g., for information that has a substantial value to a community. Examples of this type of shared content might be information about ingredients and substances of products or foods, as reflected by one of our sharing participants:

> *"Like McDonald's ingredients, I like to explain to my cousins why it's dangerous"* (Alan, 27, sharing dietary preferences).

Designing for Multiple Platforms Despite the significant attention of designers and HCI practitioners for *mobile first* design [Wroblewski, 2012], our participants still preferred desktop environments, regarding them as more efficient and easy to use for sharing novel content online. This is particularly relevant when it comes to configuring privacy and access control settings, in the sense of both limiting and reaching the desired audience [Litt and Hargittai, 2016b,a]. We suggest that mobile design should maintain a fair balance between ease to configure those settings and convenience to share (e.g. instant sharing) to the targeted audience, as well as allow a capacity to limit the audience upon user's request. Moreover, facilitating multi-channel sharing through a mobile platform may also improve access control across online services [Sleeper et al., 2016]. Finally, our participants emphasized that they preferred to have mobile access to all features offered by desktop counterparts. Therefore, mobile designers should focus on improving user experience with a sharing service, especially in their efforts of controlling the audience of the shared content and managing privacy.

4.5 Limitations

Online surveys are known to bias towards highly educated populations (84% of our respondents have one or more academic degrees). However, this choice of method allowed us to reach a very international set of participants: our survey received replies from 15 countries across four continents. It is important to note that our findings cannot be easily generalized: most of our participants were under 35 years of age and male. Nonetheless, we believe that we were able to reach the correct target group for novel content sharing practices (i.e. university students, ICT professionals), since some of the basic characteristics of early adopters of technology in general are young and middle age, a high level of education, and

past experience of using similar technologies [Ito et al., 2009; Dee Dickerson and Gentry, 1983]. We also believe that our account of these new phenomena can still help researchers and practitioners to reflect upon novel sharing practices with respect to existing sharing conventions, especially regarding privacy and device selection. While we attempted to reach a wider community of sharers (especially in the "sharing economy" category, where, for example, accommodation owners are usually older), most existing online platforms in these domains (e.g., Airbnb) do not allow one to contact an individual user without the aim to initiate a business transaction.

Furthermore, given the wide range of content items considered within the scope of our analysis, there were obvious differences in audience perceptions. For example, in culinary and diet preference sharing, the notion of a "target group" was not present, while in the "sharing economy" category, it was the largest recipient of shared content. Additionally, respondents argued that the concepts of "friends" in a social network service and "friends" in real-life differ. This was particularly visible in the travel category, where sharing to friends was frequent, but sharing to a "target group" was rare. From related work on social media, we realized that determining audience perception is a complex task. Researchers examined wide clusters of imagined audiences [Litt and Hargittai, 2016b] or suggested using computational techniques to define distinct sharing groups [Vitak, 2012].

We followed Stuart et al.'s [2012] "transparency framework" to deal with intricacies in audience perception. We incorporated the different target audiences in our survey in an order from restricted sharing (e.g., to an individual or family members) to open sharing (e.g., to an interest group or publicly). However, our participants reported that in different sharing services the more restricted audiences did not automatically mean the more preferred recipients. For example, services in the "sharing economy" category require public sharing if the user wants to make the most of the service. Additionally, some categories, such as virtual possessions, traditionally use anonymous or pseudonymous interactions, which obviously reduces the need for privacy restrictions within the service.

4.6 Summary

This chapter has outlined the results from a survey study of novel content sharing practices *to provide a comprehensive account of common digital sharing practices stemming from the advent of personal activity tracking* (**G1**). To this end, we discussed a set of six novel types of content that is increasingly being shared online, based on the self-reported behavior of 200 "sharing" responses from an

online questionnaire. In particular, we have examined peoples' practices of sharing (1) music preferences and playlists; (2) travel plans and trip details; (3) details of physical exercises and sports activity; (4) digital representation and contextual metadata about real-world items such as rooms and vehicles; (5) virtual artifacts in video games and virtual social worlds; and (6) personal culinary and dietary preferences. The selected categories differ in the amount of disclosed details and types of audience. Moreover, they cover a variety of tools used for sharing novel types of content, as well as represent different sharing mechanics (e.g., manual vs. automatic sharing).

First of all, we systematically identified content items that are being shared across various audiences within each individual sharing category. We then outlined examples of the actual online services that enable the sharing of novel types of content and illustrated the content items that our participants sought to share, despite sharing services' limitations. We also offered a descriptive comparison of those sharing categories, summarizing similarities and differences among them when it comes to the shared content and target audiences.

Secondly, we asked 56 "non-sharers" to describe their reasons to refrain from sharing personal content from these categories. Employing qualitative research methods, we analyzed information from both "sharers" and "non-sharers" to identify common privacy concerns that frame novel content sharing practices. Our analysis showed that audience perception and sharing controls are key issues in successful service design – across all sharing categories we examined. Based on our empirically-collected privacy concerns, we synthesized four design themes for novel content sharing practices: (1) holistic access control; (2) privacy mechanisms; (3) quality of controls; and (4) open sharing. These design themes are not exhaustive, they are best seen as broad observations for researchers and practitioners who explore the future design of novel content sharing practices.

Thirdly, this exploratory study also helped to improve our understanding of device usage within six novel content sharing categories. We have empirically drawn up a set of factors that influence device preferences when accessing supporting sharing services. We identified that (a) enabling hardware, (b) designated device for a service, (c) availability and portability, along with (d) ease-of-use and efficient experience with a shared service, and (e) a service's features and imposed limitations are important factors that users consider when selecting a device to access such sharing services. Based on (self-reported) experiences of our sharing participants and using quantitative analysis methods, we determined that, despite contemporary *mobile first* design efforts, desktop interfaces of novel content sharing services are often considered more efficient and easier to use – both for sharing and access control tasks (i.e., privacy).

The key contribution of this chapter is a descriptive mapping of the six novel content sharing practices online with the view to frame our future design explorations of digital sharing stemming from the advent of personal activity tracking. The findings described in this chapter influenced our work in the following ways. Firstly, although our online survey provided an in-depth outlook of the landscape of novel content sharing practices, it looked at an act of sharing in isolation, while many sharing situations can be better described in a specific context, and in relation to the activities that precede and succeed a sharing act. Secondly, owing to the intricacies of audience perception across sharing various types of novel content, we have decided to focus on one sharing context to reduce the discovered ambiguities around the target audiences. In particular, we see the value in introducing a simple spacial distinction to differentiate *with whom* sharing takes place: a co-located or remote recipients. Finally, it remains unclear how sharing controls can be implemented on the UI level (especially for mobile devices) to efficiently support novel sharing practices.

Therefore, the goal of the following chapter is to further address our research goal **G1** and to identify how the design of mobile and wearable technologies could support digital sharing within a prototypical context. We opted for the context of outdoor sports, since outdoor physical activities represent a promising design space for novel sharing practices within various social configurations (e.g., co-located participants and remote observers). Chapter 5 will describe our empirical undertakings in this space, namely contextual interviews and a focus group to better understand the sharing practices of leisure skiers. We then explore how their sharing tasks intertwine with the activities that the shared content is related to. Finally, we design, deploy, and evaluate an interactive prototype to elicit the affordances of the mobile and wearable technologies when it comes to supporting skiers' digital sharing practices.

Chapter 5

Designing for Communicative Sharing in the Digital Realm

Following our conceptual framing introduced in Section 3.1, in this chapter[1] we continue looking into communicative sharing practices in the digital realm. The main aim of this chapter is to further advance our research goal **G1**, that is *to provide a comprehensive account of common digital sharing practices stemming from the advent of personal activity tracking*. In this chapter, we specifically examine how mobile and wearable technologies can support novel sharing practices in a prototypical context of outdoor sports. Sportspeople frequently use personal devices and online services to track their routines (e.g., workouts using a smartwatch app), and, therefore, outdoor physical activities presents a major opportunity for sharing various content items with diverse audiences.

To this end, in the previous chapter, we proposed that many novel sharing practices can be categorized using a spacial distinction to determine *with whom* the sharing takes place: a co-located or a remotely-located recipient. We then picked a representative design space for co-located sharing – a domain of leisure skiing, which includes many digital sharing practices within various social configurations. In this chapter, we describe two empirical inquiries in the domain of leisure skiing with co-located sharers.

In our first inquiry, we conducted a set of in-depth qualitative interviews with amateur skiers to describe their sharing practices in greater detail. We looked at skiers sharing practices not in isolation but as a constitutive activity for decision-

[1] Portions of this chapter are also published at MobileHCI'15 [Fedosov and Langheinrich, 2015], Augmented Human'16 [Fedosov, Elhart, Niforatos, North and Langheinrich, 2016], MUM'16 [Fedosov, Niforatos, Elhart, Schneider, Anisimov and Langheinrich, 2016], DIS'17 [Wozniak et al., 2017], and CHI'19 [Fedosov, Stancu, Di Lascio, Eynard and Langheinrich, 2019].

making and planning. We were particularly interested in the role of content and context before, during and after a sharing activity with a view to inform and inspire the design of interactive technologies to support digital sharing practices of skiers (see Section 5.1). In our second inquiry, we subsequently designed, deployed and evaluated a mobile and wearable interactive prototype to support these practices (see Section 5.2). We then reflected upon the user experiences with the prototype (e.g., its use and usefulness) with a set of outdoor practitioners, detailed the nuances of content sharing in relation to skiers' activities on the slope, offered two interaction design strategies to support such activities, and elicited a set of future-looking deployment opportunities beyond the skiing context.

In addition to that, we wanted to address remotely-located sharers, whose needs were not strongly pronounced in our empirical studies with skiers. Subsequently, we made an informed decision to change the design space. We hence conducted a third inquiry and engaged in a design project in the context of video and movie viewing with remotely-located sharers. This allowed us to cover a wider breadth of sharable content items stemming from personal activity tracking. We created an interactive system in the form of a mobile application to understand social effects of sharing personal biophysical and emotional information among distance-separated couples. In Section 5.3 we offer a prototypical system in the form of a design research artifact, provide a design rationale and propose a future empirical study.

5.1 Understanding Digital Sharing Needs of Leisure Skiers

Skiing and snowboarding are highly social activities, attracting millions to the mountains every year [Vanat, 2019]. With the advent of portable GPS tracking devices, wearable sensors and dedicated sport tracking apps (e.g., Endomondo) on our smartphones, it became possible to record one's own performance data (e.g., workouts) and biophysical information (e.g., heart rate) on the slope and share it with family, friends, and other followers. However, it is unclear whether the available set of tracking parameters (e.g., an average speed, completion performance or calories burnt during an activity) is expressive enough when it comes to skiers' social sharing needs.

As a group activity, downhill skiing sees groups typically ranging from two to a dozen people or more. In certain specializations of downhill skiing, such as ski-touring, backcountry or "off-piste" skiing, forming a group is crucial for

safety. There, practitioners require experience, good analytical and physical conditions, and special attention to safety during the descent on an unmarked slope. Current technology provides limited support for those group-specific needs, such as making decisions which piste to take next, what hazards to avoid when going off-piste, or how to catch up with a separated group member in a ski resort. Therefore, a greater understanding of skiers' information sharing behaviors is necessary in order to build comprehensive, group-aware, socially-embedded sports applications.

To this purpose, we engaged in two contextual inquiries at two different ski resorts in the Alps. Firstly, we individually interviewed twelve leisure skiers at a ski resort in Austria with the goal to understand their needs for information sharing before, during and after the trip. The aim of this inquiry was to elicit the key themes for technology design to support the sharing needs on the slope. Secondly, we conducted a focus group study with seven backcountry skiers in a French Alps resort. We wanted to know what information – related to their skiing activities – they would share with each other; how they would share this information; with whom they would share it; and when this sharing would take place. Furthermore, we asked our focus group participants in a separate ideation exercise to sketch devices, services, and tools that they would like to use in order to help them plan, coordinate, and analyze their group skiing activity. Besides the aforementioned activities with skiers, we also engaged in contextual observations on the ski resorts with a view to discover "social" places and artifacts and to find opportunities for a technology intervention in situ.

5.1.1 Background

Prior work extensively examined the area of technology-mediated physical exercises (see Section 2.3.2 for our review). Of particular relevance to this study is the work of Ahtinen et al. [2008] that explored tracking aspects of outdoor sports and its motivations for exercising. Curmi et al. [2013] provided an athlete's biometric information in real time to external observers and supporters in order to facilitate social interaction during sport events. Ojala [2013] provided fruitful results on understanding social needs and motivations to share data in online sport communities. Consolvo et al. [2006] studied technology-mediated physical activity that supports social sharing among friends. Developing upon these works and guided by the Epstein et al.'s design framework [2015] for social sharing in personal informatics (i.e., a practice of collecting and reflecting on personal activity information [Li et al., 2010]), our study seeks to understand the influence of exercise context on information sharing practices of skiers.

Previous research looked at the skiing domain from a mostly technical perspective. Pfleging et al. [2013] outlined emerging ubiquitous connectivity in the mountains, where smartphones are used extensively on the slope and ski lifts support wireless access. Weilenmann and Holmquist [1999] prototyped a wearable computer to support communication during skiing, though its most significant benefits turned out to be in facilitating informal social interaction than actual skiing activities. Jambon and Meillon [2009] evaluated an "E-skiing service" that supports piste skiing. Dunlop et al. [2007] proposed to interactively visualize data for skiing activities. Hasegawa et al. [2012] presented an application to support learning for beginner skiers. Colley and Häkkilä [2015; 2017] designed and field-tested a series of technology prototypes for snowboarders and subsequently described challenges stemming from deployment such technologies "in the wild". In turn, we have not come across any empirical studies that evaluated actual group behavior and sharing practices of an amateur skiing community, where we believe the novelty of our research lies within.

5.1.2 Study Design

Our study consisted of two qualitative inquiries. First of all, we conducted a series of semi-structured interviews with leisure skiers to elicit their individual experiential accounts with regards to information sharing practices on the slope. Secondly, given that social dynamics and interaction were a matter of interest for the scope of our study, we deliberately employed a focus group format and subsequently recruited a group of experienced backcountry skiers. We specifically chose amateur sportsmen, as earlier work has shown that professionals have a distinct set of needs targeting to improve their performance [Michahelles and Schiele, 2005], whereas the goal of our study was to explore a broad set of content sharing practices around the activity. In order to achieve this goal, we drew on the key design themes introduced in Section 3.3. In the first study, we focused on the themes of **Context**, **Audience** and **Privacy**, while in the second study, in addition to that, we specifically aimed at unpacking nuances of the **Content** theme with a view to informing the design of an interactive prototype to support skiers' content sharing needs.

Study 1: Individual semi-structured interviews with skiers

We recruited 12 skiers/snowboarders (3 females), aged $23-44$ ($M = 31.8$ years) with various levels of skiing experience both on and off-piste. Their self-reported skill level of skiing varied from "intermediate" to "advanced". All participants

owned a smartphone and routinely used it on a daily basis, some of them also used specialized apps for tracking their ski runs during the activity. Each semi-structured interview lasted 30 – 45 minutes and was conducted after a full skiing day in a resort in the Austrian Alps in January 2015. In this way, we strived to make it easier for the participants to reflect upon their day of skiing. The participants were recruited among the attendees and the instructors of an annual week-long winter seminar for PhD students using a snowball sampling approach.

Each interview focused on information sharing habits in relation to the overall skiing practice, and in particular to the most recent experiences. Primarily, we asked what data they shared and what technical means they used (e.g., specialized apps or hardware). Examples of the opening questions include "How would you describe the ingredients for a good skiing day", "What information do you share about your skiing activity?" We also inquired about their chosen audience and whether they had any privacy concerns. Further questions focused on when information was shared in relation to the activity. The physical context of the sharing practices was particularly important to us — we inquired as to whether particular surroundings elicited specific sharing behaviors. Finally, we asked the participants to reflect upon the social dimension of information sharing in sports, and upon the role information played in their activities.

Study 2: Focus group interviews and a co-design session with backcountry skiers

For our second study, we recruited seven experienced backcountry skiers and organized a group interview with them to identify their information sharing practices before, during and after the skiing activity. Additionally, drawing on approaches from participatory design [Bødker et al., 1995] and co-design [Sanders and Stappers, 2008], we had participants collaboratively sketch a series of interfaces and services that could help a backcountry skiing community to share necessary information during their group rides.

Our participants were 4 males and 3 females, ranging from 25 to 31 years of age ($M = 26.4$). All were working professionals – one participant was an architect, the rest were engineers in industry or in research. Each participant had daily exposure to technology, possessed a personal smartphone and actively used it during the day for both professional and personal purposes. Participants identified their skill level of backcountry skiing from "upper-intermediate" to "advanced". Each group member also had extensive experience in on-piste skiing. Their motivations to change to off-piste skiing varied, from simply following friends, to exploring new techniques to challenging their own abilities.

We conducted two moderated discussion sessions on two different evenings during the participants' two-week skiing holiday in a French alpine resort (taking place in early February of 2015), where each group member was out skiing almost every day. The first session was an introductory one, and lasted half an hour. It was aimed to elicit the categories of content that participants share during their skiing vacations, and present the format, the nature, and the objectives of our study. The second session lasted 45 minutes and was dedicated to exploring nuances of the previously identified content types in the light of group communication, behavioral and contextual aspects of off-piste group skiing, and to learn about personal experiences and challenges with technologies for sharing these types of content. At the end of the second session, we prepared a creative follow-up activity where we invited participants to sketch ideas for mobile devices and services that would address the challenges they just identified during the moderated discussion session. This additional session took a further 45 minutes and included sketching, the presentation of ideas, and a discussion of their sketches. On two occasions, we also observed the group while skiing.

Data Analysis

Our data analysis drew on various sources from our field-work. Firstly, we recorded all sessions from both individual interviews and a focus group using a voice recorder. Moreover, during each interview, we took field notes and reviewed them immediately after. Secondly, during a focus group, we additionally used a separate video camera to capture participants' interactions and collected the design material produced from the follow-up sketching session. Thirdly, we observed backcountry participants during their rides and took accompanying documentary photographs. We began our analysis by looking at verbatim transcriptions of audio and video footage. Two researchers employed an open coding technique from grounded theory to analyze the collected data thematically [Glaser and Strauss, 2009]. Using professional software for qualitative data analysis (Atlas.ti), we then constructed logical relationships among sociological constructs, organized codes into categories and, eventually, explored emerging themes. Additionally, we adopted a temporal research lens [Ancona et al., 2001] in order to structure the data in order to identify the most relevant information shared before, during, and after the skiing activity.

5.1.3 Information Sharing Context and Expectations of Skiers

From our rich data corpus, we conceptualized five main themes related to information sharing: (1) the relationship with the greater outdoors; (2) the need for planning and risk management; (3) selecting with whom to share information; (4) maintaining privacy; and (5) choosing what information to share. We briefly report on the first four themes and support them with direct quotes from our participants. We then devote more time to describing the fifth theme (i.e. shared content) stemming from our study with backcountry skiers. We use pseudonyms to describe our study participants.

Nature

Skiing is inevitably an outdoor activity, so it is not surprising that all our participants have a developed relationship with nature. "The great outdoors" played a profound role in skiers experience:

> *"I love quiet untouched slopes with a lot of powder, maybe some nice ways through the forest... where you have 20 minutes of a great ride."* (Steve, 23)

For some participants, skiing was about performance and getting the best out of the day:

> *"I love going skiing just for myself. So, I really like this independence. With great snow, I do hours of skiing, lunch on the lifts."* (Dustin, 38)

For others, it was a social activity built around spending time outdoors with a group of people:

> *"I think [skiing as] the social construction where you can do something together without really being together is quite, I think, attractive. You have synchronization points where you are basically in a cable car or in the lift, you have the chance to talk to people for quite a while and mainly without much disturbance."* (Arnold, 44)

Collectively, these findings, albeit not explicitly linked to skiers' sharing practices per se, provided an important insight into the context of the activity, participants' attitudes, and their state of mind when it comes to skiing.

Risk and planning

Safety and risk are important concerns for skiers. Risk is a combination of environmental factors, personal self-confidence and physical condition, and the overall coordination between group members. Therefore, winter enthusiasts often seek additional information prior to the activities to increase their safety and comfort. In particular, weather conditions and information about the area (e.g., amount and type of open pistes or hazards in the area) are often inquired as both affect outdoor practices significantly. The need for planning differs between skiing specializations: while backcountry skiers go for longer trips, where careful planning is needed in order to mitigate risk and make the time investment count, piste skiing usually requires fewer preparations – skiers often make their decisions on the spot in front of a panoramic ski resort maps based on the type (e.g., length, level of difficulty) of open pistes (see Figure 5.1).

The skiers' experience was highly affected by current weather on the mountain. Snow conditions are important factors to get the best out of a skiing holiday. The amount of fresh snow at the resort, visibility, temperature, wind, a condition of the slope, and precipitation on the mountain were among the factors that influenced the decision to choose where to ski the next day.

> *"I did not plan to go skiing there, I just saw one day before that prediction of 1-meter snow. So I call this friend of mine in the evening at 10pm: 'What are you doing tomorrow? — Not so much. Do you have time until 2–3pm? So let's go there at 8–8.30 and ski for 5 hours.'"* (Chris, 34)

As backcountry skiing is known to be a high-risk sport, those practicing the

Figure 5.1. A groups of skiers making a decision where to go next in front of a panoramic map

discipline develop a number of risk management measures. Firstly, skiing groups have clearly defined roles. The lead, an experienced skier, chooses the path and the stops, and provides immediate feedback to the rest of the group. Followers are often mid-level skiers that form the core of the group. A further experienced skier is at the end of the group and provides support to anyone struggling with the route. The skiers strive to keep the lead within their line of sight:

> *"The lead chooses a safe place and the rest follow. [...] it is important not to overload the slope."* (Tim, 25)

The route of descent is chosen by the group members collaboratively during every second stop and depends on the skills of the group members. Safety is a primary concern and it is the central element of group communication.

Audience selection

The primary sharing audience is the current skiing group on a given day. Location-based content is used extensively to coordinate skiing activities and set up meeting points when the group splits. Most of the sharing activities occur when the skiers are not directly engaged with skiing activity itself, e.g. during the breaks or in the cable car.

Participants reflected that they did not want to overwhelm their social media audience with skiing pictures. Consequently, they used other means of sharing:

> *"I don't want to share it on Facebook with everybody, but [just] with the people who were in the picture. I usually send it immediately, because if I don't do it more or less immediately it's never going to happen."* (Arnold, 44)

Another audience for skiers was friends who could possibly be skiing with them. They were hoping the friends could join next time, but careful not to elicit negative feelings:

> *"I share the track with friends I kind of like [...] to show them that you were there and sometimes you can even say like 'Hey, you should have joined!', or, maybe, sometimes you can make people jealous."* (Oscar, 31)

Finally, backcountry skiers expressed a need for companion apps to have a comprehensive view of snow and road conditions to reach places with untouched powder. However, drawing upon the excitement and exclusivity of discovering less known places, skiers did not want to share all the knowledge beyond their group to avoid bringing crowds to specific spots at the resort.

> *"For all of us, [it] would be great whether an app would show how to get to a certain point in mind (to the bus, to the track), how many cm of snow in a desired location, track including a map, but then the ski resort will be too popular among others, and an exclusivity of such this small village we are in right now will be lost."* (Tim, 25)

Similar behaviors and attitudes were identified in other recreational physical activities (e.g., hiking [Posti et al., 2014]) and leisure practices beyond the context of sport (e.g., foraging [Chamberlain and Griffiths, 2013]).

Privacy

Many respondents expressed privacy concerns, not only in relation to sports data, but also regarding other sensors and apps that their smartphones were equipped with. Consequently, there was an understanding that this was unlikely to be solved within skiing alone, but that specialized services and apps should conform to a more comprehensive personal data privacy management. On the other hand, performing the skiing activity in a publicly available ski resort already implies a privacy trade-off. Modern ski resorts use RFID cards that trace lift usage, which is subsequently available online, albeit in an anonymous form. The skiers in our study reflected that they understood this data enabled the ski resort to run the facilities more efficiently, despite the fact that several concerns were raised that collected data should not be linked to a skier's identity. When it comes to the tracked activities using apps, participants expressed the desire to be fully in control over what events were shared:

> *"I think the system automatically posted something on Facebook, which I disabled, because, I mean, you don't always want other people to know where you are or what you were doing. So, I mean, I want to decide by myself what I want to share and what I want to keep private."* (Oscar, 31)

Backcountry skiers are likely to create extended visual footage during a trip. These photos and videos were usually considered private to the group. While the skiers recognized that uploading the content to the cloud would simplify sharing, they were determined to keep the footage exclusive to a closed group:

> *"Great if you could create a group page about the trip, which would include only people who were skiing there."* (Charles, 28)

5.1.4 Content Sharing Practices of Backcountry Skiers

As one can imagine, any group skiing activity usually starts with the planning of a trip. Our participants were carrying out a discussion related to the preparation and organization of the trip over E-Mail. This form of group communication was chosen over other options, e.g., social networking or IM chat, because of its wide adoption. Every group member had an E-mail account, while membership in social networks and choice of the IM clients varied heterogeneously.

During the actual skiing activity, group members shared a variety of information with each other: location, media (both with co-located and remote participants), and relevant reference information.

Location sharing

Personal location sharing is often a necessity when one is lost on the mountain or finds oneself in any other kind of emergency. It is tightly linked with skier safety and uses any means of technology available at hand, such as mobile phone or a walkie-talkie, to communicate verbally one's current (suspected) position to the nearest member of a group or to a local rescue service. Several participants had used location sharing via an online map with close group members when they had been lost. Normally, they supplemented this map information with several telephone calls or radio sessions to direct the lost skier to a familiar area to meet the rest of the group. In case of an emergency, location sharing obviously had to happen with a minimum of interaction needed. All of our backcountry participants carried both avalanche beacons and beacon detectors with them for short-range localization in such an emergency. Obviously, participants shared their location also in less dramatic situations, e.g., when members of the group needed to schedule a meeting with each other during or after a ski day. However, due to the typically high roaming costs, Internet usage is often very limited on the slope and participants preferred to arrange such meetings in advance using paper maps and meeting times, or to make a few short telephone calls or radio sessions:

> *"If we have some people who want to split, we give them the walkie-talkie and keep in touch."* (Janet, 25)

Media sharing

Taking photos and videos during the skiing day was prevalent among our participants, who often liked to share these with friends and family instantly (i.e., on the slope) to express their excitement and to feel more connected with each other.

From the interviews and our own field observations, we found that participants carried a number of media capturing devices with them during the day, ranging from smartphones and point-and-shoot cameras to high-end DSLR cameras and hi-performance camcorders. Our seven backcountry participants had four GoPro sport camcorders among them, which they use extensively. For example, the group reported that they had collected over 100Gb of raw video material during their last two-week ski-trip in the previous year. Collection of these shared media usually happened during an evening's reflection session or at the end of the trip when everybody would still be on site.

> *"[At the end of the day] it is actually a great way to agree on transferring media [...] while we are still here."* (Gabriel, 26)

A volunteer usually collects pictures and videos from other members and organizes a file transfer. The shared repository comprises media taken from phones, cameras, and camcorders. The repository is eventually uploaded and shared via a cloud service upon arrival at home. Access to the media repository is granted exclusively to the members of the skiing group. Filtering of the media is often a responsibility of each participant before transferring to the common repository. It is quite common to have lots of raw materials sitting for months and years untouched after the end of the trip. The group that we interviewed had a tradition to do a final film of each of their ski trips, featuring memorable, exciting moments during their rides. However, editing of the film always takes a lot of time and dedication and is, usually, the endeavor of a sole enthusiast.

> *"When Tim was at home, he had all the footage and made a great video cut about the trip."* (Gabriel, 26)

Upon availability of internet access (e.g., free WiFi) during the day, participants usually shared photos with selected friends and family, or sometimes publicly, augmented with a status update on a social network profile. Almost all participants used their smartphones to support such activity. After the trip ends, participants often do their own selection and re-share material to an extended group of friends and family. Sometimes the final film of the ski trip is made available on social networks for public viewing. Group members could opt-in to be tagged in the video clip.

Sharing context-relevant reference information

The availability of contextually relevant information is often crucial for an enjoyable skiing experience during descent and overall during the whole ski trip.

Reference information worth sharing for backcountry skiers includes the time left until sunset, the operational hours of a lift service at a particular location, conditions of the slope with detailed information about potential hazards during descent, such as crevices, sudden drop-offs, and cliffs. Sharing such information is typically time-critical. Our participants typically communicated such information verbally, using radio transceivers (walkie-talkies), mobile phones, or simply by shouting while on a slope.

5.1.5 Design Ideas for Content Sharing

During the on-site participatory design session, several ideas emerged that explored alternative methods of communicating information of immediate need, as well as sharing location and captured media. We describe three such ideas below: (1) assistive real-time reference feed; (2) an activity journal and (3) shared tracks. Table 5.1 describes how these design ideas fit the elicited sharing needs and practices of the skiers.

Nr.	Design Idea	Sharing Practice
1	Assistive real-time reference feed presented on AR goggles	Reference information sharing, Location sharing
2	Activity journal	Media sharing, Location sharing
3	Shared tracks on the map	Location sharing, Reference information sharing

Table 5.1. Mapping design ideas to content sharing practices of skiers

An assistive real-time reference feed Participants designed a set of augmented reality-enabled ski goggles that would inform members of the ski group about potential hazards during off-piste descents, such as tree wells, uncovered rocks, cliffs, bad weather conditions and, most importantly, avalanches. Group members and other skiers would collect this information in a crowdsourcing manner and provide it directly on a ski goggle display in form of virtual notification for each member of the group. Visual notes carry embedded geolocation information and hence can be linked to a physical environment accordingly (Figure 5.2b). The presentation of contextual notifications has to be performed in a non-intrusive manner and must ensure low cognitive load during a skiing activity. Any group member could register a virtual notification and send it to a "safety feed" using a wrist-worn device or a physical button on the goggle itself (Figure 5.2).

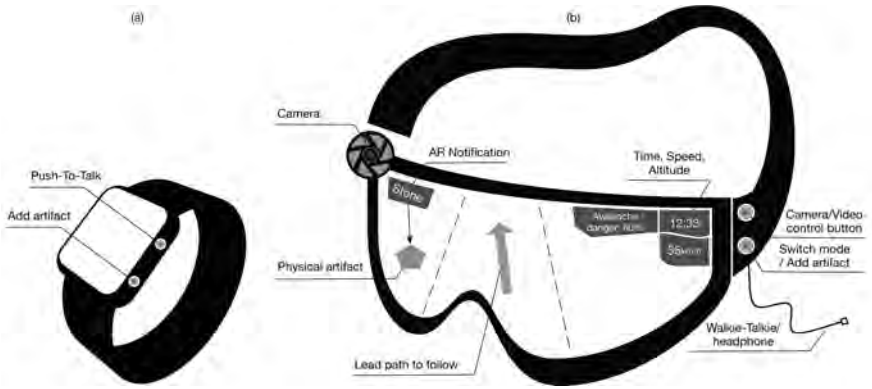


Figure 5.2. (a) A wrist-worn device to assist skiers. Generic watch image CC BY 3.0 Sherrinford on the Noun Project. (b) An augmented reality ski goggles provides contextual notifications from group's "safety feed", includes "track" of the lead to follow and custom reference information. Original goggles image CC0 1.0 Icons8 on the Noun Project.

Notifications would be automatically broadcast to group members and would be promptly available on their goggle displays. A "track" of the group lead would be always visible to the rest of the group members and could be consulted during their own descent. The trajectory of the lead would be overlaid on the physical environment and virtually represented on the transparent display in form of a continuous line or an arrow to where skier should be heading next to meet a group (Figure 5.2b).

Continuously populated activity journal A shared feed is a further idea that arose from the participatory design session. Participants were enthusiastic to have a "group feed" in form of a daily journal (Figure 5.3a) that could be automatically populated with media, POIs, and contextual and statistical details of the skiing activity, and which would be accessible online through a mobile phone or a personal computer. The feed would show user-captured events that present these on a timeline. Events could be added via a simple tap on a smartwatch-like device (Figure 5.3c) or through physical controls on the ski goggles (Figure 5.2b) or one's helmet. This "group feed" populated by custom events and memories of participants could be used as a trip report or a blog to create a narrative about ski vacations for the group members. The feed would be automatically shared among participants with an option to grant access to external observers who want

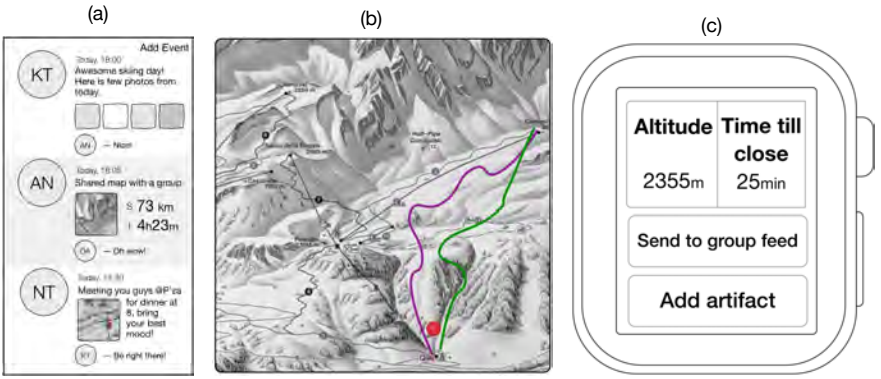


Figure 5.3. (a) A shared group feed is populated in semi-automatic fashion with user-captured events. Group members can grant access to extended circles. (b) Ski "tracks" shared between two group members on the familiar ski map of the resort. (c) An example of smartwatch-like user interface for skiers

to follow a particular participant or the entire group in near real time. Apart from pictures, videos, paths traversed, and maps, the feed could feature some relevant tracking and reference information about a location and activity (e.g. an après-ski party). The shared content of the feed could be a good conversation starter during evening reflection sessions, e.g., when some participants decided to split from the group and ski in another resort. The automatic creation of a film from various media captured by participants would solve the problem of gigabytes of raw media sitting untouched on participants' hard drives. This shared group feed could be an interesting opportunity for group members and external observers to feel more connected, facilitate both face-to-face and remote conversations, and strengthen social ties.

Sharing a map with other participants Participants found it interesting to be able to overlay their own traversed path complemented with statistical data (e.g. average speed, elevation drop) during a ski day with that of another participant, both for individual analysis and for collaborative, face-to-face reflections about performance and style. As Dunlop et al. [2007] identified, it would be important to visualize these tracks on a familiar ski map of the resort, not simply a standard online map (Figure 5.3b). In addition to tracks, it would also be useful to display contextually relevant reference information about a ski area in order to plan a descent and receive peers' recommendations.

5.1.6 Summary

In this study, we discussed group sharing behavior and practices of leisure skiers. Our participants considered planning and decision-making to be central to their safety and their enjoyment of the skiing activity. The interviewees used generic tools (e.g., e-mail, instant messaging or phone calls) both to obtain the necessary information and coordinate within groups. On the slopes, piste skiers referred to panoramic resort maps to make decisions where to go next based on the contextual information available to them at a given time. During a focus group study with seven experienced free-ride skiers, we discovered that location, media, and reference data are among the most-shared types of information that group members engage with before, during, and after a skiing activity. Additionally, several ideas emerged from a co-design session that would facilitate the sharing of such data among group members and beyond to families and friends. Consequently, in the next section we will describe a prototypical system that leverages the elements of the proposed designs (e.g., AR capability, a wrist-worn input controller), enables sharing content between skiers and provides means for *planning* and *decision-making* on the slope.

5.2 Design and Evaluation of a Wearable AR System for Sharing Personalized Content on Ski Resort Maps

As we established in the previous section, groups of skiers and snowboarders traditionally use paper maps or board-mounted larger-scale maps near ski lifts (see Figure 5.1) to aid decision making: which slope to take next, or how to catch up with friends for lunch or après-ski. However, such maps do not support the sharing of any personal content (e.g., recorded GPS tracks and pictures taken) or customized context (e.g., relevant points of interests and hazards) that are often the basis for making such decisions. A plethora of dedicated sport apps available in today's app stores do support such sharing, yet interaction with a smartphone is often inconvenient on the slope due to harsh environmental conditions and/or cumbersome gear (e.g., gloves) [Colley et al., 2015; Colley and Häkkilä, 2017]. Based on the design requirements that we extracted from the empirical studies with skiers, we developed SkiAR, a wearable augmented reality (AR) system that supports groups of skiers and snowboarders with their on-slope decision-making

processes. SkiAR offered a novel way to share personal content in situ using wearable AR equipment and a panoramic resort map.

We administered two initial user studies with a goal to evaluate the usability and perceived usefulness of the prototype with an experienced group of skiers and snowboarders. We first conducted a lab study with seven pairs (i.e., 14 participants) of winter enthusiasts to receive initial feedback on its potential acceptance. Next, we conducted a field study with 12 participants in an alpine resort to evaluate the usefulness and usability of the prototype. Both studies also included an open-ended discussion session that identified factors that may improve the design of the system and its potential use beyond winter sports. Below we briefly review related work on AR. We then describe the design requirements and the system architecture of SkiAR, report on the results of our two user studies, and discuss considerations for the design of AR systems to support group decision-making on the slopes.

5.2.1 Background

Drawing on the prior work in HCI that looked into augmenting skiing experiences described in Section 5.1.1, we particularly wanted to avoid a number of challenges while conducting experiments outdoors that involve complex software and hardware setups [Jambon and Meillon, 2009; Colley and Häkkilä, 2017]. We thus decided to use popular off-the-shelf devices that share a common software ecosystem, in our case iOS (using an iPhone 6 and an Apple Watch), in order to approximate a future gadget for winter enthusiasts. Several companies recently announced wearable devices to enhance the skiing and snowboarding experience. To mention a few: Forcite Alpine (`www.forcitehelmets.com`) attempts to redesign the ski helmet by embedding a radio transceiver and a high-definition camera into it. RideOn (`www.rideonvision.com`) eventually plans to incorporate a see-through AR display into ski goggles to support navigation and to facilitate play-on-piste. As of March 2019, however, no actual product has been launched.

Figure 5.4. An illustration of the envisioned interaction with a high-tech skiwear. Courtesy of the Recon Instruments

The Recon Instruments Snow2 MOD live remote (see Figure 5.4) is aimed at solving the interaction prob-

lem with personal devices hidden in jacket pockets by placing a glove-compatible controller on a wrist above a ski jacket, featuring a remote controller that has 6 stand-out buttons that can be easily pressed through a ski glove. These commercial products, prototypes, and visions help illustrate the overall potential of our system.

AR technologies provide a way to enhance our senses and perception of the real world by providing contextually relevant information about both objects and the environment around us. With contemporary AR technologies, finding additional information about an object of interest is as simple as pointing a mobile phone's camera to it and watching the screen. Van Krevelen and Poelman [2010] provided a comprehensive overview of applications in the space, explicitly discussing personal assistance, collaboration, and navigation tasks – all of which our system supports. Olsson et al. [2012] conducted a study covering five day-to-day scenarios, from workout sessions to shopping experiences, where an AR-enabled smartphone could assist to run those routine activities. While their study featured a single device perspective, we explicitly envision collaborative multi-device usage. Langlotz et al. [2012] introduced the so-called "AR 2.0" concept, where users can create and share user-generated content. We build on this work by adopting social AR principles and incorporating authoring capabilities into our system. Billinghurst and Kato [2002], in their study of collaborative augmented reality, discovered that interactions with an AR interface are often similar to natural face-to-face interaction in object-centered collaborations. Moreover, they discovered that an AR interface does not separate a communication space from a task space, which is crucial for decision-making tasks on the slope. The SkiAR system leverages these findings and uses a printed resort map as a physical reference to overlay personal information gathered from a user's smartphone. This should help facilitate conversation around shared content and support in situ decision-making for co-located skiers.

Schall et al. [2011] surveyed a large body of work in the area of augmented maps. Most notably, previous research explored the creation of interactive printed maps using RFID [Reilly et al., 2005], fixed [Reitmayr et al., 2005] and portable [Greaves et al., 2008] projection technologies. Schmalstieg and Reitmayr [2007] used a tangible input device to indicate a precise location on a map and show additional information about it on a PDA. All of these setups require infrastructural interventions, such as setting up a stationary projection system or mounting sensors around a map. Our system uses markerless image tracking and hence does not require any modifications of the physical space. Schöning et al. [2006] employed a magic-lens approach to interact with personalized content on a poster-size city map where a user is required to hold a phone in mid-air. In an outdoor

scenario, such as skiing, however, with its often harsh usage conditions, we instead use a head-worn display for information delivery. Morrison et al. [2009] found that AR maps can encourage discussion, negotiation, and problem-solving, and emphasized that the main potential of such systems is in collaborative usage. We accommodated the various design observations from their research, but instead of following their gamification approach we explore actual decision-making tasks while on the slope. Inspired by a study by Rohs et al. [2007] that compared 2D digital map navigation with an interface based on visual tracking, we employ a tracking interaction technique also in our system. In contrast to their study, however, our goal is not to compare different interaction techniques, but rather to probe possible scenarios where our system might be useful. Dunlop et al. [2007] discussed the importance of visualizing personalized ski data using familiar resort maps, rather than generic online maps (e.g., Google Maps). Following their findings, we incorporated the use of traditional panoramic resort maps.

5.2.2 The SkiAR System

In what follows next, we describe our design rationale and present the design requirements that we extracted from prior work, we then provide the overview of the main components of the system's architecture, and ultimately outline the input and output capabilities of the SkiAR system.

Design Requirements

Ski goggles, a helmet, and gloves are typical attributes of any skiwear. We built our prototype with a vision of using ski goggles as an output display to provide additional information to skiers and snowboarders. While today's dedicated winter sport apps[2] already enable outdoor enthusiasts to examine current slope conditions, locate and communicate with friends on the slope, and log comprehensive field performance data, such devices are far from ideal when it comes to on-slope use [Fedosov et al., 2015]. We thus opted for a wrist-worn controller in our setup in order to eliminate the trouble of having to take a phone out of a pocket. Our SkiAR prototype approximates future technologies (as head-mounted optical see-through displays for active sports and "gloves-friendly" input interfaces, see Figure 5.4) with the help of a conventional smartphone that is mounted in a head-worn phone holder and a smartwatch for control. Note that skiers and snowboarders often wear non-transparent, reflective goggles that prevent direct eye contact during social encounters and, due to the peculiarities of the

[2] http://www.tomsguide.com/us/best-apps-for-skiers,review-2570.html

design, usually limit their peripheral perception. Therefore, our prototypical setup approximates a realistic deployment quite well, which allows us to evaluate the perceived usefulness of presenting map augmentations and to examine how interaction and collaboration can be facilitated in decision-making scenario in front of a shared physical map. While existing in-goggle displays (e.g., the Solos smart glasses, see `www.solos-wearables.com`) offer simply an extra screen that can be used for notification purposes, our video see-through interface not only offers a more immersive experience, but also resembles more closely envisioned AR products such as the RideOn goggles with its optical see-through setup. We particularly chose a video see-through AR platform for our first prototype, not only because of the wider field of view in contrast to modern state of the art optical see-through commercial devices (i.e. Microsoft Hololens) [Xiao and Benko, 2016], but also due to the brighter display capabilities, which is critical for outdoors usage.

From our previous contextual inquiry (see Section 5.1.6) we identified that the sharing of personal and contextual information among skiers is not only crucial for safety and decision-making, but also often one of the key components of a positive skiing experience. The most important information skiers shared within a group was reference information necessary for a descent, an up-to-date location of a skier in a group and captured photos and videos. Consequently, our first prototype supports sharing four types of GPS-enriched content: pictures, tracks, points of interests (POIs), and hazards. However, our study participants provided us with further suggestions for content that the system could support in order to offer contextual aid while on the slope – see Section 5.2.5 for details.

System Overview

The SkiAR system consists of: (1) an input device (smartwatch) that offers a simple selection interface; (2) an output device in the form of a head-mounted display (HMD) of a mobile phone running a SkiAR application that overlays user-selected content onto familiar resort maps, and (3) a SkiAR server that handles synchronization of content between multiple users of the system in real time. Figure 5.5 shows the system configuration at a glance. Figure 5.9 shows how the setup is worn by a user.

The SkiAR system enables skiers and snowboarders to add and review personalized content in the form of pictures taken previously, tracks run, hazards and POIs encountered, as well as to share these details among group members using a familiar resort map. The system supports two modes: personal and sharing. In personal mode, a user can review personal information. This information is

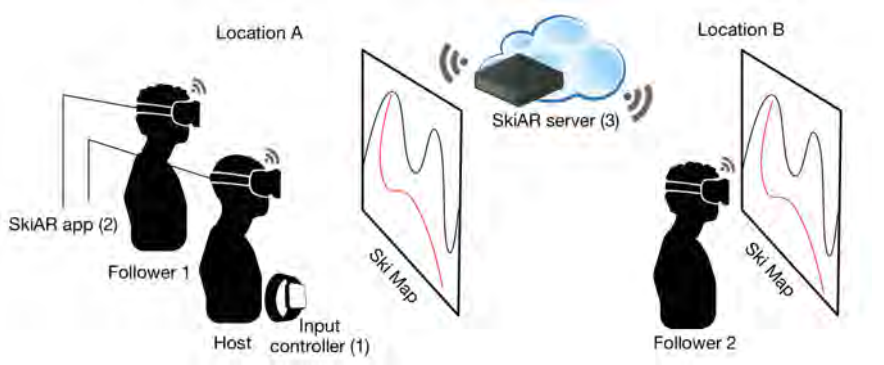


Figure 5.5. SkiAR system overview. Generic HMD and watch images CC BY 3.0 Boudewijn Mijnlieff and Sherrinford from the Noun Project.

only visible within the user's AR goggles. The sharing mode supports sharing such information within a group. In the current prototype, groups need to be set up ahead of time (i.e., before starting to ski), as this still requires a number of manual setup steps, such as establishing a shared data storage for the group (e.g., on a WebDav share). Moreover, the prototype does not yet support concurrent information sharing – at any point, only one user can be the *host* of a sharing session, while all other group members are simply *followers* (see Figure 5.5). We acknowledge that in a real decision-making scenario, roles in a group may change frequently, depending on the situation at hand. Therefore, in our system, any group member can request and subsequently take over the host role and start sharing their content with others. Future research should investigate both ad-hoc group forming as well as concurrent content sharing.

The SkiAR server is implemented using Node.js. It offers basic group management and controls individual sharing sessions. Our prototype requires that all skiers have Internet connectivity throughout the ski resort. In principle, followers do not have to be co-located with the host (see Figure 5.5).

SkiAR App and Input-Output Interface

The SkiAR app uses printed maps of a ski resort as a tracking reference to overlay user's virtual content on top of it. We used the Metaio SDK for iOS to support markerless tracking on the resort maps. To allow for the use of a commodity smartphone in an HMD-mount (e.g., Dive 5, see `www.durovis.com`), SkiAR renders two screens next to each other (see Figure 5.6). The iPhone 6 that we use in

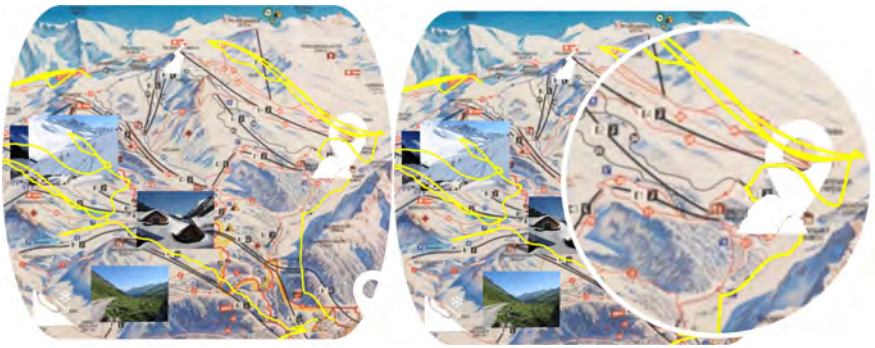


Figure 5.6. AR content delivered to HMD with a close-up view (right)

our prototype provides a resolution of 750x667 pixels per eye at a refresh rate of 60 fps. The horizontal field of view (FOV) of our assembled setup is similar to other wide-FOV AR systems [Xiao and Benko, 2016]: 60 degrees for the phone itself and 90 degrees for the HMD headset that we used. The actual frame rate and screen resolution are controlled by the Metaio SDK. Figure 5.6 illustrates the system's current user interface as seen through an HMD. The SkiAR app positions photos, tracks, hazards, and POIs at their corresponding physical locations on the ski map. Photos and tracks are imported directly from a user's smartphone (e.g., photo gallery, workout tracking app). The placement of these items is based on their embedded latitude and longitude information (e.g., EXIF information for pictures or GPS waypoints for tracks).

Our SkiAR prototype uses a smartwatch as the input device. The watch is wirelessly connected to a smartphone in *host* mode and runs a companion app. Figure 5.7 shows the watch user interface in SkiAR. The user can control information presentation using left and right swiping gestures. Figure 5.7a corresponds to the information presented to the user in Figure 5.6, where all available virtual objects can be seen in a single view. However, users can filter and display only one category of objects at a time (e.g., only "Hazards", or only "Photos") by using a left swipe gesture. Photos are presented in a thumbnail view or in larger scale upon a user's request (a tap on the watch). Additionally, as shown in Figure 5.7b, it is possible to add new objects to the system using the watch interface (e.g., when encountering hazards such as tree wells, avalanches, cliffs, uncovered rocks, or crevices). In this mode, the system reads the current GPS position of a skier and registers a new hazard at this position. Finally, the host of a session can share any content category with other skiers in the group

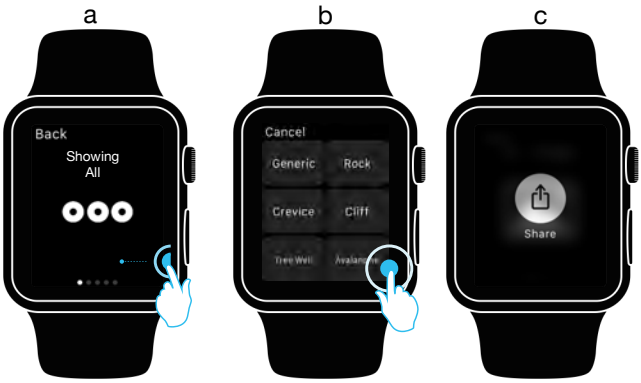


Figure 5.7. SkiAR input interface on a smartwatch. Generic watch image CC BY 3.0 m from the Noun Project

by applying a touch gesture while in the corresponding category and pressing "Share" (Figure 5.7c). The SkiAR system will then update the corresponding information for all followers automatically. The currently selected object – a POI, an image, a track, or a hazard – will be highlighted in red and will become visible for all users (see the ski map illustration in Figure 5.5).

In order to visualize personalized content on a panoramic resort map at the appropriate location, we designed a conversion algorithm for our system. The goal of our algorithm is to estimate the position of a point on a panoramic map given its GPS-coordinates. For efficiency reasons, we divide our algorithm into two phases. The first phase (preprocessing) consists of manually identifying correspondence points in the two maps (we developed a simple iPad-based tool for that) and constructing the necessary data structures. Showing the topographical map (e.g., Google Maps) and the panoramic map side by side, we mark easily identifiable points such as the beginning and end of slopes/ lifts, the location of restaurants, etc., in both maps (see the white pins in Figure 5.8). The more such corresponding points one identifies, the better the fit will be. In our experiments, about 20 points were usually sufficient to achieve a good fit.

The second phase is the actual computation of the position of a given point in the panoramic map. For this, the algorithm uses the Delaunay triangulation [1934] on the points in the topographical map and carries the connectivity of this triangulation over to the panoramic map. In this way, if three points are connected in the topographic map, the corresponding three points will be also connected in the panoramic map (Figure 5.8). Once this connectivity has

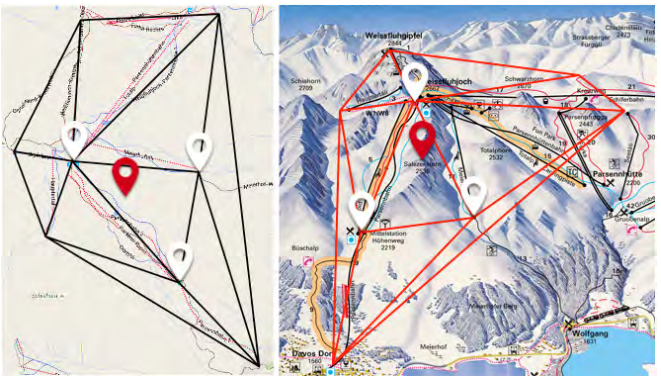


Figure 5.8. An example of triangulation of points in a topological map (left) and a corresponding panoramic map (right)

been computed, we can directly translate between GPS coordinates and "map coordinates", e.g., locating an arbitrary POI (see the red pin in Figure 5.8) and subsequently drawing a GPS trace onto the resort map (see yellow tracks in Figure 5.6).

5.2.3 SkiAR Deployments

The aim of our prototype is to aid decision-making and in situ information sharing among skiers or snowboarders in a group. In this study, we were particularly interested in examining the insights from the deployment of SkiAR in relation to two key sharing design themes (see Section 3.3) – **User Experience** and **Content**. Thus, we set the following three research questions:

1. **Perceived usefulness and purpose:** What application usage scenarios do snowboarders and skiers envision for such a system?
2. **System usability:** Is the proposed system and interface usable for sharing content on the slope?
3. **Content sharing:** What information is most useful to share in a group when making decisions about where to go next?

To answer these questions, we conducted two user studies: (1) we performed an in-depth evaluation of the system with seven groups of skiers in the lab; (2) then, we conducted a field experiment to evaluate the prototype outdoors in a ski resort in the Alps with 12 participants. Both studies were conducted in front

of a poster-size ski resort map: indoors for the lab experiment, and outdoors for the field study. These maps were chosen as a shared physical frame of reference because the space around them is highly social and enables collaboration during decision making between skiers and snowboarders in a group (e.g., see the setting shown in Figure 5.9).

Lab Experiment

We first performed a controlled laboratory experiment. We recruited seven pairs of skiers with various levels of experience through university mailing lists and personal contacts. Two participants considered themselves beginners, six intermediates, five advanced, and one an expert. The age of our 14 participants ranged from 22 to 34 years, the average age was 28 years ($SD = 4.1$), 3 of them were female. Participants were recruited in pairs to approximate actual in situ group decision making while on the slope.

Study Setup A session with a pair of participants lasted on average 50–60 minutes. Firstly, we briefed participants on the goals of the study and asked them to sign a consent form. Two researchers conducted the study: one administered the study while the other was observing and taking notes. Each session consisted of five stages:

1. A pre-study demographics questionnaire to assess participants experience with winter sports, and their familiarity with traditional ski resort maps.
2. A demonstration of the SkiAR system in front of a poster-sized ski map. One researcher demonstrated the system, followed by a short trial session where participants were able to try the prototype themselves.
3. Participants worked through two scenarios that require decision making in front of the map. Each participant acted once as a *host* (sharing predefined content) and once as *a follower* (reviewing content and supporting conversation).
4. A post-study questionnaire to evaluate the usability and usefulness of the SkiAR system.
5. A semi-structured interview to reflect on the experience with the prototype.

Scenarios In the first scenario, the first participant acted as *host* and the second as *a follower*. Participants were asked to envision the end of a ski day, in which the host had skied while the follower had not. The task of the host was to describe his/her ski day through reviewing and sharing pre-defined virtual content

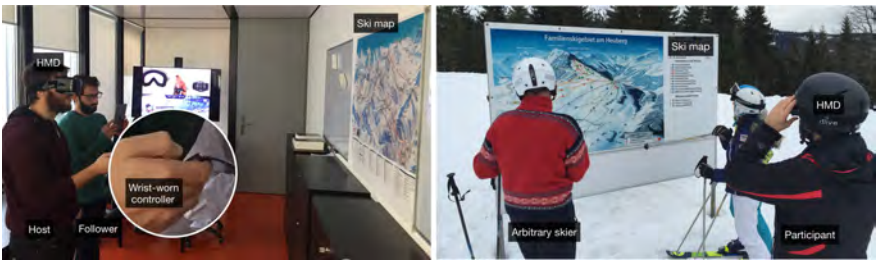


Figure 5.9. The laboratory setup of the SkiAR system and the field study setup

(pictures, POIs, tracks, hazards) on the map in order to plan the next day together with the follower. Since we had only one head-mounted gear and smartwatch pair-unit (which was used by the host), the follower had to use a tablet computer during the study session (see Figure 5.9).

In the second scenario, participants switched roles. This time, we asked them to envision a lunch break, where both participants had been skiing together since morning. The composition of the virtual content on the augmented map was different from the first scenario. In this scenario, the two participants were asked to decide on the safest route to take in the afternoon, based on various hazards the host had encountered along his/her respective tracks from the morning runs. In both scenarios, the host was asked to explicitly share (Figure 5.7c) pictures, hazards, tracks, and points of interests with the follower, so the follower could see them on the map.

Field Study

For the field experiment, we recruited twelve skiers and snowboarders with various levels of experience during a week-long winter seminar for PhD students at a ski resort in the Austrian Alps (taking place in February 2016). Participants were recruited using snowball sampling. Two participants considered themselves beginners in skiing, three intermediates, two advanced, and five experts. The age of our 12 participants ranged from 25 to 36 years, the average age was 28.9 years ($SD = 3.25$), two of them were female.

Study Setup Throughout a week, we followed participants on the slopes for few hours and, subsequently gathered them individually (on two occasions we had a pair) for a study session in front of a board-size map at the resort. During the ski run, participants and the researcher were taking pictures together, recording

tracks, and adding few hazards encountered on the way. We manually added a number of fixed POIs for all participants before the study to ensure completeness of a dataset with respect to virtual content types. On four occasions, it was not possible to arrange a ski run with participants – in these cases, the researcher met them directly for the study session. The actual study session in front of the map took on average 15–30 minutes. First of all, we briefed the participants on the goal of the study, requested consent and then asked to try the prototype that showed (localized) sample content previously entered into the system by the researchers. Two researchers conducted the study: one administered the study while the other was observing, taking notes and pictures.

Sessions In contrast to the lab study, our field trial did not have any pre-defined scenarios, but rather asked participants to decide where to go next, given the current state of the content added to the system earlier. To reduce the time of the experiment, participants were only required to wear the head-mounted smartphone and review the content (see Figure 5.9) – a researcher was using the wrist-worn controller to drive the discussion. In summary, the study consisted of 4 stages:

1. Collecting content (pictures, tracks, hazards) while skiing together with one researcher.
2. While in front of the map, participants were asked to reflect on personalized content and decide where to go next. Participants were *followers*, while the researcher acted as *a host*. A few participants also wanted to (and were allowed to) try acting as a host.
3. A post-study questionnaire to evaluate the usability and usefulness of the SkiAR system.
4. A semi-structured interview to reflect on the experience with a prototype in a real-world setting. Demographic information was also collected at this stage.

Data Analysis

In both studies, we asked participants to complete a post-study questionnaire in which they needed to indicate their level of agreement on several statements regarding the usefulness of the SkiAR system, using a 5-point Likert scale (see Figure 5.10a). Furthermore, immediately after our participants experienced the prototype, we administered a System Usability Scale (SUS) questionnaire [Brooke, 1996] with ten questions, also using a 5-point Likert scale. The SUS questionnaire is an established method in HCI to evaluate the usability of a system. SUS

scores are between 0 to 100 points; systems that score more than 68 are considered usable above average. Ultimately, we conducted a NASA TLX workload test [Hart, 2006] to evaluate the mental, physical and temporal demands of the system.

The last part of both studies was a semi-structured interview. The goal of this part was to unfold the user experience with the prototype, and to collect suggestions for its design. We recorded all interviews using a voice recorder, then transcribed recordings verbatim. Furthermore, the researchers took detailed notes of each interview. To analyze this data, we followed an iterative process, going back and forth between the data, the researchers' notes, and the emerging structure of empirical categories that we developed through recurrent reading of the material [Miles and Huberman, 1994]. To draw out the common factors of the system, we adopted a contextual design methodology and constructed an affinity wall [Holtzblatt et al., 2004]. This technique helped us to define ideas for new content and applications of the SkiAR system, as well as to inform the interaction design to better meet skiers' and snowboarders' sharing needs. In addition to discussing each theme, we also collected participants' quotes to support the topics that emerged for each category. We use pseudonyms to describe study participants.

5.2.4 Perceived Usefulness, Usability Evaluation, and Purpose of SkiAR

Participants from both studies regarded the SkiAR system as generally useful to reference throughout a day of skiing or snowboarding. Figure 5.10a shows that participants from the field study generally gave higher scores (higher perceived usefulness for the system in general, as well as for each functionality – review, share, and add content). In contrast, participants of the lab study especially appreciated the convenience that the system provides when watching the overlaid information through the goggles and operating it through a wrist-mounted controller. We speculate that this may be because field study participants were in a more realistic setting when facing a current decision-making activity.

Next, we wanted to evaluate whether the system is usable for sharing content. After the decision-making scenarios, we asked our participants to evaluate the system using a SUS questionnaire. Primarily, we were interested in evaluating the usability of the head-mounted display setup – an approximation of the envisioned high-tech skiwear. The SUS of the system scored 73.75 ($SD = 12.46$) in the lab

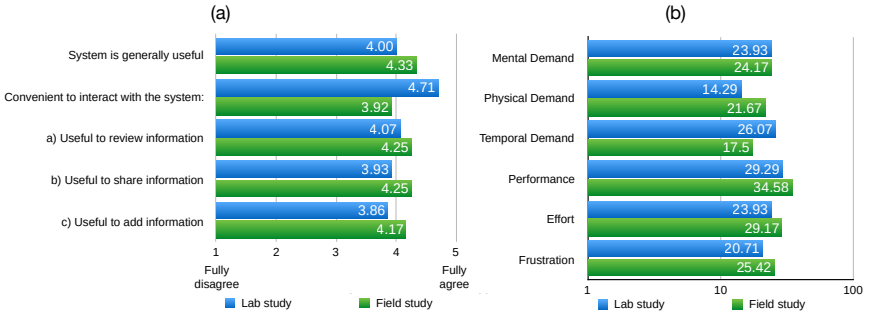


Figure 5.10. (a) Perceived usefulness of the SkiAR system. (b) NASA TLX mean score for content reviewing task represented on logarithmic scale (lower value is better). Lab Study $N = 14$, Field Study $N = 12$.

and 79.19 ($SD = 10.07$) in the field study, which suggests that the system that we developed is usable above average.

We then evaluated the content review task using the NASA TLX questionnaire. Figure 5.10b presents the respective mean values of mental demand physical demand, and temporal demand. It also shows self-assessment for performance, effort, and frustration. The total average workload reported scored 23.04% ($SD = 9.91$) in the lab study and 25.42% ($SD = 12.32$) in the field study respectfully. The lowest parameters measured were physical demand (lab) and temporal demand (field), the highest was self-performance. We speculate this is due to a markerless technique for visual tracking that we employed. Surprisingly for an outdoor scenario and on a sunny and clear day, where there were many glances on the map, the tracking system produced a poorer result than anticipated. Participants need to find an initial point with respect to a map where tracking works best before starting to review the content. We hypothesize that other tracking techniques (e.g., point cloud tracking or edge-tracking) might result in a better performance. However, we believe that content reviewing and sharing task among participants can be independent from underlying technology (e.g. AR).

During a semi-structured discussion at the end of each session, participants provided also insights about scenarios where the SkiAR system could be used. As anticipated, participants valued the system's ability to support decision-making while on the slope:

> *"I usually get confused with the slopes you already took and the ones you haven't, with the prototype you immediately see where we have been."* (Cornelius, 29).

Decision-making is aided through the quick review and the sharing actions of personal content with group members. SkiAR alleviates the burden of reaching out into a pocket for a smartphone to show some additional information to another member of a group.

> *"It is easy to share with the group, also quite quick. I don't need to pull out my phone."* (Adrian, 33).

Furthermore, the app appealed to skiers and snowboarders in the event that they got lost or split from a group, for it enables them to coordinate with others:

> *"Useful to share with a group. When I'm lost I can send my position that we can meet at some restaurant. Great way to catch up with others."* (Jessica, 23).

Additionally, users saw value in reflecting upon personal and group activity through the app after a ski day.

> *"I see reviewing my content with friends at home or in a hotel using the app"* (Leon, 29).

Next, participants suggested that the app can provide greater awareness about the variety of places available around a resort (e.g., where to meet for a lunch), or for pointing out dangerous spots on the slope.

> *"I think it is really nice to have an overview while skiing, especially in bigger ski resorts."* (Clarence, 26).

Finally, users mentioned that the app can facilitate content mediated interaction with other skiers, without having to use verbal channels.

> *"App is great for reducing shouting on the slope. If I got lost, I'd like to use this [app] to know where my peers went, so I do not need to worry [about] a taking wrong turn [...] just because of sharing content with a group puts everyone on the same page."* (Adrian, 33).

One participant mentioned that SkiAR could provide connectedness to the group members through shared content:

> *"if it is like 20 people going, it could create this feeling of connectedness with the whole group using this prototype"* (Cedric, 34).

Participants mentioned daily journaling through sharing with remote friends as a useful application, which can serve not only as a storage of content (e.g., a photo album) but also facilitate ideation and storytelling.

> *"I think it is useful when you can store [content]. Then you could see where you had been last year [...] you can also give some recommendations and exchange ideas with friends"* (Debbie, 26).

5.2.5 Nuanced Considerations for Content Sharing

Our participants found hazards to be the most important content category that they would like to review and share in situ with other skiers, even beyond a private group, especially in an unfamiliar ski area.

> *"I only go off slopes in the skiing areas I know very well. But for example here, I would not know where is safe to ski, that would be valuable for me to use this system"* (Don, 36).

POIs and tracks were also found useful during the day. Pictures, on the other hand, were preferably shared and reviewed with the group when a ski day was over.

> *"It is useful to share pictures, say, in the group of 10, no need to approach everyone individually and need to remember where this one was taken"* (Adrian, 33).

Additionally, participants expressed wishes for new content that SkiAR should support. They liked to know about the current location and the state of skiers within a group.

> *"Once I went skiing in a forest and got stuck under a tree, but they [brother and sister] were on the piste. I was not able to communicate to them. It would be cool that app can notify about your location and location of others"* (Craig, 29).

One of the most requested details is waiting times at a ski lift that can influence the decision which piste to choose next, as well as contribute to traffic efficiency at a resort.

> *"I'd like to know that information in advance, and I would have taken another one that was not that crowded. Today it would save me 30 min."* (Don, 36).

Furthermore, a ski resort operator could provide an assessment of how crowded would be at a location throughout a day based on the queue data at a lift.

> *"Given the frequency how people scan their badges at the station or using a camera there, you can give a very good prediction on how crowded area is"* (Don, 36).

Detailed contextual information related to meteorological conditions at a resort (e.g., weather, visibility) and on a particular piste (e.g., snow conditions, a speed of wind) were also regarded as highly relevant to making a decision.

> *"I'd appreciate getting information about snow quality and conditions at the given time, also those red or green lights to show whether piste is open or closed"* (Taylor, 27).

Few participants also wanted to attach personal performance data to a piste (e.g., best time, top speed, number of falls) to spice up a competition among friends and beyond. Participants also mentioned videos and time-estimates to complete the run as potentially interesting content items to include. Up-to-date reference information (e.g. deals for daily menu at a restaurant, discounts on rental equipment, last bus schedule) was named as another factor to consider when planning the next run.

> *"I'd like to see POIs with offers* `"cheap beer"`*. I would definitely go there"* (Manuel, 28).

An interesting discussion revolved around limited and public sharing. Participants were willing to share informative contextual details such as hazards, POIs, queues at lifts, weather information, as well as anonymized statistics about personal runs. However, locations and pictures were preferably shared only within private groups. Few participants were concerned about the quality of publicly shared content, though we found a need to maintain and filter public crowd-sourced content.

> *"[seeing] duplicates of the same pictures on the map would not be that cool"* (Jessica, 23).

Adding a further stakeholder to the system, such as a resort owner, could perhaps ensure the continued relevancy of critical contextual information like hazards. Since resort-organized ski patrols usually prepare and maintain slopes throughout the day, a system like SkiAR could benefit from their content input.

> *"Resort should take care of reviewing and updating that kind of information [hazards]"* (Manuel, 28).

5.2.6 Considerations for Interaction Design to Meet Skiers' Sharing Needs

Our field observations quickly confirmed that board maps are highly social artifacts. As seen in Figure 5.9b, skiers are closely approaching the map, pointing toward it with a pole and discussing where to head next when returning to a slope (often from a lunch break or a lift ride). This fact justifies our choice of supporting poster-size maps as an anchor point in our studies. Given that a physical space around the map is shared among other skiers, designers of systems that use this space for interactions (i.e. SkiAR) need to account for possible outcomes (e.g., lost visual tracking) during their use (e.g., adopt more robust tracking techniques). This leads us to suggest to designers of such systems that they define a set of *points-of-interaction*, i.e., locations where decisions are being made where to go next, and then optimize the user experience for such encounters. For SkiAR, these points-of-interaction are the poster-sized ski maps near a lift base station or on top of a mountain, as well as pocket-size paper maps that are used while on a lift.

> *"I may be interested in such a system on the lift [...] because there you have more off-time. Once you are hopping on the lift, you always want to see where you can go next"* (Don, 36).

Our current prototype of SkiAR requires explicit sharing of each content category. To reduce unnecessary interactions with a wristband controller, having an automatic sharing technique would be beneficial in a group setting.

> *"Sharing is the most useful part of the app. I suggest automatic sharing between the rest of the group while hosting the session"* (Clark, 28).

The SkiAR supports a 2-tap input of hazards while on the go by automatically reading the GPS location of a skier and indexing it with a user-selected type of hazard. However, participants raised concerns about the implicit expectation in this design to add hazards right after passing them. The SkiAR app should thus define a mechanism to insert hazards encountered previously at an appropriate time for a skier or snowboarder (e.g. during a ski lift ride).

> *"People could add important hazards later on; they are unlikely to add them on the spot directly"* (Manuel, 28).

The *temporal aspect of interaction* is an important factor to consider for decision-support systems like SkiAR. We observed that interaction with a shared ski map is rather short; people quickly decide where they want to go. On the other hand,

during a lift ride people have often more time to spare and discuss their decision. An explicit "follow-up" mechanism could be useful that would allow one to pick up a prior conversation and/or decision taken, e.g., during a lift ride, and show it again at a later time, e.g., a poster-sized map. Additionally, few participants expressed a wish to see overlaid personal content in the real world (e.g., a track directly "painted" onto the slope) to support decision making during off-time on a lift or at short breaks while on the slope.

> *"It would be really cool If you can see those hazards or pictures in situ as well because if you ask me now about where the hazards are, I probably remember only a couple."* (Don, 36).

Some participants were also interested in contextual turn-by-turn navigation after choosing the POI to go to, then a suggested route can be calculated automatically (like when driving a vehicle).

> *"One can say 'Let's just go to a bottom of that cable car!' and everyone gets the navigation aid on his device, to head a bit more on the left or on the right"* (Irvin, 28).

One participant expressed a wish to consult a virtual map upon request:

> *"Would be great to pull the map virtually whenever you are on the slope and check it. I don't like to get [a] foldable map from the pocket."* (Sherman, 29).

Ultimately, the ability to support hand gestures in mid-air was mentioned a few times in our interviews. One user mentioned finger detection, while selecting a point on the map, another was referring to pinching in/out to zoom for a particular place on a map using both hands to get additional information about a region of interest. Both ideas are similar to MIT's SixthSense system [Mistry and Maes, 2009].

5.2.7 Future-looking Applications for SkiAR

Several study participants suggested applications for our technology in areas beyond winter sports activities. Scuba diving has similar equipment requirements as skiing and snowboarding. Divers always wear a mask and many use wrist-worn dive computers to measure depth and dive time for calculating a safe ascent profile. Therefore, virtual augmentations of a shared physical focal point can be explored further in this discipline. Recreational divers do not often have access

to voice communication equipment and use non-verbal communication channels instead. The SkiAR concept could be extended to support such requirements. Other recreational physical activities such as running, cycling and hiking could also take advantage of our system. Sportspeople often bring measurement devices (e.g., chronometers, GPS trackers, smartwatches) along to track their activity.

> *"Wristwatch with haptic feedback could notify about hazards along the route"* (Carlton, 22).

Modern wearable devices for runners and cyclists (e.g., the Solos smart glasses) provide comprehensive statistics about sport activity in real time. Cyclists and hikers often consult a map during their activity and would benefit from shared information left by fellow sportsmen.

Several participants suggested targeted use of our system for training and testing purposes when it comes to the disaster simulations like controlling spreading fire or monitoring an area after an avalanche. Emergency management is a promising field to deploy our system given that physical maps are widely used for disaster analysis and support tasks. Finally, museums and amusement parks always provide paper maps and larger-scale poster maps to their visitors to aid navigation within premises. The SkiAR system could provide interactive contextual information and improve navigation during a visit:

> "*Maps of museums could be more interactive, informative with POIs to show different artifacts"* (Alexandra, 24); *"it can show queues at the rides in an amusement park on the map"* (Kate, 23).

5.2.8 Reflections and Limitations

While we received positive feedback about the system from a total of 26 participants, our prototype represents only an initial approximation of a potential future consumer product for skiers and snowboarders (see Figure 5.4). We found that participants highly valued the usefulness of not having to hold a phone or even a paper map in their hands while on the slope. Half of our subjects from our lab study were able to operate the wristband controller without even looking at it. Given that none of them had prior experience using a smartwatch, this suggests that our simple UI and the minimal interaction with the system was the right choice for outdoor winter activities.

Further development of the prototype is required in order to accommodate day-long use of the system. For example, in order to interact with the touch screen of the smartwatch, skiers currently need to take their gloves off. While the choice

of using a smartwatch in our prototype allowed us to easily support interaction with augmented content on the map with the set of simple micro-interactions (swipes), an improved version of SkiAR would feature a remote control device that supports button-push events while wearing gloves (e.g., the Recon Instruments Snow2 MOD live remote, see Figure 5.4). Similarly, the availability of sport-tailored optical see-through display technologies (e.g., the RideOn ski goggles) would allow us to fully support the experience that a system such as SkiAR may provide.

Future developments of accurate outdoor tracking systems would also benefit overall SkiAR performance. In particular, using visual tracking technologies outdoors is a known challenge due to different lighting conditions throughout the day [Schmalstieg and Reitmayr, 2007]. We used a so-called "markerless" tracking technique in our prototype, which requires most of the tracking region (e.g. map) to be visible by the phone's camera at once. In our field experiment, our system thus lost track several times as other skiers passed by or stepped in front of the poster-sized map. More robust tracking techniques and algorithms (e.g., point-cloud tracking) could significantly improve the user experience of our system.

While our prototype used a video see-through technology for overlaying virtual content (in contrast to, e.g., the envisioned RideOn commercial product, which should use an optical see-through system), our findings described in sections 5.2.6 and 5.2.7 do not rely on any particular AR technology – and hence in general would benefit designers and developers of various AR systems to support collaborative decision-making on-piste and beyond. Furthermore, our qualitative insights related to personal content reviewing and sharing described in sections 5.2.4 and 5.2.5 (e.g., what pictures to share, or entering a new POI) can be seen independently from AR and thus in principle also apply to any system, which supports collaborative skiing.

As a limitation of our study, we recognize the lack of concurrent sharing scenarios of digital content in our experiments that may be important in collaborative decision-making. Our lab participants had to assume the roles of *a host* and *a follower*, partially due to the architectural peculiarities of our system to handle shared resources, and the fact that we had only one HMD unit at our disposal. Therefore, participants in the lab experiment had to alternate roles in order to present content. In principle, the current SkiAR prototype already allows any group member to request and subsequently take over the host role and begin sharing their content with others. However, our next iteration of the system would certainly benefit from actual concurrent sharing support. Nevertheless, we believe that probing the prototype in the lab and in the field helped participants

to envisage various application scenarios and provided the opportunity to include personalized content in a discussion in front of a map. This enabled us to collect design requirements and answer our research questions about perceived usefulness and purpose, system usability, and important types of content to share in a group when making the decision where to go next. On the plus side, however, the host-follower setup that we employed might also be seen as supporting additional interactions beyond the originally envisioned decision-making use case. For example, skiers or snowboarders who just joined the group could use the content acquired by other "hosts" in order to "catch up" on the groups' prior activities. Similarly, remotely located people who do not participate in the skiing activity at all (e.g., friends or family at home), may still enjoy receiving updates and could thus "follow" and stay connected to the group. In these "out-of-slope" cases "follower" may benefit from the use of a tablet computer as exercised in the lab study instead of wearing an HMD.

While our lab and field participants found the system to be useful and stated that they would be willing to share information with group members in this fashion, actual user behavior can of course only be explored in an uncontrolled ("in the wild") natural setting. Nonetheless, our studies unveiled two interesting aspects that one can take into account when designing in situ content sharing systems that support decision-making encounters in the context of outdoor winter sports: (1) *points-of-interaction* (i.e., the location where actual group decisions are taken) and (2) the *temporal aspects of interactions* (i.e., the fact that those interactions are often time-constrained). These aspects already emerged with the help of our relatively simple video see-through based prototype. Future sport-tailored optical see-through head-mounted displays with accurate outdoor positioning might benefit from these two key design considerations by expanding spatial and temporal contexts for decision-making on the slope. It could be achieved by rendering augmented content on the real environment without occluding much of reality. For example, snow enthusiasts can explore benefits of in situ decision-making and information sharing that the prototype affords while riding a long lift up to the mountain [Fedosov et al., 2015]. They are usually not pressed in terms of time, yet share physical space (and focal points) that prototype leverages.

In general, we did not encounter significant tensions when it comes to the perception and the use of our prototype. On the contrary, we observed a clear affinity of our participants for such technology throughout the wide breadth of the points-of-interaction when deciding where to go next. Specifically, Don and many other our participants proposed an extension of the SkiAR system's capabilities beyond the interactions with physical panoramic maps, towards interactions

with augmented content (e.g., reference information about the conditions of the slopes, contextualized suggestions about hazards) that directly superimposed on the real-world references (e.g., terrain, trees, cliffs) during the actual skiing activity or during the breaks (e.g., while on the lift) in order to further aid decision-making process in situ.

Additionally, we chose traditional poster-size maps as shared physical reference points instead of a virtual one. On the one hand, a virtual map would allow skiers in a group to access customized content anywhere on the slope. On the other hand, presenting a shared virtual map on-slope might raise a safety issue. While we see the value of a virtual map in some cases, e.g. when one is lost and looking to catch up with a group, we believe that an AR map is more suited to stimulate collaboration between skiers. However, we hope that we will soon be able to take advantage of sport-specific optical see-through displays and thus directly examine the differences between physical and virtual shared references among skiers in a group.

Given the nature of the methodology we adopted in our study, a qualitative inquiry, we had no control condition to measure the effect of our system for the activities that require collaboration, decision, and sense-making in front of a ski resort map. The lack of control condition is for two reasons: firstly, current navigation options (e.g. physical paper maps or digital maps on smartphones) do not take into account user-generated content; secondly, alternative setups (e.g. handheld AR [Schöning et al., 2006]) are often found inconvenient for the winter context [Colley and Häkkilä, 2017]. However, even though there is no direct equivalent to our system among traditional decision-making practices on the slope, future research would nevertheless benefit from a quantitative inquiry. Our current study provided a set of insights into how technology might be used in collaborative skiing: what kind of personalized content can be used in decision-making within a group and how virtual augmentations of these content can be presented on the map with a shared physical focal point.

Last but not least, an interesting discussion arose around the issue of access control of shared personal content. Skiers and snowboarders should be able to decide how to share their information: publicly, within a group, or only with certain individuals. This points to a need for designing interfaces that can administer fine-grained access and usage control over shared data in AR [Roesner et al., 2014].

5.2.9 Summary

In this section, we presented the SkiAR system, a wearable augmented reality system for in situ sharing of personalized information on ski resort maps. We

conducted a laboratory experiment with seven experienced pairs of skiers and an outdoor field study with twelve skiers and snowboarders. Our participants found SkiAR to be useful in tasks that aid decision-making, group organization, self-reflection, and that it helped to provide better awareness while on the slope.

We found that the interactivity that a pair of AR-enabled "goggles" and a wrist-worn controller afforded was considered useful and usable for sharing tasks among skiers within a group and beyond. We found that sharing and discussing hazards is crucial to make group decision where to go next (especially relevant when going off-piste in unfamiliar locations). Pictures taken during the day were considered less important for decision-making, but rather useful for a review after a ski day within a group. We described our design considerations for the systems, which facilitate in situ decision-making through content sharing and collected application scenarios for extending our system beyond outdoor winter activities.

Drawing on these learnings, we decided to engage in a prototyping project beyond skiing. Particularly, we wanted to examine more types of "sharable" content stemming from personal activity tracking, namely biophysical and emotional data, which did not emerge in this study with skiers. What is more, turning back to the spacial distinction related to the shared audiences (see the introduction of this Chapter 5), we saw the value to explore a more meaningful scenario in the light of these personal types of content. We, therefore, picked the context of video and movie viewing for distance separated-families/couples and designed an interactive prototype with a view to eliciting their sharing needs and experiences.

5.3 Enabling Emotions Sharing for Distance-Separated Sharers

In order to adequately address remotely-located sharers, whose needs were not clearly pronounced in our empirical studies with skiers, we have made an informed decision to depart from the context of outdoor sports. Thus, our third research inquiry in this chapter concerns with the context of video and movie viewing among remotely-located sharers, and explores the sharing of a wider breadth of novel types of content collected from personal lifestyle-tracking devices and smartphones.

On the whole, collaborative movie viewing with loved ones increases connectedness and social bonds within family members and friends. Furthermore, with the rapid adoption of personal mobile devices, people often engage in this activity when geographically separated. However, conveying our feelings and emotions

about a recently watched movie or a video clip is often limited to a post on social media or a short blurb on an instant messaging app. Drawing on the popular interest in the quantified-self, we designed and developed Movie+, a mobile application that utilizes personal biophysical data to construct an individual's "emotional fingerprint" while viewing a video clip. Movie+ allows the selective sharing of this information through different visualization options, as well as rendering others' emotional fingerprints over the same clip. In what follows next, we outline the design rationale, describe our application prototype and propose its empirical deployment.

5.3.1 Background and Design Rationale

The advent of social, mobile, and ubiquitous computing enabled people to fulfill their aspirations to support and maintain social relationships with their loved ones, whether they live geographically close or far away [Forghani et al., 2014]. Researchers (e.g., [Brubaker et al., 2012]) argue that the mass adoption of video-mediated communication technologies (e.g., Skype) in domestic environments supported a need and desire to move beyond verbal conversations and focus on sharing activities through digital media. For example, remote movie viewing provides lots of social benefits among family members and friends, such as increased connectedness [Macaranas et al., 2013] and feelings of intimacy [Shamma et al., 2008]. However, synchronized video viewing may not be often possible due to various factors, such as a frequently traveling parent, or distance-separated couples.

A recent literature review in HCI on unconventional user interfaces for emotional communication [Li et al., 2018] mapped out the design characteristics of interactive tools that facilitate long-distance relationships. Forghani et al. [2014] demonstrated that sharing personal media (family pictures, Facebook posts) during a video call, made the communication more engaging and supported emotional connection between participants. Furthermore, Curmi et al. [2013], looked beyond these traditional digital content types and argued that real-time biophysical data (e.g., heart rate) gathered from amateur athletes during a running competition can also increase engagement with the remote audiences. In turn, we seek to understand whether and how personal biophysical data, captured during the movie viewing, can enhance togetherness and feelings of presence in the context of geographically-separated families/couples. To investigate that we developed Movie+, an Android application that allows creating, storing, and sharing personal emotions captured during video viewing activity.

The novelty of our prototype is that it enables the creation of an individual's "emotional fingerprint" for each video clip (e.g., YouTube video) and allows sharing it with family members and friends. In general, understanding emotions of video clips (e.g., advertisements on TV) is seen as a key challenge in marketing research efforts, such as to determine likability of ads (e.g., [McDuff et al., 2014]). Furthermore, in the future, we envision that experience sharing of movie viewing will be immersive. Few commercial products are already available on the market today, which enable a viewer to see a movie in virtual reality with a co-presence of others (e.g., Plex VR, CINEVR.io). Therefore, we see the value in understanding design opportunities to incorporate more personalized social movie viewing experiences based on an individual's emotions.

5.3.2 Movie+ Ecosystem for Creating and Sharing Emotional Fingerprints

The software ecosystem of Movie+ comprised from (1) an Android application, which captures and processes biophysical data from companion devices and services; (2) a web-service, which handles retrieval and storage of users' emotional fingerprints.

Movie+ Android App

The Movie+ app enables the user to watch video clips, generates the user's "emotional fingerprint" of the video, and enables the sharing of a customizable report, which contains several representations of aggregated emotions (see Figures 5.12a–c).

Movie+ offers a social experience to the user: one can watch YouTube video clips and examine, above those clips, the emotions of particular users' or, collectively, all users who previously watched those clips in real-time (Figure 5.11). We argue that this modality could provide a close approximation to the actual experience of watching videos together (e.g., with the loved ones).

In order to create an emotional fingerprint, Movie+ combines the emotional information gathered from users' biophysical signals and from their facial expression. In particular, Movie+ unobtrusively collects users' heart rate (HR) and the electrodermal activity (EDA) from the Empatica E4 wristband (`empatica.com/research/e4/`) in real-time while they watch a video. In addition to the biophysical data, the app detects a set of basic emotions (see Figure 5.11) from users' facial expressions utilizing the Affectiva SDK (`affectiva.com/product/emotion-sdk/`).

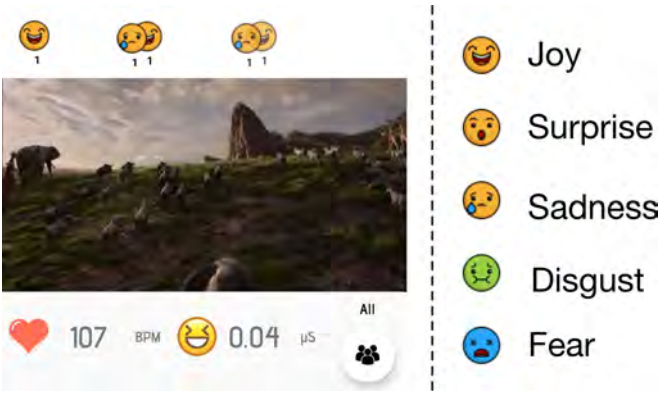


Figure 5.11. The emotions of previous viewers are displayed on top of the video clip, creating a social experience for the user (left); The emoticons we used for encoding five basic emotions (right). Icons designed by Freepik, Trinh Ho, Vectors Market from Flaticon. Background image CC BY GameSpot Universe Trailers on YouTube

Drawing on the *Post Content* metaphor offered by Epstein et al. [2015], which refers to the format and the composition of the shared information, the Movie+ system generates two types of emotional fingerprints at the end of the playback, based on the collected data: (1) synthesized summaries in the form of graphs (e.g., Figure 5.12a), illustrating the polarity of the emotions over a clip's timeline (Figure 5.12b) and the user's physiological signals, namely, HR/EDA (Figure 5.12c); and (2) "the most emotional moment" of a clip (Figure 5.12d). Subsequently, the user can select the one that best represents their own experience and which is worth sharing with others either privately (e.g., as an instant message) or publicly in the anonymous form (e.g., with our metadata server).

The Supporting Web-Service

The RESTful metadata service stores users' individual and aggregated emotional fingerprints for each YouTube clip using JSON format. Emotional metadata are linked to a specific user, video, and moment in time, so they can be eventually retrieved and visualized in real-time mode. We additionally implemented Go-bindings for FFmpeg multimedia library to generate a summary (in the form of a GIF) of the most exciting moment of the clip for a given user.

Figure 5.12. The types of "emotional fingerprints" in the Movie+ app: (a) the bar chart illustrates a summary of a user's emotions; (b) the valence component (e.g. the polarity), stemming from the user's facial expression, on the video clip's timeline (represented in seconds); (c) HR of a user during the video clip's timeline (represented in seconds), we use a heart symbol to identify the highest value of the HR, representing the most exciting moment of the video clip; (d) computationally-identified "the most exciting scene" moment of the clip for a user based on their emotional feedback. Icons designed by Trinh Ho, Vectors Market from Flaticon. Background image CC BY GameSpot Universe Trailers on YouTube

5.3.3 A proposition for a Future Work

In this section, we discussed the design and the system architecture of Movie+, an interactive prototype that allows one to create and share emotional fingerprints of a recently viewed video clip or a movie with family members and friends. We also

offered our design rationale, and outlined how the fingerprints can be captured and collected in the context of movie-viewing among remotely-located sharers.

In our view, the natural unfolding of this work would be a field deployment of Movie+ to elicit social dimensions of users' emotional fingerprints for YouTube video clips and movies. We particularly see the value of exploring such effects when video clips are being played on a handheld device (e.g., a tablet) owing to changing video and TV consumption patterns towards mobile devices for young adults in the US[3]. One direction that future research could take is to explore the amount and types of *Post Content* [Epstein et al., 2015] configurations that are most attractive for users when it comes to sharing emotional fingerprints among family members and friends. Another promising avenue would be to elicit and to synthesize users contemplations and reflections on how personal ubiquitous technologies can facilitate practices of emotions sharing in the future when movie viewing experiences will be ubiquitously available in virtual immersive environments.

5.4 Summary

This chapter has further contributed towards our research goal **G1**, that is *to provide a comprehensive account of common digital sharing practices stemming from the advent of personal activity tracking*. In particular, looking at a prototypical context of outdoor sports, we examined in-depth how mobile and wearable devices could support digital sharing practices of leisure skiers.

At the outset, we conducted two contextual inquiries recruiting in total 19 skiers and snowboarders, and engaged them in individual and group interviews to uncover their information sharing needs before, during and after the activity. We elicited and discussed five themes related to information sharing emerged from these two empirical studies: (1) the relationship with nature; (2) the need for planning and risk management; (3) content selection; (4) audience selection; and (5) maintaining privacy. Looking further in the content selection theme, we discovered that location, media, and reference information about a ski resort (e.g., amount and types of hazards in the area) are the most-shared types of information within groups of skiers. In a follow-up co-design exercise session with a group of backcountry skiers, we extracted design requirements with a view to devising an interactive system to support skiers sharing practices. We concluded that the system should (a) support group planning and decision-making activities in situ as those seen to be central not only for skiers' safety, but also for their

[3]https://www.statista.com/chart/8660/smartphone-vs-tv-usage/

enjoyment of the activity; (b) support panoramic ski resort maps since they often serve as a basis for the decision-making while on the slopes; (c) provide adequate interaction with the system utilizing existing skiwear (e.g., ski googles, gloves) and avoiding inconvenience to reach out for a smartphone due to usually harsh weather conditions; and (d) enable the collection and sharing activity-related content (e.g., tracks, contextual information) within a group.

Next, drawing on these requirements we subsequently designed, developed and deployed SkiAR, a wearable augmented reality system for sharing personalized content on ski resort maps. SkiAR enabled the capturing and sharing photos, points-of-interest, recorded tracks, and hazards in the area within a group of co-located skiers. The virtual content was superimposed on a familiar physical paper-based or larger-size panoramic resort maps to aid decision-making in situ. We evaluated the SkiAR system in the lab and in the field with a total of 26 skiers and snowboarders. We discovered that the interactivity afforded by an AR-enabled head-mounted display and a wrist-worn input controller was found useful and usable for adding, reviewing and sharing digital content within groups of skiers. We illustrated that the SkiAR system prompted prospective reflections on various activities beyond decision-making and planning. Those activities spanned from improving a skier's context awareness with a view towards safety in the area, to facilitating connectedness with the other members of a skiing group through content-mediated interactions, to self-reflection on individual and group skiing activity, to providing navigational aid for a lost group member with an effort to find his/her way back. We also introduced two interaction design concepts for in situ content sharing systems that support decision-making encounters: (1) *points-of-interaction* i.e., the location where actual group decisions are taken, and (2) the *temporal aspects of interactions*, the fact that those interactions are often time-constrained. What is more, we reflected on the technological opportunities for the envisioned high-tech skiwear with the view to improve user experience design for digital sharing on the slopes. Finally, the insights from the SkiAR study further informed and extended our considerations for the shared content among skiers and opened up future-looking opportunities for its deployment beyond skiing.

Lastly, we took a step back and set to explore the context of emotions sharing with remotely-located peers. We, therefore, made an informed decision and departed from the domain of outdoor sports. We found a more appropriate scenario – a movie-viewing with distance-separated families/couples – to meaningfully leverage emotional and biophysical data sharing. To this purpose, we designed and developed Movie+, an Android application that allows one to capture and share a personal emotional fingerprint of a recently watched video clip or a movie with a long-distance intimate collaborator (e.g., a couple, a family member, a

friend). The emotional fingerprints were computationally calculated based on the biophysical data gathered from a wrist-worn sensing unit and a viewer's facial expression taken from a front-facing handheld device's camera. The emotional fingerprints were delivered to the user in the form of synthesized personalized summaries (e.g., the graphs with HR) over the clip's timeline or in the form of "the most emotional" moment of the video clip. Both could be subsequently shared to a selected audience privately or publicly to a social media platform. The natural continuation of this prototyping effort would be a field deployment to discover the social end experiential effects of sharing emotional fingerprints.

In sum, we discussed breadth (see Chapter 4) and depth (this chapter) of common digital sharing practices stemming from the advent of personal activity tracking **(G1)**. We conducted a series of empirical studies reaching out collectively to 291 participants. We identified their needs, practices, and tools that support or inhibit digital sharing, outlined considerations for the design of future digital sharing services and systems, and discussed in-depth the role of mobile and wearable technologies in one prototypical sharing context. Drawing on these learnings, we turn next to the physical technology-mediated sharing practices in the context of the sharing economy. In the next chapter, we focus on the motivations and user experience requirements of sharing physical purchases as well as examine in-depth sharing practices of a tool-sharing community.

Chapter 6

Empirical Studies of Distributive Sharing in the Physical Realm

Following our conceptual framing introduced in Section 3.1, we examine in this chapter[1] distributive sharing in the real world. The goal of this chapter is to *describe nuanced design characteristics for interactive technologies to support physical sharing practices in the context of the sharing economy* **(G2)**. In order to achieve our goal, we conducted two empirical inquiries. The first looked at the physical sharing practices of individuals, the second at the practices of an established resource sharing community.

The first study (see Section 6.1) was conducted in collaboration with Leonid Ivonin, a researcher from the University of Bristol (UK), and aimed to explore the "everydayness" of the sharing economy when it comes to consumption (i.e., purchasing of services and goods). Motivated by "the challenge of under-sharing" of physical resources and the growing number of underutilized personal physical possessions at home, we particularly picked the context of everyday consumption. We set to determine if and how individuals share their purchases (i.e., the actual items bought, not spreading information about the purchase), *what* everyday purchases are being shared, *what motivates* people to share their purchases, and *with whom* sharing takes places. Relatedly, human behavior research has shown that spending money on *others* contributes not only to a higher satisfaction from purchases, but also increases personal happiness. To better understand the "social" effects of personal spending, and how satisfaction from a purchase affects sharing it with others, we developed a personal finance logging application. We

[1] This chapter is adapted from papers published at British HCI'18 [Fedosov, Ivonin and Langheinrich, 2018], DIS'18 [Fedosov, Odom, Langheinrich and Wakkary, 2018], and MobileHCI'18 [Fedosov, Bexheti, Ermolaev and Langheinrich, 2018].

subsequently distributed the application through both the Apple App Store and Google Play in order to recruit participants and to capture the social and hedonic aspects of their purchases. Using a mixed-methods analysis, we computationally identify how overall purchase satisfaction relates to its sharing, and elicit motivational and experiential factors that drive our participants' sharing of everyday purchases.

The second study (see Section 6.2) looked at how interactive technologies may facilitate sharing within an existing sharing economy community. In collaboration with William Odom and Ron Wakkary from Simon Fraser University (Canada), we were able to establish a case study at the Vancouver Tool Library (VTL), a tool sharing cooperative. The aim was to investigate how the experience of sharing real-world artifacts can be improved using personal mobile devices. We especially wanted to understand whether and how interactive technologies can support some of the emergent challenges inherent to resource sharing communities (the subset of which was described in Section 2.4). We designed, developed, and deployed an interactive system aimed at supporting the capture and sharing of tool-use experiences among VTL's members. Following a qualitative research methodology, we examined the VTL's ongoing ICT practices (e.g., the use of their inventory system) and highlighted their ongoing organizational challenges. The study offers insights into how resource sharing cooperatives and collectives could be better supported by proposing design opportunities that facilitate sharing both physical objects and digital information about their use.

Ultimately, drawing on the findings from both empirical studies, in Section 6.3 we argue how modern smart contracting technologies can adequately support sharing economies of personal artifacts. To this end, we designed and prototyped a mobile service to enable the shared use of underutilized personal physical possessions at home (e.g., power tools, outdoor sports gear, toys). We then describe the design rationale, the system architecture, and reflect on future infrastructural and architectural opportunities for an eventual "in the wild" deployment.

6.1 Perceptions of Sharing Everyday Purchases

People regularly buy a significant number of goods and services. In the UK, for example, weekly household expenditure is averaged at £572.60 in 2018[2]. While

[2]UK Office for National Statistic. Statistical bulletin: Family spending in the UK. https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/expenditure/bulletins/familyspendingintheuk/financialyearending2018

many purchases are for immediate consumption and/or daily use, others may see significantly fewer uses and instead end up lying around our homes and garages until another occasion rises. A plethora of emerging sharing economy services (e.g., Peerby, BlaBlaCar) are using networked digital technologies to optimize the use of those underutilized resources (e.g., household items and vehicles) by sharing them with others. Sharing such not-in-use purchases not only improves their economic and environmental sustainability, but also helps to create and maintain social ties [Kennedy, 2015]. In addition, prior work [Dunn et al., 2008] has shown that spending money on others rather than oneself can lead to greater satisfaction from those purchases.

Consumer research (e.g., [Belk, 2014b]) distinguishes between collaborative consumption (i.e., sharing economy) and sharing. This distinction is made on the grounds of "expectation of compensation", as true sharing does not actually expect compensation. Despite the difference, both practices promote pro-social behavior, i.e., trust, mutuality, fairness and openness [John, 2017] and imply community-fostering [Kennedy, 2015]. Furthermore, Belk [2010] defined "sharing-in" as an act of inclusion and extension of our self to our nearest members of family and friends, and "sharing-out" as an act that involves dividing something between relative strangers (which is where he positioned most of the sharing economy services).

Following Belk's theoretical framing, we designed a study to explore current practices surrounding the physical sharing of everyday purchases, as well as our participants' affective experiences of this. Additionally, we wanted to map how "sharing-in" and "sharing-out" are represented in everyday consumption. Our research questions are as follows:

1. What type of everyday purchases have been shared or co-consumed the most?
2. How does one's satisfaction of a purchase affect subsequent sharing?
3. What motivational factors should user experience designers consider when it comes to sharing everyday purchases?

We developed a personal finance logging app for smartphones that allows one to manually record one's daily purchases, one's satisfaction with those purchases, and any follow-up sharing of the purchased item. We recruited 71 participants to use it continuously within a period of 30 days. In the remainder of this section, we briefly summarize related work, describe the study design, and discuss our main findings.

6.1.1 Background

Prior research has extensively looked at sharing personal material possessions in domestic environments (see Section 2.5) and within the broader context of the sharing economy (see Section 2.4). To the best of our knowledge, no prior work addressed sharing everyday purchases (i.e., physically, not simply posting the fact on social media). Of particular importance to our study is the work of Bellotti et al. [2015] on motivations that drive participation in sharing economy services. Drawing upon their findings, we wanted to understand the motivating factors in sharing everyday purchases and how they relate to sharing other items in the sharing economy.

As we illustrated in Chapter 1, the term "sharing" describes a wide range of acts and activities. What is more, in the context of consumer theory, Belk [2010] described it as a type of interpersonal interaction and distinguished the process of sharing from other consumer behaviors, such as gift-giving and reciprocal exchange of goods, by virtue of not requiring reciprocation. Belk used mothering (i.e., maternal caregiving) and the allocation of resources in a family (i.e., joint ownership) as two key prototypes for sharing. Similarly, Cappellini and Parsons [2012] examined the practices of food consumption within a family and concluded that sharing plays an important role in defining family identity. They argued that the family meal practice is closer to sharing than gift-giving: it reaffirms a family as a collective unit, rather than a group of individuals. These studies contextualized sharing activities within domestic environments and discussed them within everyday family practices and routines, where we expect the majority of purchase sharing taking place.

Furthermore, our work is motivated by the emergent trend of HCI research in personal finances [Kaye, Vertesi, Ferreira, Brown and Perry, 2014], which explores social, technical, and economic aspects around everyday user interactions with money. Kaye, McCuistion, Gulotta and Shamma [2014] interviewed 14 individuals about their current practices of dealing with personal finances and suggested that often money gets managed not only individually, but also for immediate family members (e.g., a spouse/partner, children). They concluded that modern financial software and online services do not often account for such common arrangements. Furthermore, they pointed out that mobile apps and systems for managing personal finance do not include the emotional component that often characterizes people's relationships with their finances. Our work accounts for both: (a) it incorporates emotions and (b) leverages a social component through collecting and reviewing self-reported satisfaction and inquiring whether the sharing or co-consumption occurs for each purchase made throughout a day.

Finally, drawing upon a qualitative inquiry of the Bristol Pound [Ferreira et al., 2015], a mobile payment system, which outlined opportunities for making new connection to other people, places, and communities while spending money, we try to quantify how much peoples' everyday spending and consumption are attributed to their social interactions. Last but not least, Dunn et al.'s work [2008] on spending money on others revealed that this promotes happiness. Hence, our secondary focus on how satisfaction mediates sharing in everyday purchases and consumption practices.

6.1.2 Study Design

In this study, we aimed at establishing an exploratory account of sharing everyday purchases. To facilitate this, we drew on the key sharing dimensions introduced in Section 3.3. At the outset, we established a common frame of references identifying *what* purchases are shared and *with whom* sharing take place stemming from the **Content** and the **Audience** themes. Subsequently, we detailed the **Motivations** and the **User Experience** themes to elicit motivational and experiential aspects of sharing everyday purchases.

In order to achieve our goal, we recruited 122 subjects in total, but only 71 of them actively participated in the study (55 of them were female). The data from active participants was used in the analysis. The average age of participants was 26.86 years ($SD = 6.59$), most of them live in Western Europe. Participants were recruited via specialized recruitment websites for user studies and through our respective universities mailing lists. They were required to speak English and to have a smartphone. Before enrollment to the study, participants were asked to answer a questionnaire that included questions related to demographics and number of purchases usually made per day. Participants younger than 18 years old or making less than one purchase per day were rejected from participation in the study. Participants needed to log their purchases using a custom-designed application and answer several questions whenever they bought something. Participants were compensated for their participation depending on both how long they took part in the study and how much data they submitted, but not more than the equivalent of 30 Swiss Francs for 30 days of participation. Some, however, participated without a financial incentive.

We developed a personal finance management app (for both Android and iOS) that allowed participants to add information about price, merchant, date, and category of purchase (see Figure 6.1a). In addition, participants needed to assign the level of satisfaction for each purchase on 5-point Likert scale: 1 being "very unsatisfied", 5 being "very satisfied" (Figure 6.1b). We also asked participants

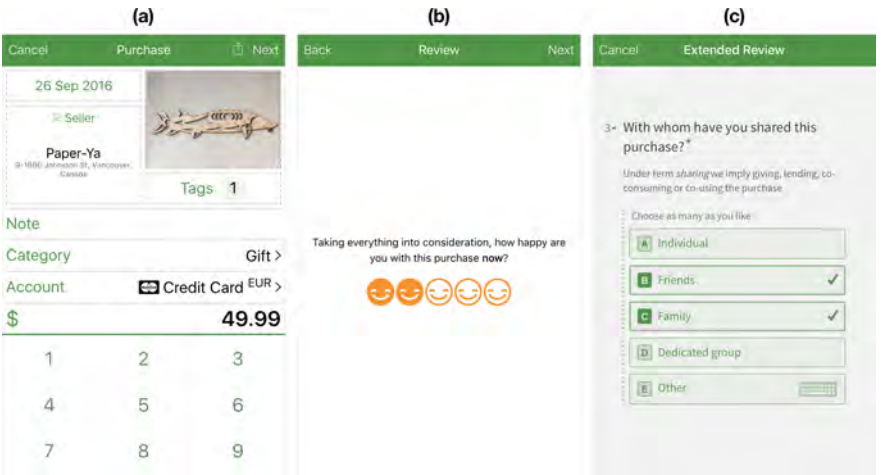


Figure 6.1. The app for data collection: (a) a purchase details screen; (b) a purchase review screen; (c) a purchase sharing questionnaire

to provide some information whether they were willing to share their purchase with anyone else, and whether it was subsequently shared or co-consumed (see Figure 6.1c). Participants could defer rating their satisfaction in case the consumption or sharing did not take place immediately after purchasing. A free-form text field allowed participants to indicate positive or negative experiences related to sharing each purchase. We excluded answers with senseless responses (e.g., gibberish, cursing) for these questions during the data cleaning process. Similarly, we removed the duplicated responses and the ones with unrealistic answers (e.g., exaggerated prices of the purchases). We distributed the application through both the Apple App Store and Google Play. While we collected data throughout 6 months, each participant had to log their purchases continuously within a period of 30 days only.

We employed a mixed research methodology to analyze the collected data. For numerical data related to purchases and satisfaction from them, we used frequency and regression analysis [Field, 2013]. For open-ended answers about participants' positive or negative experiences of sharing or co-consuming a purchase, we employed content analysis from grounded theory to count sharing instances [Glaser and Strauss, 2009]. The unit of analysis was the act of sharing a physical item (e.g., a pair of movie tickets). In addition to that, we engaged open- and axial-coding from thematic analysis [Berg and Lune, 2004] to extract emerging motivational factors from participants' quotes.

6.1.3 Sharing of Purchases and Satisfaction from It

On average, participants spent 50.8 Swiss Francs on 2.2 purchases each day. We collected detailed information from over 1700 transactions for a total sum of 44'500 Swiss Francs worth of purchases. We first report on the average frequencies of participants' shared purchases, then we inquire how satisfaction from them affect sharing, and finally we analyze participants' experiential accounts to identify factors that motivated them to share their purchases.

Over 40% of all purchases were related to immediate consumption (e.g., food, drinks). Purchases related to the "Home" category (e.g., groceries, rent) and transport expenses were the second and the third most popular categories (18% and 13% respectively). The next largest categories of purchases (nearly 7% each) were associated with entertainment (included experiences like movies or events), personal expenditure (e.g., medicines) and miscellaneous (various minor categories, like gifts or services). The participants also spent money on clothes but only rarely.

While a quarter of all purchases were shared (25.4%), participants were potentially willing to share or co-consume as much as 67% of their purchases under some circumstances (these were marked "sharable"). Figure 6.2 details the actual sharing and co-consumption behavior per category. The most shared purchases were related to the "Home" category (31% of all purchases in this category) and miscellaneous spending (38%), which includes vacation lodgings and services. The next-biggest set of shared purchases was related to entertainment and included experiences like movies and events (28%), and food and drinks (28%). The least shared were expenses for transport (13%) and clothes (15%).

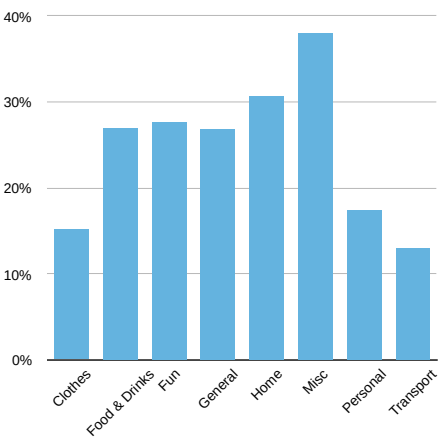


Figure 6.2. Frequencies of shared purchases by category

Our participants shared their purchases mostly with family members (47%) and friends (44%), sometimes with other individuals such as partners, colleagues or flatmates (21%), rarely with "a dedicated group" (5%). Please note that multiple selections were possible for this question (see Figure 6.2c). Most of

our participants did not use any apps to share their purchases. Those who did use "technology" for this, simply made arrangements via instant messaging; a few used social networking services, calls or e-mail. Rarely did dedicated online sharing services facilitate sharing.

We asked participants who did not share purchases with others the reasons why they did not do so. Half of the responses specified that "No-one has asked for it", around 33% indicated that a purchase was exclusively for private use, 22% suggested that there was simply not enough of it to be shared. Other reasons not to share a purchase included lack of personal gain (10%), hygienic reasons (8%), fear that a purchase would be either damaged or not returned (both around 4%).

Following Dunn et al. [2008] finding that spending money on others (e.g., giving gifts) promotes happiness, we looked at the impact of sharing (or consuming a purchase together with other individuals) on the satisfaction of purchasing it. Firstly, using the Kolmogorov-Smirnov test of normality we determined that our dependent variable – a level of satisfaction from a single purchase (measured on 5-point Likert scale: 1 being "very unsatisfied", 5 being "very satisfied") was not normally distributed. We subsequently performed a non-parametric Wilcoxson-Mann-Whitney test and found a significant association between satisfaction and sharing ($z = -5.99, p < 0.01$). Secondly, we aggregated the average satisfaction per participant and performed a t-test for matched samples. The analysis confirmed that purchases shared with other people were typically rated higher ($M = 3.97, SD = 0.65$) than the ones consumed individually ($M = 3.66, SD = 0.76$), as demonstrated by the parametric t-test: $t(60) = -2.85$, $p = .006$.

We further performed binary logistic regression to ascertain the effects of satisfaction and potential "sharability" of a purchase (i.e., whether a participant could share or co-consume a purchase with someone else under some circumstances) on the likelihood that participants share the purchase. The logistic regression model was statistically significant ($\chi^2(2) = 352.02$, $p < .001$). The model explained 25.6% (Nagelkerke R^2) of the variance in sharing purchase and correctly classified 74.6% of the cases. Both predictors, satisfaction from the purchase and its "sharability", were statistically significant ($p < .001$). Potentially "sharable" purchases were 19.7 times more likely to be shared than those that are used or consumed individually. Increasing satisfaction was associated with an increased likelihood of sharing a purchase (odds ratio=1.42, 95% $CI = 1.27 - 1.58$). To put it more simply: a more satisfying purchase has a higher probability to be shared or co-consumed.

6.1.4 Motivating Factors to Share Purchases

Next, we sought to understand what motivational factors drove people to share or collaboratively consume everyday purchases. Drawing on Bellotti et al.'s motivational framework of participation in the sharing economy [2015], we engaged in coding of the open-ended responses relating to our participants' positive or negative sharing experiences. Table 6.1 presents the motivational factors that emerged from our thematic analysis of our participants' experiential accounts.

Common theme	Occurrences
Social connection/Relationship	155
Sharing food, experience, fun and joy	91
Norms and reciprocity	90
Split cost/Save money	33
Provide help and support	31
Sustainability	19
Self-development	12

Table 6.1. Motivational factors of sharing purchases

In most cases (155 instances), sharing something was a way to create and maintain relationships within immediate family or friends:

> *"It was nice to share food with my family, especially [be]cause my brother-in-law was there and we don't get to see him that much."* (Evelyn, 26).

Enjoyment of sharing food and the overall experience of being with friends was the second most frequent category:

> *"I bought some things from a new store I found, selling local stuff. They had pralines made with aceto, which sounded weird, so trying them out with my roommates sounded like fun. Which it was. I also bought a pumpkin for carving, which really would only be half as fun alone."* (Roxanne, 27).

Social norms (e.g., gift-giving) and reciprocity (e.g., grocery shopping for a shared household) were also rather frequent among our participants:

> *"I paid for a friend and myself to climb at a local wall in return for him driving us there. It's always nice to reciprocate [a] favor."* (Ella, 28).

As shown in Table 6.1, utilitarian motives (e.g., to save money) was less frequent among our participants. What is more, group/collective purchases (e.g., to get a set of concert tickets) can result in some negative experiences, such as delayed payments, or create false expectations of reciprocity, as in the following case of a bill splitting:

> *"The cost-sharing helps my economy, but at times this can generate misunderstandings."* (Constance, 26).

Moral motives (e.g., sustainability), altruistic motives (e.g., provide help to others), and personal development were less frequent reasons to share. Roxanne provides an example that collectively describes the three:

> *"I [bought groceries and] cooked dinner, then shared it with my flatmate. Another friend texted me if I wanted to meet up, so I invited her over for dinner too. Since my flatmate had worked late and was tired and my other friend was in the middle of moving, it was nice to help both out by cooking for them. What's also positive is that there's still some food left, so I can take it along for lunch tomorrow. I've been trying to bring more food to work, so this makes me feel like I'm reaching a goal."*

6.1.5 Discussion and Implications

Our participants shared a quarter of their registered purchases with family and friends, and this co-consumption led to higher satisfaction than from purchases consumed individually. While acts of sharing are known to carry positive social values [John, 2017], our findings suggest that higher satisfaction from purchases could facilitate their sharing or co-consumption. One possible explanation is that participants wanted their friends or family to try things or experiences that they themselves enjoyed. Sharing occurred most often with family members and friends (often in the form of a meal), and was usually seen by our participants as an act of maintaining social connection, supporting relationships, and emphasizing togetherness [Cappellini and Parsons, 2012]. These findings suggest that sharing everyday purchases resonates with Belk's 2010 notion of "sharing in" – an inclusive process where people share with a social group as a way of strengthening bonds and extending an individual's sense-of-self through other people. While our findings suggest that positive social values of cooperation and participation driven by sharing might benefit our own well-being, it is reasonable to expect that they will also contribute to the development of sustainable communities. However, the motivational factors rooted in social values (e.g., sustainability) and empathy (e.g.,

provide support to others), albeit important, were less represented in our sample. Finally, in line with Bellotti et al.'s [2015] findings on participation in the sharing economy, our participants also aimed for convenience when co-consuming their everyday purchases (e.g., splitting car parking cost). This behavior is described by Belk [2010] as "sharing-out". While these utilitarian motives are dominant in the sharing economy, they were far less present in our sample of sharing everyday purchases.

Our initial enumeration of the motivational factors to share everyday purchases is a first step to inform designers of future services that involve sharing purchases. Even though our study revealed generally positive perceptions of sharing purchases, we encountered potential tensions. For example, we found several instances of possible negative consequences for co-consuming a purchase, e.g., when it comes to money management. Some of our participants reported that getting money back for a "shared-out" purchase (e.g., a pair of concert tickets) resulted in delayed payment and generated several misunderstandings. We speculate that service designers in personal finance [Kaye, McCuistion, Gulotta and Shamma, 2014] could account for that type of transactions to facilitate more positive user experiences, e.g., by allowing involved parties to quickly reach mutual understanding and agreement. One strategy may be to integrate automated reminders or send a to-do note to the counterparty related to a purchasing transaction. Similarly, future "social" personal finance apps could also support conversation, helping users to reminisce upon "together moments" with family and friends. Recent work, e.g., of Ferdous et al.'s [2017] illustrates how interactive technologies can orchestrate the sharing of memories during family meals.

Furthermore, researchers explored the role of online communities (e.g., [Ganglbauer et al., 2014]) and mobile technologies in supporting food-sharing practices to reduce domestic waste (e.g., [Farr-Wharton et al., 2014]). Conversely, in our study, the role of sharing food was central when it comes to social connection and experience sharing, and rather tangential in the discourse of environmental sustainability. In other words, our participants were largely motivated to share purchases based on their aspirations to maintain social relationships and a sense of community rather their environmental concerns.

Finally, given that our non-sharing participants largely did not share their purchases because no-one has asked them to do so, future personal finance apps (e.g., mobile banking services) could address this "missed opportunity" by prompting users to consider sharing or co-consuming them with others (e.g., after the purchase being made, or at the end of the day). Such persuasive mechanisms may not only help to minimize personal expenditure, but also to leverage social, hedonic, and environmental aspects of everyday consumption.

6.1.6 Summary

In the study described above, we examined the purchasing and sharing behaviors of 71 individuals, each over a period of 30 days, and identified their practices and perceptions of sharing everyday purchases. The most-shared categories of purchases were related to "home" expenditures as well as "experiences" (e.g., concerts). We found that sharing and co-consuming everyday purchases with others led to increased satisfaction levels. We also elicited seven common themes that could help user experience designers to further explore motivational and experiential factors that drive the sharing of everyday purchases. Lastly, we discussed future-looking design opportunities to leverage those factors.

On the whole, we observed that modern interactive technologies play a tangential role in facilitating our participants to share their everyday purchases. To put it more simply, the participants used a generic set of tools (e.g., instant messaging apps, emails) as communication channels to make sharing arrangements. Drawing upon the concept of social UX introduced in Section 2.6, we argue that mobile technologies could play a much more significant role in shaping peer-interactions in physical sharing practices.

In our view, the natural unfolding of the work presented here would be an in-depth qualitative inquiry to examine physical sharing practices of an existing sharing community in order to determine the specific role of mobile technologies in their activities. As a result, in the next section, we present a technology probe that we developed to elicit peoples' perception of participation and agency in a tool sharing organization. We report on individual and community-level findings stemmed from a field-testing of this technology prototype. We then distill a set of design recommendations for supporting tool sharing organizations through interactive technology and discuss them in the light of their emergent interpersonal and organizational challenges.

6.2 Encoding Digital Histories of Use into Shared Objects and Tools

The emergence and rapid adoption of social and economic models for shared use, known as the sharing economy, have enabled people to coordinate, acquire, distribute, and temporarily use many kinds of resources. In addition to commercial services such as Airbnb or Uber, an increasing amount of community groups and organizations have established cooperatives (e.g., libraries of equipment) that often prioritize environmental, social, and cultural values within their local

communities over economic gain. However, prior research has articulated several challenges that these resource-sharing cooperatives and collectives face. These include the large degree of anonymity and a general sense of transience among "community members", which can negatively impact organization endurance and growth [Bardhi and Eckhardt, 2012]. Odom [2014] further points out the lack of visibility of other members' activities and poor treatment of the shared resources (e.g., tools), which may threaten a cooperative's long-term sustainability.

Recent technological shifts to social, mobile, and cloud computing may offer a promising way to help document the creative potential of members, increase the appreciation of individual tools, de-anonymize members of resource sharing cooperatives and collectives, and potentially help create a stronger sense of community membership. To investigate this opportunity, we created Roaming Objects, a mobile application that aims to support the capture, retrieval, and sharing of digital experiences with tools that *roam* from one borrower to another. We deployed the application with 16 members of a tool-sharing cooperative over an eight-week period. Our goal was to use the Roaming Objects application as a probe to investigate people's attitudes toward and perceptions of digital records of shared tools, to support the capture and review of digital experiences with shared resources, and to explore how these experiences might shape their practices on individual and social levels.

Specifically, our two main research aims are:

1. to investigate how an interactive system can facilitate sharing "experiences of use" within a tool-sharing cooperative, thus bridging physical artifacts (e.g., tools) and digital narratives;
2. to explore opportunities for designing interactive systems that positively shape people's relations to shared objects and to the broader social tool-sharing organization.

This study makes two contributions. Firstly, it describes the design of the Roaming Objects system and findings from an eight-week deployment study in a tool-sharing cooperative. Secondly, it proposes design opportunities that facilitate sharing both physical objects and digital information about their use, thus offering insights into how resource sharing cooperatives and collectives could be better supported through technology.

6.2.1 Background

Our work lies at the intersection of two principal research areas: (1) the sharing economy and (2) studies of personal physical and digital possessions. We

described the attendant challenges of both profit-driven and non-profit forms of the sharing economy (i.e. platform co-ops) in Section 2.4. Subsequently, we examined the prior work from interaction design research on physical and digital possessions in domestic environments in Section 2.5. Below we additionally relate our work to the recent studies in HCI of DIY communities and review the concept of *digital histories of use* – the main design strategy we adopt in our study. Recent research in DIY communities [Kuznetsov and Paulos, 2010; Houston et al., 2016], including making [Taylor et al., 2016] and urban farming [Odom, 2010], examined the potential of digital technologies to support DIY practices. DIY communities share many commonalities with tool sharing collectives, e.g., emphasizing sustainability, resourcefulness, creativity, learning, and knowledge sharing over economic benefit (e.g., [Odom, 2010; Kuznetsov and Paulos, 2010]). In fact, tool sharing often plays a supporting role in these communities [Houston et al., 2016], as it enables DIY practices at large [Kuznetsov and Paulos, 2010]. Clearly, the implications of our study thus relate to DIY communities. However, tool sharing also has its own challenges, such as high demands of inventory management (incl. tool storage, maintenance, repair), space organization (e.g., to accommodate new tools), and often constraints on labor supply (e.g., to build volunteership) [Arif et al., 2015].

Today's smartphones make it easy to create, share, and review digital information and histories of our everyday objects. A growing amount of work investigated how interactive systems can account for digital histories that capture everyday things and everyday experiences [Benford et al., 2016; de Jode et al., 2012]. One theme within this work explored how histories of use [Benford et al., 2016] can catalyze strong attachment and perceived longevity [Odom et al., 2009]. Researchers suggested that wear and patina resulting from everyday use can be represented digitally through material [Gaver et al., 2006; Lee et al., 2016; Roesner et al., 2014] and spatial [Dong et al., 2014] histories. Other work explored how digital histories of individual and shared experiences can become valuable resources for self-reflection and social connection [Nunes et al., 2008; Odom et al., 2011; Petrelli and Whittaker, 2010], and prompt behavioral changes in people's everyday practices [Lee et al., 2015; Khot et al., 2014; Stusak et al., 2014]. We aim to extend this research by investigating how the accrual of digital histories of use around everyday tools might shape people's practices in relation to these things, and community members using them.

In summary, prior research outlined emergent challenges of local resource sharing cooperatives and communities. In this study, we specifically focused on three issues of resource sharing organizations: the large degree of members' anonymity [Bardhi and Eckhardt, 2012], poor visibility of members' work and

the lack of accountability for shared resources [Odom, 2014]. Our work aims to build on this prior research with a view to identifying design opportunities to attend those challenges. In particular, we explore how interactive technologies can be leveraged to support capture and review of the digital experience with shared resources.

6.2.2 The Roaming Objects System

Digital services have made it easy for people to share everyday objects such as household items, domestic electronics, and even vehicles. However, these services in principle can also allow the personal experiences of sharing objects to be captured. Such experiences can catalyze personal attachments with the object itself. They can also spark curiosity about previous use or ownership of the shared object and, in doing so, provoke social speculation and intrigue about it. The checkout card in a library book offers a simple example of how histories of use can be captured in a borrowed object. Like books, equipment in tool libraries *roams* among its members. Inspired in part by the checkout card metaphor, we designed Roaming Objects, a software ecosystem and interactive system that aims to support the capture, retrieval and sharing of digital experiences with physical objects. Our research methodology draws on related approaches, including technology probes [Hutchinson et al., 2003] and research through design [Fallman, 2003; Zimmerman et al., 2007]. These approaches can help in understanding current user needs in a real-world setting as well as can inform the design of new interactive systems and artifacts to adequately support those needs. Ultimately, they opened a critical dialog on the role of technology in everyday life and facilitated the transfer of ideas between research communities.

Design Process, Rationale and Implementation

In a review of empirical studies (a sample of which are described in Section 6.2.1) that examined how material and virtual possessions support and record interactions with individuals and groups, we identified three conceptually related, yet distinct design strategies that articulate how personal or social digital data could be valuably associated with physical objects: accrual of metadata [Odom et al., 2011], tracking provenance [de Jode et al., 2012] and collecting histories of use [Benford et al., 2016]. Using these strategies to frame our next steps, we then ideated, sketched, and refined several scenarios that explored different social and material contexts in which such interactions may take place. Importantly, we also explored how system concepts could shape people's experiences on individual

and social levels at the time of use, as well as over time as histories accumulated around different objects.

Our concept development session also explored BookCrossing initiatives (`www.bookcrossing.com`) and sport gear rental shops where people borrow specialized equipment (e.g., for ski touring). This gave us a breadth of different kinds of user-generated content that a system could capture and display in and across experiences revolving around a specific object. Our system's infrastructure was in part inspired by the Tales of Things tagging platform that provides an online presence to everyday objects by augmenting them with owners' anecdotes [Barthel et al., 2013].

The software ecosystem to support Roaming Objects consists of (1) a set of augmented physical rental objects, (2) a mobile application to capture and share people's experiences with them, and (3) a web service to maintain the inventory of objects (and associated metadata) and to coordinate the practical details of loaned objects exiting and returning to their home organization.

Augmented Physical Objects. We ideated various application scenarios to explore how different kinds of user-generated content could form an object's digital history (e.g., audio notes, real-time video broadcasts, live location tracking). Ultimately, we decided to support three content types: textual information (e.g., comments, a five-star rating scale), personal media (photos and short video clips) taken during the rental period of the equipment, and location details (e.g., GPS points of interest). Inspired in part by the many successful deployments of the Tales of Things platform [de Jode et al., 2012; Barthel et al., 2013], we decided to also use QR codes to access the digital history of the object. Additionally, QR-codes offered an easy, inexpensive approach to tag various physical objects without changing their design or dramatically compromising its aesthetic integrity. Both of these factors were important to the tool library that used Roaming Objects in our field deployment.

Mobile Application. The mobile app enables people to "connect" to a borrowed tool to add or retrieve digital information encoded "into" the tool (Figure 6.3b). An overview page shows the list of borrowed tools and their return date (Figure 6.3a). System-generated data is added automatically (e.g., how many times a tool was lent, how long it was used). User-generated data can then be added manually using the mobile app. We incorporated a range of disclosure settings, from full name with a profile picture to completely anonymous, to let users decide how their identity should appear once their experience is shared with the tool library

Figure 6.3. (a) The view of the companion app, which shows a list of currently borrowed items by the user; (b) The view of the item's profile as seen by the user; (c) The UI of the web-based inventory management system with details of a tool as seen by a volunteer

members. We allow users to change this setting over time (e.g., if they become more or less comfortable with disclosing their identity).

Web-service. A web service handles inventory, storage, and retrieval of shared objects. The backend is implemented using the Java-based Spring framework and a non-relational database (MongoDB) to enable robust deployment and scaling. A companion web application (Figure 6.3c) enables rental shop administrators (e.g., volunteers) to maintain tool inventory, retrieve a status of a tool, and notify the current user about an upcoming expiration date. End-users of the mobile app (i.e., borrowers) have no direct access the web application.

We specifically designed the web application to support creating new inventories (e.g., though generating a QR code for each item) and to extend the existing ones (e.g. using already established inventory codes). We built the front-end UI using Dust (a Javascript templating language). Importantly, we did not design the Roaming Objects ecosystem to be a solution to optimize experiences of shared objects. Rather, Roaming Objects is devised as a technology probe [Hutchinson et al., 2003] to explore how these experiences might shape sharing practices on individual and community levels.

6.2.3 Field Deployment

We conducted our field study with a non-profit tool-sharing cooperative called the Vancouver Tool Library (VTL), which is located in Vancouver, Canada. At the

time of the study (the winter of 2016), the VTL cooperative had over 2000 tools in their possession and served over 1500 members (although not every member is actively borrowing tools). It is a collective community resource that is run primarily by volunteers (around two dozen) and is coordinated by the board of directors (seven individuals elected by and among members). The tools varied from simple hand tools for home and garden maintenance (e.g., jack plane, pipe clamps) to high-end power tools (e.g., table saws, air compressors). More unusual equipment, such as precision sewing machines and a vintage cider press, were also available.

To implement Roaming Objects in the VTL's street level location, we used their existing alphanumeric inventory codes from a subset of tools (around 100 items) instead of creating new (QR) codes. This choice enabled us to easily scaffold the VTL's existing organizational infrastructure and more fluidly integrate Roaming Objects into cooperative members' everyday practices. Each inventory code used the unique identification of the corresponding tool within the Roaming Objects system. A key issue for our field study was that we needed to build up a repository of digital histories of use of various shared objects in Roaming Objects in order to make the system appealing to cooperative members and investigate our research goals (a common challenge new crowdsourcing systems face [Zimmerman et al., 2011]. Thus, we decided to focus on the most frequently used tools for inclusion in Roaming Objects (e.g., sanders, power drills, and Mitre saws). The repeated rentals of these tools enabled them to accrue rich histories that captured various projects that members created with the tools. We also bootstrapped provenance details to these tools. Tool library volunteers assisted in registering each time a tool from the Roaming Objects tool subset was borrowed via our web-application, which ran in a web browser on their centrally located desktop computer that logged tool check ins/outs.

Participants, Data Collection, and Analysis

Study participants were recruited through various approaches. We advertised our study on the website of the tool sharing cooperative, their social media page and included details in several weekly newsletters. On a few occasions, we also distributed flyers on site at the VTL. The Roaming Objects mobile application was implemented in iOS; thus, one requirement of our study was that participants already own and use an iPhone. In total, twenty-one members participated in our study and installed the Roaming Object mobile app on their phone. The average age of participants was 35.5 years old ($SD = 9.31$), five of them were female, two described their gender as non-binary. Our study participants held

various occupations, including librarian, lawyer, film-maker and cook. We asked participants to use the Roaming Objects to annotate and share the ongoing work that they did with the borrowed tools.

We conducted the study in the winter of 2016 for two months. During this period, we twice observed participants for several hours at the VTL, and used the shadowing method [Beyer and Holtzblatt, 1997] to follow a volunteer at the checkout desk (Figure 6.4f). This enabled us to understand potential challenges in logging information in the Roaming Objects system and to provide guidance if needed. During these field observations, we also took note of activities occurring in the VTL (e.g., tool maintenance and organization). These observations clearly illustrated the lack of visibility of members' work outside of the tool library, and the lack of accountability for the tools themselves. We took extensive notes during multiple informal, open-ended conversations with key stakeholders (i.e., volunteers and members of staff) and took accompanying documentary photographs.

At the end of the two-month period, we recruited a subset of our participants for follow-up interviews. To elicit rich accounts of usage, we particularly looked for participants who had different experiences with the tools in terms of: (a) what they produced with tools; (b) how they may have valued the tools; and (c) their level of experience with the tools. In general, we were looking for "power-users" (who borrowed tools more than once during period of the study) to better understand how Roaming Objects may have shaped their relations to the shared tools. After reviewing the digital content that participants submitted to the system, we excluded five participants from our interviews due to their infrequency in tool-borrowing. The remaining sixteen participants agreed to take part in semi-structured follow-up interviews to discuss and reflect on their experiences with the system. Note that at this stage, we sought to detail the **Experiences** subtheme within our categorization of the key design themes for technology-mediated sharing (see Section 3.3), therefore we developed our interview script around eliciting experiential accounts of the use of Roaming Objects. Each interview session lasted approximately thirty minutes, was audio recorded and transcribed verbatim. We conducted interviews and took extensive field notes; findings after each interview were captured immediately in reflective field memos [Glaser and Strauss, 2009], which we reviewed throughout our analysis.

Our data analysis drew on various sources from our fieldwork: participant observations, participants' reports on the rental experiences through the Roaming Objects app, and semi-structured interviews. Our process for data analysis consisted of several stages. Firstly, we used affinity diagramming [Beyer and Holtzblatt, 1997] to understand the collected data thematically and to model

connections and differences across participants. We held bi-weekly meetings first to establish a common coding strategy, and later to discuss emergent findings. We followed an iterative process, going back and forth between the data, the researchers' notes, and the emerging structure of empirical categories, which we developed through recurrent reading of the material. We also held meetings with researchers outside of the project to challenge our assumptions and to corroborate the themes. We distilled three sets of results that reveal how Roaming Objects mediated people's experiences, and we explored how these experiences might shape their practices on an individual and community level. The themes that emerged are not orthogonal; they describe intersecting characterizations our participants' sharing experiences. In the following sections, we present examples that help capture these themes and support them with participants' quotes from follow-up interviews. We use pseudonyms to describe study participants.

6.2.4 Overview of the Findings

Despite the relative simplicity of Roaming Objects, it elicited a range of reflections and reactions across members of the tool library – from contemplations on personal relations and uses of tools, to deeper consideration of their involvement on the community level, to mindful attention to the care and sharing of tools and projects.

While the library's inventory system (`www.myturn.com`) provided comprehensive statistics about the registered rental transactions (e.g., who rented the tool, when the tool was checked out and returned, and any associated fees incurred from the rental), details of the borrowers' experiences were largely unknown to these different library stakeholders. Volunteers at the VTL attempted to gather information about members' experiences with tools through written reminders placed on and near the check-out computer (Figure 6.4d). However, it was insufficient to capture the breadth of members' tool-use experiences. Our in-person observations revealed that volunteers and management used post-it notes to communicate information about tool-related issues that required attention (Figure 6.4e). Yet, these notes were easily misplaced and often lost.

Over the two-month field study, 16 participants submitted their experiences with 49 different tools. Participants rated the tools and left detailed annotations of 19 personal projects that contributed to the digital histories of the tools. Overall, participants borrowed a diverse selection of equipment, ranging from hand tools (e.g. chisels, clamps) to power tools (e.g. mitre saws, drills). The most reviewed tools were sanders, drills, and planes. The digital histories accrued by Roaming Objects were perceived as valuable not only by the VTL members, but also by volunteers and the management, who were interested to know how the tools

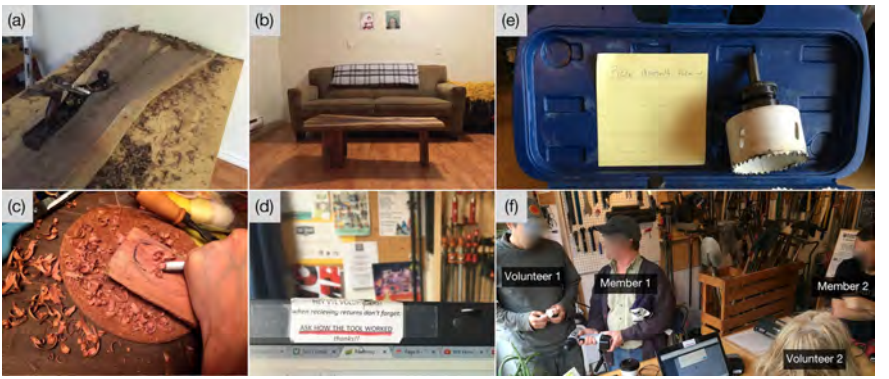


Figure 6.4. (a) work-in-progress project; (b) finished wooden coffee table; (c) process of carving wood; (d) message for volunteers: `"When receiving returns don't forget to ask how the tool worked"`; (e) post-it note pointing to the broken item: `"Piece doesn't turn"`; (f) shadowing volunteers at the checkout desk at the Vancouver Tool Library site (street level)

were used, what projects members were working on, and whether tools required any repair or maintenance (e.g., a library volunteer could provide timely tool maintenance after a prior user left a comment indicating that the edges of a jigsaw were dull). Before the deployment of Roaming Objects, this information was not consistently available to key library stakeholders as there was no formal policy established to collect members' tool-use experiences.

In what follows, we describe the ways in which Roaming Objects shaped participants' perceptions of (i) their individual and personal practices with shared tools, and (ii) their participation and agency in the broader tool-sharing community. We also describe our insights into how Roaming Objects mediated participants sharing experiences and prompted prospective reflections on opportunities and issues in this emerging design space.

6.2.5 Individual-level Findings

While browsing through the collection of pictures linked to a hand drill at the Roaming Objects mobile app Conan, 59, explained:

> *"It is all about the project, the tool facilitates the end-result."*

As reflected in this statement, the collective use of the Roaming Objects system yield insights into the central role shared tools played in the enabling creative

potential and practices of the members through accruing digital histories documenting their personal projects. These projects were diverse and spanned from home and garden maintenance to building everyday artifacts (e.g. a wine stand) to making creative gifts for others (e.g. pizza paddle). Personal projects were documented through the app as a set of pictures and textual descriptions, all of which revolved around a single project. Submissions varied from complete (Figure 6.4b) or incomplete projects (Figure 6.4a), or described the process of making (Figure 6.4c).

Self-development and Learning

Participants typically put a significant amount of effort into the process of learning how to use a shared tool. A common motivation for this effort was to build and develop their competences for successfully completing DIY projects. For example, Reagan, 33, reflected upon how self-development and skills acquisition over time is crucial to his overall personal progress:

> *"I have accomplished my task with a tool, but I was wondering what would be the better tool or technique to accomplish my task quicker, less messy and easier. I felt successful but perhaps not most optimal."*

Self-development was not only attributed to pragmatic skill acquisition; it was also illustrated through emotions (e.g., frustration and elation) that participants discovered through the process of using the tool:

> *"If it took a lot of effort to understand the tool and use it properly, it kind of takes on an emotional journey that allows you to discover the tool itself and discover different aspects of myself. In a way it tests you and pushes your limit."* (Liz, 29)

Personal Creative Practices and Potential

Personal experiences with tools provoked curiosity and speculation of the circumstances where people use them, for example in their own homes (see Figure 6.5a):

> *"There are so many layers of history in the flooring, 2–3 layers. It is interesting to go through them and to see what material they were using in those times. Flooring is probably 30–50 years old. The heat gun revealed old wood that was used in a flooring. The floor was there from 1900s there, when it was first build."* (Paula, 39)

Figure 6.5. (a) A participant showed how a heat gun revealed an old flooring; (b) An unconventional use of a cider press for a scavenger hunt challenge

Sometimes the borrowed tools were used in divergent ways, which led to vivid and memorable experiences. For example, one participant included the vintage cider press as a prop in a photographic session (see Figure 6.5b) for a competition she wanted to participate:

> *"I have used the cider press unconventionally as a part of the scavenger hunt challenge featuring the XIX century theme. I have covered up the plastic parts of it to look more appropriate for that epoch. It was a cool staged picture, everyone [the tool library community and contest jury] would like it I am sure."* (Dorine, 32)

Several participants reported that having the capacity to review other members' experiences with the tools was valuable for supporting the process of beginning and developing a new project:

> *"I like to see other people creations, whether it is from workshops or [how] they look online. You actually see it with a given tool that was used in a process. I think it is pretty neat. There is a bit a curiosity [as to] how they did it. Would I do it differently?"* (Stefan, 40)

Archiving Histories of Use: Utilitarian and Symbolic Meanings

The Roaming Objects enabled people to create and archive digital records of their personal projects and activities with borrowed tools. Personal digital archives are often represented in numerous digital forms, such as collections of pictures, notes and video clips. Those collections served as a diary for some of our participants that they could revisit and reflect upon whenever they needed to:

> *"I like the idea of packaging of the experiences. It would be an archive of those many experiences around the tool and the creation of another artifact. It would be great to review them if I needed [to]."* (Silvana, 54)

Often the personal records archived though Roaming Objects serve as a platform for creating narratives around tools that could be used in future (digital) storytelling:

> *"[It is exciting to discover] how old the item is, it could have a different meaning to everyone. That would apply for various antique objects. If it is very old, it would be fun to know how it was fixed if it was broken. Following ownership would be also interesting to know."* (Dorine, 32)

Digital records are linked to the personal accomplishments achieved while making something, especially if a final project turned out well:

> *"I wrote how I applied the tool [a heat gun] in my [guitar restoration] project to remove the plastic headstock overlay. I have attached the [final] photo, not in the process of working on the project. I left the photo because it is very visual."* (Reagan, 33)

All our participants submitted at least one annotated picture to document the project in order to complement plain text descriptions. In turn, failed accomplishments were kept by participants for themselves and not shared publicly within the tool library members:

> *"If our project would not fail, I would put more content to the submission. Now we just have holes everywhere on the wall."* (Ashby, 26)

Collectively, these reflections help to illustrate how the Roaming Objects provoked personal reflections around the shared tools and demonstrate what our participants valued in them. Participants shaped personal practices and developed relations to shared tools in a variety of ways: from spending time learning the tool through exercising personal creativity, to representing themselves using the means of digital archiving. We now describe how sharing tools shape peoples' practices and attitudes at the broader community level.

6.2.6 Community-level Insights

Participants expressed a great interest in learning the previous history of items, and any associated story that it carried from its previous ownership. For example, one reflected on the social aspirations embodied in the system:

> *"Even just for the name 'Roaming Objects', I like the imaginary that it evokes. It speaks to these things that are around us, that are shared and we do not know their story. From the temporal point of view, we have got no sense of the history of the object other than we know it has being used by someone else. And when it leaves our possession, we do not know what happened there[after] either."* (Stefan, 40).

Getting Benefits from the Community of Makers

In a handful of cases, participants inferred the quality and reliability of the tool based on the previous digital records found in the app:

> *"I saw the picture of the wooden desk someone built. I have learnt from it [how] this drill was powerful enough and it might be easy to control."* (Vincent, 18)

Others were looking for help and advice for their own project:

> *"I am personally looking to reach out to people with skills and experience with these particular tools. If there would be an indication of the skills regarding the tools, I would definitely ask for [other community members'] advice. I would be also willing to share my own experience."* (Liz, 29)

In these instances, both participants assumed the role of receiver of the shared information, aspiring to learn from the community (e.g., by reaching out to expert amateurs).

Providing Functional Guidance and Advice

Participants were interested in not only receiving feedback about the best tool or technique for their task at hand, but also desired to share their personal experiences with others:

> *"[I have included some information about] what benefit I have found and how I use the tool. I have spent a lot of time trying to get this right, I can help you avoid that by the giving you shortcut, the most optimal way to do that."* (Reagan, 33)

In this instance, Reagan demonstrated the role of sender in the hopes that others will learn from his tool-use experience.

Our participants documented the functional capabilities of a tool and their personal experience from their use:

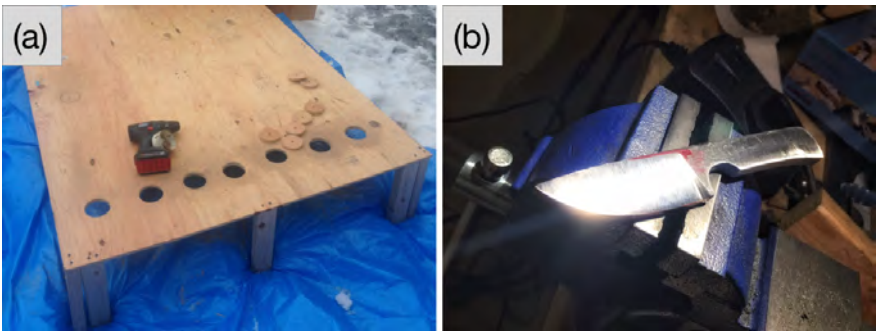


Figure 6.6. (a) Josy illustrated the use of the tool; (b) Vincent emphasized a power for the tool making a beveled edge on metal

> *"I have uploaded a picture of the bevel grinding [see Figure 6.6b] to show the power of the tool that it can be used for the metal, not just wood. I also wrote how I felt while using that."* (Vincent, 18)

Several participants also incorporated instructions for the projects into their submissions to guide others who face a similar challenge:

> *"The picture that I chose shows the project pretty well [see Figure 6.6a]. It clearly shows what the drill is being used for: to make these particular holes in the bed base. I have chosen this particular angle to clarify what I have used drill for."* (Josy, 28)

Inspiring Others in Making and Posting

We have received detailed submissions (in the form of pictures and textual descriptions) that aim to promote acts of DIY and inspire others to start own projects. Some participants were particularly comprehensive specifying amount of effort and costs involved to finish a project:

> *"What I have shared [about this project are]: it did not cost me much, it did not take a lot of time, I used free recycled material and that I am happy with the outcome."* (Stefan, 40)

Most of our participants read through the posts submitted by the previous borrowers before sharing their own experiences, which was often cited as a key factor motivating their contributions:

> *"When I saw that previous post about a table: good photographs and a short description about the coffee table [Figure 6.4b], I thought ... oh, I have got some pictures. I am gonna put together couple of sentences. Seeing this post I was kinda guided in terms of content."* (Conan, 59)

Community-fostering

Participants drew on Roaming Objects to project and reinforce shared aspirations, values, and interests among cooperative members:

> *"I find that it is very appropriate that I can add to the narrative of the tool. This way I can simply say that I am a maker too and feel a part of the community. That I have shared interest."* (Silvana, 54)

Furthermore, participants were interested in building and expanding their social circles through sharing physical artifacts:

> *"This [Roaming Objects] platform has a potential to create a sense of community, or community-inspired projects where people can share projects on a more complete scale by indicating the different tools that they have used throughout the project. It would be inspiring for people who uses this app to spark discussion or even collaborations."* (Liz, 29)

Liz reaffirmed the value in contributing to the tool library community by creating, preserving and sharing a tool's digital histories:

> *"I see the value of creating a broader, extended identity and the meaning of the tool speaking to the community and the users to form an opinion about it [tool] and make an impact for its users though the tool beyond what it actually is."*

This quote illustrates the potential of decoding and encoding histories of use to play an important role in creating sense of tool sharing community at large.

Collectively, these reflections help illustrate how peoples' perceptions of the tool sharing community formed and shaped throughout the use of the shared objects. Roaming Objects stimulated speculation about the tools and their value on a broader community-level, based on the digital histories the tools accumulated throughout their use across members of the cooperative. Our participants exhibited both altruistic and utilitarian motives when it comes to interacting with other members, and highlighted the importance of the new kinds of interactive systems, such as Roaming Objects, to support and nurture the tool sharing community. In the following section, we provide further details about the challenges and opportunities that participants raised over the course of the study.

6.2.7 Reflections on the Roaming Objects

At a general level, Roaming Objects not only shaped individual relations to rental tools and prompted contemplations on tool-sharing community at large, but also offered prospective reflections on opportunities and issues within the design space for tool-sharing practices.

Interpretations and Purpose of the Roaming Objects

One of the main benefits that the Roaming Objects provided is a way to organize different kinds of information related to the project at hand in one place. This included both machine-produced forms of information and metadata captured by virtue or use of the platform infrastructure (e.g., GPS, return date of the tool), and human-produced digital records through directly taking and uploading the information (e.g., photos of projects, textual annotations). Our participants valued the utility and ease of reviewing different digital information associated with the project (and subsequently with tools) in a single place. Roaming Objects introduced structure and hierarchy that helped to retrieve and review those digital records capturing prior experiences of use:

> *"For me [it] was very exciting. Because right now my personal projects are all over the place, some descriptions are sent over email or WhatsApp, some pictures on Instagram. Usually the experience is really fragmented. And that's a joy of your app, where all this fragmentation is taken care."* (Silvana, 54)

Many participants indicated the need to accommodate the "transformation" of the captured personal digital experiences with tools over time (e.g. in the form of "before and after" pictures or step-by-step descriptions of the different stages of a DIY project), in particular when those experiences are subsequently shared with broader audience. These temporal transformations will help the user to review their own progress and provide achievable milestones for others who want to start a similar project:

> *"It might be relevant to have a series of steps related to the tool or project if you are trying to accomplish something in a certain sequence. If someone was inclined to upload a series of pictures of each step, especially with the things you need to assemble or disassemble, just to know what the steps are, it would be very useful."* (Reagan, 33)

Next, when it comes to the borrowing decisions, the provenance information (e.g., manufacturer) and tools description (e.g., category, technical details, func-

tional scope) provided in the application supported them to choose an appropriate tool. For example, Sunny, 24, described how pictures of the tools and textual descriptions shaped his capacity to make informed decisions about tool selection:

> *"Given that there are lots of user-generated information, I can just browse the app and see what I need before actually going to the library. What are the dimensions of the tools that suit my need."*

Participants also highlighted the need to ensure the quality and reliability of the tool before deciding to borrow a specific tool. In the event of malfunctioning, this should be clearly communicated with possible alternatives presented to the user.

Another observation that became apparent from our data analysis is the opportunities for interactive systems to facilitate collaboration in a digitally distributed way, for example, via comments and support through Roaming Objects. Several participants expressed an interest to share their experiences to the wider audiences beyond the tool library community (e.g. on social media), suggesting that the shared content produced within Roaming Objects can be interoperable (e.g., seamlessly added to and remixed within other platforms). It was also common that participants collaboratively built projects with friends or family members that provided an advice or, simply, helped during the process of making. For example, Liz indicated that she would be interested in recording a video of herself carving a spoon from a chunk of wood (see Figure 6.4c); however, she could not hold the phone during the process of making to capture the whole experience. Including others in the process of production of the digital content plausibly can inspire people to collaborate on a common project as well:

> *"I could not find a right place where I could put my phone to record the process. My hands were busy when I was working on it. I almost need[ed] someone to be staying besides me taking videos to be able to zoom in and focus on the tools meeting the material. This part would be effective and inspirational to share with others. Since I am working by myself, video recording was not that easy." (Liz, 29)*

Implications for Privacy

An interesting discussion with participants arose around the issue of privacy. The Roaming Objects application built in support for participants to choose various levels of self-disclosure – from completely anonymous, to initials only, to full name with a profile picture and email (see Figure 6.3b) – when sharing their experiences. Most of the participants left their full name as default to annotate

their submission. However, few noted that progressive disclosure mechanism could be beneficial upon commitment to collaborate or response on the reach-out inquiry. In particular, it became evident when participants reflected about lending their personal items outside of the tools, such as lending a baby stroller that is not in use anymore. In these cases, participants were particularly cautious about disclosing their personal details:

> *"By default, the app might want to ask a user to pick the nickname or something that the user is known of. For example, if I have decided to contact this person about some tools or project: to collaborate or actually meet in person, one should be able to confirm whether he or she would like to share more personal details." (Liz, 29)*

Many of our interviewees also refrained from uploading pictures with their real faces while annotating a tool and chose a neutral image or personalized artwork to represent their profile (see Figure 6.3b). Nevertheless, some decided to snap a selfie as a personal avatar to de-anonymize themselves and/or build more attractive social profile. Besides, overly restrictive profiles were not considered to be trustworthy:

> *"There is a personal value that I would not make an anonymous review. It is important to leave my identity, if I could make some kind of personal judgement in fairness to the people [with] whom I am interacting. It is about honesty in communication. That's means that sometime I do not leave the review at all."* (Stefan, 40)

Future Applications Beyond Tool Sharing

Overall, participants regarded Roaming Objects as a useful tool to support sharing personal digital experiences through sharing tools. Furthermore, several study participants suggested applications for our system beyond tool sharing organizations. Participants indicated various platform co-ops that may benefit the Roaming Objects collect their histories of use, such as bike or car-sharing initiatives:

> *"I am thinking of car co-ops. Sometimes it is about the journey, not about the destination. I went to the grocery store to get groceries, not sure whether it is a compelling story for people. But sometime, the story could be: 'Look, I have moved to a new house, and the vehicle helped me doing it'."* (Stefan, 40)

They also named applications from tracking loaned money to documenting time banking activities to annotating rental sport gear (e.g., for skiing or kayaking) with personal experiences:

> *"It would be a pretty good resource for anything that is rented, [such as] equipment [or] a mountain equipment coop. People rent their snowshoes, for example. It could have some explanation of their trip with some pictures that would encourage other people to do similar thing."* (Leanora, 40)

Collectively, these reflections help to illustrate how the Roaming Objects yielded future-looking opportunities to support resource sharing cooperatives, and collectives, and provoked discussion about personal virtual possessions and privacy implications associated while sharing them.

6.2.8 Addressing Challenges of Resource Sharing Cooperatives

Our findings show that the Roaming Objects system provoked personal reflections about shared tools in diverse ways: from spending time learning the tool through exercising personal creativity, to representing themselves through digital capturing, sharing, and archiving experiences. We found that these shared digital histories of use in particular stimulated speculations about shared tools themselves and their value on a broader community-level over time. Collectively, these findings suggest new opportunities and issues for designing technologies for resource sharing cooperatives and collectives, which we turn to next.

Reviewing and contributing to the history of a tool, supported and enhanced cooperative members' individual experiences in exercising their creativity and developing competences with the tool. In several cases, these practices also inspired members of the cooperative to start their own DIY project and encouraged the re-use of the shared resources. These findings suggest that recording and archiving experiential use histories enabled members to gain valuable glimpses into the largely unseen practices of how tools were being applied in a range of members' respective everyday projects outside of the site of the tool library. This, in turn, helped reinforce and sustain higher-level community values, such as creativity and everyday resourcefulness [Wakkary and Maestri, 2007]. What is more, tool histories can be a useful instrument to address emerging challenges in DIY and maker communities, where researchers have repeatedly reported detachment between DIY documentation and created artifacts [Kuznetsov and Paulos, 2010], or emphasized the inability to track outcomes from shared maker spaces [Taylor et al., 2016].

There are opportunities to scaffold this approach and further improve the visibility of the members' activities. For example, an added feature could remind borrowers via a push-notification service (e.g., an e-mail or SMS message) to

review and rate the shared resources they were utilizing through tighter integration with existing inventory platforms that hold records of rental transactions. Additionally, lowering the barrier to creating and sharing digital histories of use through offering simple automated recommendations (e.g., "Members who used this tool also borrowed…") could also offer a lightweight and feasible, yet promising opportunity to better support re-using existing resources within cooperatives and perhaps, more broadly, any grassroots rental-driven organization.

We also found that accrued digital histories of use became useful indicators for the volunteers of the tool library to ensure up-to-date and detailed inventories, timely maintenance and repair of the tools. This decision led to an increased overall accountability of the tools among volunteers and members. It also better supported decision making processes among members in terms of choosing the appropriate tool for a job. Resonating with the study of Hedegaard and Simonsen [2013] on retrieving elements of user experience information from online product reviews, the Roaming Objects system enabled community members to document personal use-experiences of a *specific* tool. This helped to avoid misunderstandings (e.g., not the right tool for a task at hand) and frustrated returns (e.g., due to the dull blade of a jigsaw). It also suggests an opportunity for sharing co-ops to make resource identification more explicit, for example through tags (e.g. smartphone-readable QR codes), as well as more publicly available through distributed networked systems (e.g., website, mobile apps, situated displays) to better support members in reviewing *the social profile* of a shared item prior to making a borrowing decision. This information could also include data about an item's maintenance, along with accrued histories of use – automatically generated and kept up-to-date. For example, in the context of a sport equipment coop, listing details, such as how long a pair of skies was used throughout the season and its maintenance schedule, could increase an item's overall accountability.

Our findings also revealed how Roaming Objects offered a platform for members to choose to de-anonymize their community membership if desired and on their own terms. For example, members were able to create personal profiles with various levels of social disclosure to mitigate their privacy concerns. Despite this feature, the vast majority of the participants decided to use the default setting that showed their actual names, and continued using this setting. This suggests an opportunity for exploring how the technique of progressive self-disclosure – the gradual revealing of one's identity or individual information in relation to a shared resource – could be leveraged to different degrees of sophistication in future systems aimed at building trust within community membership [Lampinen et al., 2015].

These findings also suggest an opportunity for exploring how progressive self-disclosure could play a role in designing future systems, which would better enable and sustain a stronger sense of shared practices, values and intimacy between the tool library members and the community as a whole to emerge overtime. For example, future systems could offer members an overview of their activities with tools accompanied by information that suggests a set of potential social encounters (e.g., based on members profiles and preferences) through the tools. This may offer promise in terms of creating *bridging ties* and strengthening *bonding ties* of the members of the cooperative [Lampinen et al., 2015]. On a higher level, these findings show that striking a balance between making members' practices more visible, while enabling them with diverse disclosure techniques could be crucial to overcoming challenges of transience and anonymity [Bardhi and Eckhardt, 2012], and sustaining community growth.

6.2.9 New Opportunities for Digital Histories of Use

Roaming Objects aimed to mobilize and extend Odom et al.'s [2014] proposal that the placeless quality of virtual possessions can enable them to accrue social metadata. They argued that virtual possessions enriched with social metadata can be a valuable resource for supporting individual and group interactions, as they move between virtual environments and the real world. While Odom et al. reported on this phenomenon in the context of teens' and young adults' domestic lives, it emerged in numerous instances in our field study. For example, Josy drew on digital images, her own textual annotations, and the comments of other participants to construct a narrative that communicated the significance of her project (see Figure 6.6a) to create holes in the bed frame – which was to allow the flow of air to circulate in order to avoid condensation in her van. Josy and many other cooperative members frequently relied on their mobile phones to provide pictures and metadata annotations to construct and share narratives of use, and to reflect on the result of their respective work with a tool.

Our findings indicate that Roaming Objects was largely successful in addressing fragmentation by providing a cohesive digital place for members to collate, augment, share, and interact with different aspects of tool-use experiences (i.e., textual descriptions, pictures, videos, and location information). Digital histories of use enabled members to tell stories, which opened opportunities to valuably shape their relations to physical tools and to each other. Our work aimed to advance ideas on how *experience-oriented metadata* [Odom et al., 2013] could be extended as a resource for supporting experiences beyond solely self-reflection and reminiscence. While comprised of rich elements, the life story centered

archives that experiential metadata help construct are often framed around somewhat static digital representations of past life experiences. In contrast, Roaming Objects, highlights the need to actively support creating dynamic thing-story assemblages that can and will need to change over time, as the physical things themselves change many hands and acquire new narratives and histories.

We targeted the relatively rapid pace of object exchanges in the tool library to develop a design sensibility for viable techniques and issues in building in support for an experience-oriented metadata accrual process in a community-based setting. While our approach was successful in the short term, a clear key challenge is how interactive systems can be designed to account for both archiving and leveraging such assemblages over longer periods of time. There is an obvious need to visualize and archive assemblages of things, activities, and social interactions. Yet, over time, it will also be potentially important to support expanding these assemblages across multiple devices (e.g., from personal mobile devices to interactive, situated community displays on site) and through multi-context representations (e.g., accommodating them within various spatial and social contexts), as our experiences with shared artifacts through digital collections grow.

6.2.10 Summary

We have revealed the prominence of encoding and sharing digital histories of tool-use within a resource sharing organization. The Roaming Objects system stimulated critical discussion about both the shared tools themselves, as well as their value at the individual and community-level over time. Moreover, we presented future design opportunities and issues, and outlined possible interventions, detailing how an interactive system may address the common challenges of resource sharing cooperatives. Finally, our participants suggested several applications of the system beyond tool sharing organizations: rental-driven services, such as sport equipment shops (e.g., for outdoor gear rentals) and vehicle sharing platforms (e.g., car or bike sharing) could further benefit from the histories of use that accompany the experience with the shared resource, and could provide more expressive and rich mementos with them.

Future research could explore sharing practices around emergent "informal" economies of *personal* artifacts (e.g., renting unused sports gear to earn extra money). There, in contrast to collective ownership in the VTL, we expect a different level of attachment to personal or family-owned physical possessions (e.g., household items). We, therefore, envision aggravated issues of accountability for the shared resources. What is more, following the attendant challenges of

platform co-ops (see Section 2.4), we particularly see accrual of trust as a central theme for designers of online sharing platforms, where participants are typically unknown. To explore this avenue, in the next section, we describe a prototyping project that employs emergent smart contracting technologies in order to improve trust and ensure shared resources accountability within informal economies of personal artifacts.

6.3 Sharing Physical Objects Using Smart Contracts

The convergence of social, mobile, and cloud computing has enabled efficient and effective sharing of personal possessions. A plethora of online sharing economy services aimed to lower the entry barrier for both peers-producers and peer-consumers. However, prior research has identified several challenges within sharing economy services (see Section 2.4). In this work we specifically examine how interactive technologies could approach two emergent challenges: (1) the weak levels of trust among peers [Luckner et al., 2015]; and (2) the burden of dealing with intermediaries (e.g., insurance companies, financial institutions), especially when services or goods have been inadequately delivered [Hansen Henten and Windekilde, 2016].

Today's digital sharing services address the issue of trust by incorporating reputation systems into their online platforms [Zervas et al., 2015], where peers can rate each other in the form of textual summaries, numerical scores, and imagery. These reviews guide end-users' decision-making to engage in an online transaction, and influence perceived trustworthiness of the peers [Snijders et al., 2017]. Nonetheless, online marketplaces receive a growing number of "fake reviews" [Luca and Zervas, 2016], which in turn aggravate the issues of trust among participants in sharing economy platforms.

To reduce the need for intermediaries, several sharing economy services provide (limited) insurance to protect owners of the shared resources against misuse, damages, or theft. However, these often come with convoluted terms and conditions [Traum, 2015]. Similarly, dealing with "traditional" insurances (e.g., home, vehicle, household contents) can be equally confusing. Besides that, many "insurance gaps" exist in which owners of the shared resources are covered neither by an online sharing platform nor by personal insurance (e.g., when an Uber driver is en route to a specific passenger) [Edelman and Geradin, 2015]. Moreover, grassroots sharing initiatives and local sharing communities (e.g., neighborhood libraries of shared things) with no centralized platform in place might not have any means to offer own insurances.

Today's popular blockchain technology and its smart contracting feature may help to (1) increase trust within online sharing communities; and (2) simplify the process of dealing with various intermediaries, especially in the case of a dispute. To explore this potential, we created "Just Share It" (JSI), a system and smartphone application that facilitates the sharing of physical objects using smart contracting technology. Firstly, JSI implements a reputation review system using the blockchain's immutable storage technology, which offers review integrity and prevents retrospective review editing. Secondly, it provides a platform for conflict resolution (using smart contracts) in order to resolve potential disagreements between a lender and a borrower regarding the state of a shared item.

HCI researchers looked into applying blockchain ecosystems for social sharing. Recent work of Elsden et al. [2018] offers a typology of blockchain-based applications, including crowdfunding, payment services, voting, copyright management, supply-chain tracking, authentication services, and distributed organizations. They emphasized that all of these applications have to deal with issues of establishing online identity, managing online privacy, and peer-to-peer online collaboration [Elsden et al., 2018]. Pazaitis et al. [2017] specifically explored the potential of blockchain technologies in the context of the sharing economy and detailed the concept of value creation in peer-review and peer-evaluation systems. They have also argued for the importance of maintaining human interactions in "trustless" blockchain ecosystems, especially in the context of sharing personal resources and assets. Drawing on their recommendation, in our JSI smartphone application, we instruct the peers to enter their contact details (e.g., a phone number, an email or an instant messaging handle) in order to get in contact with each other to arrange necessary details of a transaction, for example to reach an agreement about an item's delivery and return.

6.3.1 Motivating Scenario

We offer a prototypical scenario (see Figure 6.7) to better contextualize the envisioned application of JSI. A potential lender (Alice) is interested in making some extra money from her infrequently used high-end ski-touring gear. She thus creates a listing in a local sharing economy service. Bob responds to the ad, gets in touch with Alice, borrows the equipment (Figure 6.7a), and eventually goes on a ski-touring trip. During his trip, he damages the gear on rocky terrain (Figure 6.7b). Once Bob returns the gear, Alice asks Bob to pay for the damages. While Alice's insurance will not pay, as the skis were rented out, Bob finds out that his insurance does not pay, as he opted out of the "gross negligence option" in his premium (Figure 6.7c). In the end, Bob agrees to pay half of the amount

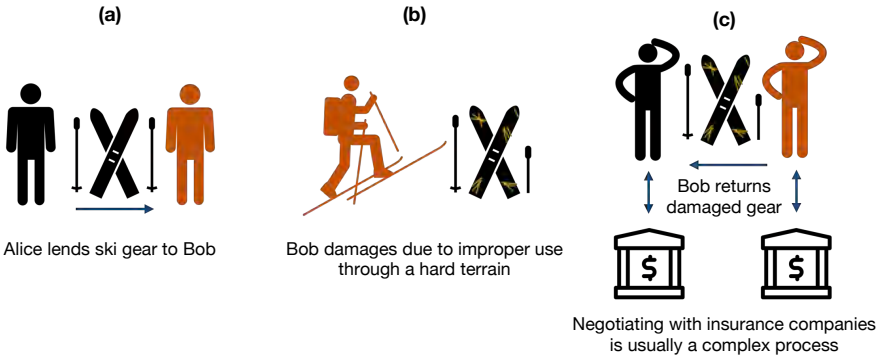


Figure 6.7. A motivating scenario of sharing personal possessions. Icons by Sergey Demushkin, Vaibhav Radhakrishnan, Marc Serre, Andrew Doane, Icon Fair from the Noun Project

Alice asked for. Both remain unhappy with the overall transaction. We envision that JSI can improve the overall satisfaction from this prototypical transaction by implementing a reputation review mechanism into a platform's design, and by reducing the amount of intermediaries through leveraging an escrow property of smart contracts (see e.g., [Elsden et al., 2019]).

6.3.2 JSI Ecosystem

JSI is a software ecosystem to support the efficient sharing of personal physical objects. It is comprised of three components:

1. A cross-platform smartphone application that connects lenders and borrowers.
2. An underlying layer of smart contracting technology (using the Ethereum platform) that facilitates online contractual agreements.
3. A backend server that handles account management and maintains personal inventories of shared items.

Mobile Application

The smartphone app allows lenders to create personal inventories of items they would like to lend. A lender can assign a name, a category and an item description, and set a security deposit and optional period-based price (Figure 6.8a). A borrower can search for an item in his or her vicinity (Figure 6.8b) and subsequently

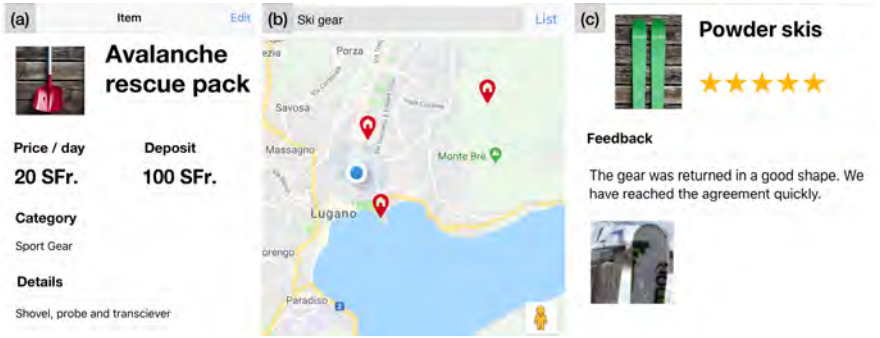


Figure 6.8. (a) A lender's view of an item. (b) A borrower's search result. (c) A review left to a borrower after a transaction is completed.

make a request to borrow it. The lender can look at a social profile of a borrower and her previous transactions, and then accept or reject the request. In the current iteration of the prototype, we did not provide a private messaging functionality within the app, but rather rely on existing services such as WhatsApp, E-mail, or simply a phone call for parties to come to an agreement (e.g., to arrange an item's pickup/delivery and return) – in-app messaging could obviously be trivially integrated into a future version. Our mobile application was in part inspired by our Roaming Objects system (see Section 6.2.2), a tool-sharing platform that provides an online presence to everyday objects by augmenting them with the borrowers' personal experiences in the form of user-generated reports/reviews. Drawing on Roaming Object's design strategy (i.e. digital histories of use), we incorporated and extended it into the reputation review mechanism of the JSI app. Lenders and borrowers can rate their overall experience of interaction with each other in the form of images, ratings, and textual descriptions (Figure 6.8c). The purpose is twofold: borrowers provide histories of use for a given shared object, while lenders can report whether the object was returned in good condition. If needed, the app implements a dispute resolution mechanism to resolve potential transaction conflicts (see the Trust Model section). JSI uses the Web3 JavaScript framework to interact with blockchain smart contracts, which we explain in more detail below.

Blockchain Smart Contracts

JSI uses two types of smart contracts: *transaction* smart contracts (TSC) and *rating* smart contracts (RSC). A TSC models the state of a transaction from the

moment a borrower's request is accepted by a lender, to the moment when the shared item is returned. When a lender accepts a borrowing request, a new TSC is created containing both numerical identities of lender and borrower, as well that of the requested item. At this stage, the security deposit and the usage fee, as specified by the lender, are automatically transferred from the borrower's account to the TSC. Note that we use an external service (`www.coinmarketcap.com`) to automatically convert all fees from a user's base currency (e.g., Swiss Francs) to Ether cryptocurrency. Once the sharing period is over and the item is returned, the lender can request to terminate the TSC. At this point, the item usage fee will be transferred from the TSC to the lender's account. In case of a damaged or non-returned item, a lender can also request the security deposit that is "stored" in the TSC. All payments require a 2-out-of-3 multi-party agreement. Typically, both the lender and the borrower agree and hence can trigger the payout or payback. However, in the case of a disagreement, a trusted third-party can break the tie and decide on who receives the fee and/or deposit, thus terminating the TSC. Until then, all fees are locked in the TSC.

After terminating a TSC, both lender and borrower may rate each other's services regarding the shared item. Rating results are kept in users' individual RSCs, which are created as a part of users' registration. To minimize blockchain processing overhead (and minimize transaction execution costs), we combine blockchain-based RSCs with off-chain storage. Detailed rating data (textual and image-based reviews) are stored in an off-chain database, while a single rating score (i.e., an average) is committed to the user's RSC. To ensure the integrity of the detailed rating data, its fingerprint (computed using a hash function) is also committed in the user's RSC. Each RSC has a built-in access control mechanism which prevents users to rate themselves or to rate a fictitious sharing experience (i.e., "fake reviews"), but also to retrospectively modify their historical ratings.

We designed both TCS and RCS using Solidity, a contract-oriented programming language. We deploy contracts to an Ethereum blockchain testnet through Infura – a service provider for Ethereum infrastructure (see Permissioned vs Open Blockchains section for reflections on "in the wild" deployment opportunities).

Backend Server

The backend server administers inventory, storage and retrieval of the shared items for each user, and handles its profile data. It is implemented using JavaScript-based frameworks (Node.js and Express.js) and a non-relational database (MongoDB) to enable robust deployment and scaling. The server can be accessed using

a RESTful API. As in the mobile client, we use the Web3 framework to manage smart contract interaction at the server side. The backend uses a push notification mechanism to inform users throughout the transaction stages (accepted, rejected, returned, in-dispute).

6.3.3 Trust Model

Trust in JSI comes from two factors. Firstly, each user has a (pseudo-)identity (e.g., picture, name, location) as opposed to the completely anonymous alphanumeric identities used in many other blockchain applications (i.e., Bitcoin). Secondly, reputation scores and reviews allow peers to build-up a reputation, thus allowing others to assess their perceived level of trust prior to engaging in a sharing transaction.

Obviously, this is far from guaranteeing conflict-free sharing experiences. A malicious lender could fail to deliver an item after accepting a borrowing request and then claim for compensation of her allegedly lost item, or incorrectly report that a returned item was damaged by the borrower. A dishonest borrower may equally refuse to pay the security deposit for an item he or she broke. JSI thus relies on "multi-party" smart contracting to resolve such disputes. In case of a disagreement between the lender and the borrower, a trusted third-party is needed to resolve the dispute by deciding who gets how much of the already pre-paid fees for the disputed transaction. The assigned intermediary can listen to both parties and inspect any system logs for evidence. Note that, however, a detailed description of how one can resolve a dispute is outside the scope of this work. This marks a salient opportunity for future research.

Ultimately, we imagine that the role of this trusted third-party would be delegated to the borrowed things themselves. In an IoT-enabled future, a "smart thing" would feature sensing, computing, and communication capabilities, allowing it to detect its own state throughout its use (Figure 6.9). Should a dispute between the involved peers arise, the smart contract would then resolve any disagreement based on evidence from the actual borrowed object. While such a solution would effectively remove any intermediaries from the system, it would need to carefully assess (and address) any vulnerabilities of a malicious peer bypassing an item's self-sensing system.

6.3.4 Permissioned vs Open Blockchains

The original blockchain model (e.g., Bitcoin and Ethereum) is "open" – anyone can join the network and participate in the consensus-building process when

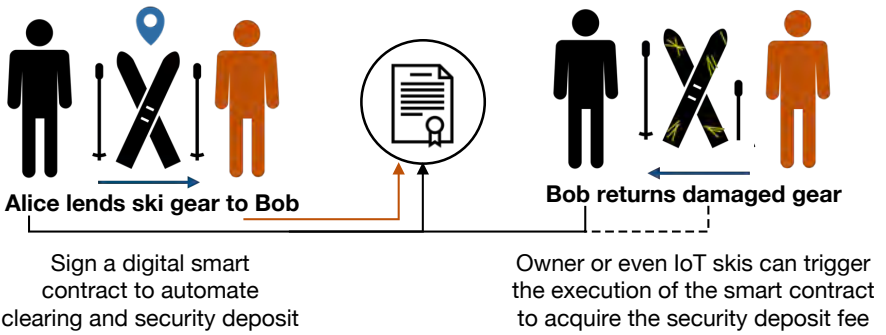


Figure 6.9. Future scenario, where the lender (Alice) provides the GPS-enabled ski-touring gear with a trusted platform module to the borrower (Bob), and eventually executes smart contract once received damaged equipment back. Icons by Sergey Demushkin, Vaibhav Radhakrishnan, Chameleon Design from the Noun Project

executing a transaction (i.e., appending a new data block, creating new smart contracts, or editing existing ones). This model is known as a "permissionless" (or public) blockchain. In this model, network participants do not trust each other, and they are not required to reveal their true identity. However, they rely on a computationally expensive protocol ("Proof-of-Work") to achieve consensus in order to maintain the integrity of the chain and to build up trust.

Contrary to this, there is the "permissioned" (or private) blockchain, which restricts who can join the network and who can participate in the transaction execution process. Here, new transactions are validated by a subset of recognized entities, resulting in a more efficient consensus-building protocol. However, this model assumes that there exists some level of initial trust among network participants.

In both versions, performing a blockchain operation requires a user to pay a monetary fee. In the permissionless version, this fee acts as an incentive for network participants to validate a transaction: the lower the fee, the longer it will take for "the blockchain" (i.e., the community of participants) to commit a transaction to the ledger. As a consequence, the amount of money paid by peers for their transaction directly influences how quickly their contract would be executed.

Conversely, in the permissioned model, transactions are executed only by a recognized set of participants (and/or by the blockchain infrastructure provider). As a result, one can agree at the beginning on a fixed execution cost for all

future transactions (e.g., by means of contractual agreement with the blockchain provider), removing the need for an incentive-setting pricing model. This would ensure constant transaction execution times and potentially reflect positively on the overall user experience with JSI.

In summary, depending on which blockchain model we select (permissionless vs. permissioned), there are several factors that can potentially impact a user's experience with our system. Among such affected factors are: 1) user waiting times before an operation can be committed to the blockchain, 2) the initial trust level towards those that ensure ledger's integrity, and 3) the level of active user involvement (i.e., cognitive load) when dealing with blockchain-based operations.

6.3.5 A proposition for a Future Work

In this section, we outline the rationale, the prototypical scenario, and the architecture of the "Just Share It" (JSI) application. The JSI client runs on a mobile platform and incorporates both blockchain and smart contracting technologies (using Ethereum, an open-source distributed computing platform). In a permissioned blockchain setting, JSI may offer reasonable costs and usability. On the whole, transparency of sharing transactions and integrity of the peer reviews as design strategies can be valuable for establishing trust within a sharing service at hand.

In our view, the natural unfolding of this work would be a field deployment of JSI within an existing online sharing community (e.g., Peerby, Sharely). This will not only allow future research to elicit aspects of perceived trust within a sharing platform and to examine the role of blockchain technologies in trust accrual, but also identify challenges and opportunities related to the actual use of emerging blockchain-based ecosystems in the sharing economy services. In particular, we see the value in raising the following two questions for the HCI community: "What are the users' perceptions of trust enabled by the smart contracting technologies within a sharing economy community?" and "How blockchain-based technology interventions can facilitate or inhibit trust within a community and within a supporting platform?" Ultimately, we hope this work inspires future research into how blockchain-based technologies can further support physical sharing practices in an IoT future, where everyday things are controlled by a machine agent, and thus have their own decision-making capabilities and power to execute smart contracts.

6.4 Summary

This chapter contributed to our research goal **G2** that is *to describe nuanced design characteristics for interactive technologies to support physical sharing practices in the context of the sharing economy*. We conducted two empirical studies to achieve this goal. The first one examined the physical sharing practices of individuals, the second one – of a resource sharing community.

At the outset, we recruited 71 participants and examined their individual sharing practices of everyday purchases. We identified the most shared categories of purchases, namely purchases related to "home" expenditures (e.g., groceries) as well as to "experiences" (e.g., trips, events). We subsequently determined that sharing purchases typically takes place with close family members and friends. We also computationally identified that overall perceived purchase satisfaction positively affects its sharing. Looking further into the relationship among satisfaction from a purchase and its sharing we elicited the motivational and experiential aspects of sharing everyday purchases. We outlined seven categories of motivational factors spanning social, hedonic, eudaimonic and environmental aspects of everyday consumption. We then reflected how selected factors can be used in user experience design of future persuasive technologies that support purchase sharing.

Next, we established a case study with the Vancouver Tool Library, a tool sharing cooperative, to examine sharing practices of their community members. At this stage, we identified three emergent challenges of the tool-sharing community: (1) the large degree of members' anonymity, (2) poor visibility of members' work, and (3) the lack of accountability for shared resources. We hypothesized that those challenges can be partially addressed through capturing and sharing members' tool-use experiences. For this purpose, we designed and developed the Roaming Objects mobile application. We subsequently field-tested and deployed the application at the VTL for eight weeks. We additionally conducted a series of follow-up interviews with 16 members to reflect on their experience with Roaming Objects. Through encoding and sharing digital histories of tool-use, Roaming Objects elicited a range of self-reflections across members of the VTL – from contemplations on personal relations and uses of tools, to speculations about shared tools themselves and their value on a broader community-level over time. Drawing on these insights, we synthesized a set of design recommendations for resource sharing cooperatives and collectives to attend to three aforementioned challenges. Firstly, we demonstrated the added-value of the progressive self-disclosure design technique – the gradual revealing of one's identity or individual information in relation to a shared resource. Roaming Objects allowed the VTL members to create

personal profiles with various levels of social disclosure to mitigate their privacy concerns. Thus, this technique has potential in *de-anonymizing* the community membership, and enable and a stronger sense of shared practices, values and intimacy between the tool library members and the community as a whole to emerge overtime. Secondly, recording and archiving experiential histories of use enabled members to gain valuable glimpses into the largely unseen practices of how tools were being applied in a range of members' respective everyday projects outside of the site of the tool library. Thus, the digital histories of use *increased visibility* of members' practices. Thirdly, accrued digital histories of use became useful indicators for the volunteers of the tool library to ensure up-to-date and detailed inventories, timely maintenance and repair of the tools. This decision led to an increased overall *accountability* of the tools among volunteers and members. It also better supported decision-making processes among members in terms of choosing the appropriate tool for a job. Lastly, we illustrated that Roaming Objects supported creating dynamic thing-story assemblages that can and will change over time and acquire new narratives as physical things change many hands. We consequently discussed the opportunities for expanding those assemblages across multiple devices and contexts beyond tool-sharing communities.

Building upon these insights, we looked beyond local resource sharing communities and explored the context of "informal" economies of personal artifacts. Prior research identified that contemporary online sharing platforms face several challenges related to the establishment of trust among peers, as well difficulties to deal with the growing number of intermediaries (e.g., payment, insurance) needed to ensure an adequate service delivery and accountability for shared resources. To approach these challenges we designed and developed "Just Share It", an interactive system that enables the sharing of personal physical possessions (e.g., power tools, toys, sports gear) by directly connecting lenders and borrowers, as peers, through mobile technology. The JSI system utilizes a blockchain ledger and smart contracting technologies to improve peer trust and limit the number of required intermediaries respectively. We argued that transparency of transactions and immutability of storage afforded by blockchain ecosystems could be seen as valuable design resources to ensure the integrity of reputation review mechanisms. Ultimately, we reflected on prospective architectural challenges and outlined opportunities for designers of future technology-mediated sharing practices that look into incorporating emergent blockchain technologies in their design concepts.

Collectively, this chapter developed the design sensibilities and outlined specific design strategies for interactive technologies to support physical sharing practices in the context of the sharing economy. In particular, we discussed the UX

design opportunities to support individuals in sharing everyday purchases. We also demonstrated how the digital histories of use as a design strategy can attend to the interpersonal and organizational challenges of resource sharing communities. Finally, we offered a design intervention employing nascent smart contracting technologies to approach the emergent issues of trust, disintermediation, and accountability within informal economies of personal artifacts. Drawing on the findings described in this chapter, in the next chapter, we specifically inquire how designers of sharing economy services can adopt this design research knowledge in order to improve existing platforms, as well as to devise new value-added services in the context of the sharing economy.

Chapter 7

Supporting Designers in the Context of the Sharing Economy

In the previous chapter, we offered a set of design strategies to support physical sharing practices in the context of the sharing economy. Yet it remains unclear how design practitioners can use this type of design research knowledge in their creative practices. The goal of this chapter[1] is *to investigate how designers can specifically support technology-mediated physical sharing practices in the context of the sharing economy* **(G3)**. In order to meet this goal, we first elicited a set of design implications for sharing economy services (see Section 7.1) based on the mapping of the design space between digital and physical sharing described in Chapter 3. Next, using these design implications, we developed a design toolkit and a corresponding methodology for sharing economy services targeted user experience and service designers (see Section 7.2). We then partially validated the toolkit with the view to identifying how it can be adapted to the designers' creative practices in individual and collaborative settings.

At the outset of this chapter, we turn to the key design themes of technology-mediated sharing practices introduced in Section 3.3 in order to inform the design of contemporary sharing economy services. In particular, we review the commonalities and differences between digital and physical sharing practices in the light of prior work in HCI. In other words, we reflect on the diversity of shared content, users' motivations to share, audience management, privacy and trust issues, and user experience requirements across both digital and physical sharing practices. This allowed us to formulate an initial set of design implications for devising novel sharing economy services.

[1] Portions of this chapter are also published at NordiCHI'18 [Fedosov, Albano and Langheinrich, 2018] and CHI'19 [Fedosov, Kitazaki, Odom and Langheinrich, 2019].

Based on these design implications, we developed the Sharing Economy Design Cards, a design toolkit for sharing economy services in the form of a card deck, and a corresponding design methodology. The main idea behind the toolkit is to aid the transfer of domain-specific knowledge between design research and practice. We deliberately chose the format of the cards for our toolkit, owing to its familiarity to (and wide adoption among) design practitioners. In order to examine the use of the cards, we subsequently deployed them in two settings: (1) we collected feedback from individual evaluation sessions with a set of designers and sharing economy experts and (2) we conducted two creative workshops with UX and service designers. Our findings showed that the use of the cards not only facilitates the creation of future sharing platforms and services in a collaborative setting, but also helps to improve existing sharing economy services as an individual activity.

7.1 Design Implications for Sharing Economy Services

The goal of this section is to elicit a set of implications for design for sharing economy services, drawing upon the comprehensive mapping of the design space between digital and physical sharing practices described in Chapter 3. Consequently, our point of departure lies within five key themes of technology-mediated sharing practices (see Figure 3.3) introduced in Section 3.3: (1) shared content; (2) audience management; (3) motivations to share; (4) privacy and trust issues; and (5) user experience requirements.

We first briefly review the gist of those themes. **Content** refers to the type of the shared artifact. It addresses the question: "What is being shared?" **Audience** refers to the recipients of the shared content. It addresses questions like "To whom is the content being shared and how is it being communicated?" **Motivations** are what drive people to share. It addresses the question: "Why is the content being shared?" **User Experience** concerns aspects of a user's internal state, the characteristics of the interaction, and the context where interaction between the user and the system occurs. On the whole, it addresses the question "How does sharing take place?" **Privacy and Trust** relates to people's desire to control information dissemination. It addresses questions like: "How do users feel about privacy and trust issues when deciding to share, and how does it affect their choices?"

What is more, our empirical study of technology-mediated sharing practices described in Section 3.3 helped to illustrate the commonalities and differences of sharing of digital and physical artifacts. Five key differences between these two

practices are: (1) the shared content: sharing physical artifacts often encompasses not only the shared material object itself, but also the accompanying layers of (meta)data; in digital sharing, content is exclusively immaterial; (2) the recipients of a shared artifact: unknown audiences in physical sharing vs. family members and friends in digital sharing; (3) the motivations for sharing: physical sharing is often driven by economic and practical needs (e.g., getting monetary benefits), while digital sharing is largely guided by self-expression; (4) the substantial concerns of trust in physical vs digital sharing; and (5) the sharing triggers: in physical sharing, a borrower/renter proactively needs to express an interest in a shared artifact, while sharing digital artifacts is often initiated by a sharer.

Building upon this dichotomy, in what immediately follows, we formulate a set of the implications for design for contemporary and future sharing economy services by reflecting on the key findings from our original study (see Section 3.3) in the light of the related work (see Chapter 2).

7.1.1 Leverage the Twofold Nature of Shared Content

Many of our participants (e.g., see the quote of Worden on page 36) indicated the dual nature of content when sharing physical artifacts. Besides sharing "a thing" itself (e.g., a car), there is a supporting layer of digital information that is shared along with it. This included both machine-produced forms of information and metadata captured by virtue or use of a platform's digital infrastructure, and human-produced digital records through directly taking and uploading the information (e.g., photos of a car, textual annotations). This information often affords opportunities to build a narrative around the artifact itself. Leveraging nascent research in HCI that aims to bridge the gap between physical artifacts and their digital representations through collecting metadata [Odom et al., 2011], provenance [de Jode et al., 2012] and histories of use [Benford et al., 2016], we see the value for designers to use these strategies to communicate information about the ownership, duration of a share, provide contextual suggestions of use of an artifact, and preserve and share previous interactions with it. This not only can improve the overall user experience with the shared artifact itself, but also can afford opportunities for social interactions around it (for further reflections see Section 6.2.9).

7.1.2 Adjust Levels of Self-Disclosure Over Time

Our findings (see Section 3.3.3) suggest that physical sharing is largely carried out with unknown people [Ikkala and Lampinen, 2014; Lampinen, 2014; Ozanne

and Ballantine, 2010]. It can be partially explained by the advent of the sharing economy services, where people participate in an exchange for monetary compensation [Bellotti et al., 2015]. To effectively advertise and execute the sharing transaction, sufficient level of details must be provided about the shared artifact or service. Designers of sharing economy platforms should provide appropriate levels of controls for the user that help balance adequate level of disclosure of personal information and the details of a shared artifact. Modern sharing economy platforms incorporate progressive disclosure mechanisms that reveal adequate amounts of content at a given stage in the transaction. In addition to that, service designers may want to consider *concealing information* upon the completion of a transaction, due to some possible negative consequences (as in the case of Danny, who was accused of smoking after having already departed from a rented property, see his quote on page 40). One interesting option in this respect may be smart-contracting technologies [Elsden et al., 2018], which can automatically enforce a "departure contract" by simply retrieving data from installed sensors at home (e.g., smoke detectors). While such technologies may offer straightforward evidence and minimize ambiguities, when it comes to the issues of liability in sharing economy, the extent of their deployment and enforcement should take the larger social organization of the service into consideration, since it can influence social relationships among peers and the community at large. Finally, in contrast to digital sharing, where shared content can scale to reach multiple audiences at the same time [Vitak, 2012], physical sharing limits people share to one individual (or small group) at a time, which may delay decision-making as in the case of Dacie (see her quote on page 39). We suggest that designers of future physical sharing services explore viable user interface techniques (e.g., access control mechanisms), where the shared artifact (and their digital counterparts) can be ultimately accessed and maintained by a group of involved stakeholders.

7.1.3 Attend to Communicative Aspects of Physical Sharing

When it comes to motivations to share, we want to return to our framing of two different logics of sharing (Figure 3.2). We found that prior research in HCI has paid a lot of attention to digital sharing as an act of *communication*, while only few works explored this logic in the context of physical sharing practices (e.g., sharing printed photos [Frohlich et al., 2002; Miller and Edwards, 2007; Nunes et al., 2008]). Researchers explained that participation in online sharing stems from people's desires to create and maintain social ties [Goh et al., 2009; Lange, 2007], needs for self-expression (e.g., [Goh et al., 2009; Van House et al., 2005]), and generally from the hedonic qualities of sharing experiences online (e.g., [Acquisti

and Gross, 2006; Bayer et al., 2016]). However, these social phenomena were less accentuated in prior research into physical sharing. This may indicate an opportunity for research to explore communicative aspects of physical sharing. In practice, designers of sharing economy services can explicitly emphasize the advantages of maintaining social relationships, for example, through illustrating the benefits of reciprocity. As our participant Morten proposed (see his quote on page 44), this can facilitate enrolling new users in a sharing economy platform.

7.1.4 Provide Instruments to Improve Trust

Our findings (see Section 3.3.3) identified that the main concerns of sharing physical artifacts are rooted in the lack of trust in a counterpart of the sharing transaction [Ikkala and Lampinen, 2014; Luckner et al., 2015]. Given that sharing economy services are carried out broadly with unknown individuals, trust is something that strangers do not naturally have for each other. Therefore, we have emphasized that it is of utmost importance for designers of physical sharing services to provide mechanisms and tools to build trust between potential exchange partners. Furthermore, we speculate that presenting accounts of successful exchanges may contribute to the overall endurance and growth of the sharing platforms and communities over time. Some commercial sharing economy services have already adapted various mechanisms to build trust within the community and the platform through reputation review systems, transparent profiling, and offline-identification for the providers of the shared resources. It follows that in order to build attractive and trustworthy social profiles within platforms, designers need to explain the benefits and provide tools to de-anonymize participants within a sharing platform, as aliases, nicknames, or incomplete profiles are not considered trustworthy to engage in community building [Bardhi and Eckhardt, 2012]. Note that while more disclosures are encouraged, owing to the fact that self-descriptive profiles can contribute to making informed decisions [Ert et al., 2016] and are perceived more trustworthy [Ma et al., 2017], there may be some negative consequences designers should be aware of, such as “digital” discrimination based on the aspects of appearance, e.g., race, gender [Edelman and Luca, 2014].

7.1.5 Explore Sharing Triggers

Throughout our analysis (see Section 3.3.3), we have encountered a difference between the triggers to share in physical and digital sharing. When sharing physical artifacts, the number of shares that happen by request from the audience

is much more represented than whilst sharing digital artifacts [Bellotti et al., 2014; Lampinen et al., 2013; Ozanne and Ballantine, 2010]. The difference may be explained by the motivations to share. While digital sharing is driven by self-expression and self-representation, physical sharing motivations are largely instrumental and driven by inquires to borrow an object or provide a service based on the demand of the audience. Designers of future physical sharing platforms may proactively explore the needs of the audience to leverage these behaviors.

Note that the pro-social rhetoric of sharing (e.g., openness, trust, commonality and understanding between people) [John, 2017] is rarely placed at the center of attention in popular profit-driven sharing economy services. Nevertheless, we envision that the wider adoption of platform cooperatives [Scholz, 2016], with their commitments to cultural and community values over economic gain, can empower service designers to develop and evaluate sharing triggers that follow from social interactions.

Ultimately, in our data (see Section 3.3.3), we found no instances of sharing 'determined by the system' in physical sharing. However, examples of such practices exist (e.g. Airbnb's 'instant booking' feature, which allows guests who meet predefined requirements to automatically book a space without an additional host's approval). Sharing economy services could take a step further in this direction and allow a supporting digital platform, for example, to instantly share a WiFi password, provide an access code for a building, or even open a door or locker using some IoT-based technology (e.g., `Slock.it`) after a user confirms a reservation. Designers of physical sharing services could explore the opportunities to include automatic sharing capabilities, based on user needs and available infrastructure. For example, community-owned lending libraries of things (e.g., `thethingery.com`) may benefit from the computerized pick-up/drop-off stations (similarly to the self-service parcel lockers used by a number of European postal services) for their members to facilitate exchanges of tools and equipment, and to assist in emergency preparedness in neighborhoods.

7.1.6 Towards Operationalizing the Design Implications

In Section 3.3, based on an extensive literature review and expert interviews, we offered a mapping of the design space between digital and physical sharing. In particular, we presented 13 sharing dimensions (see Figure 3.3) that characterize technology-mediated sharing practices. We aggregated them into five main themes: (1) the diversity of shared content; (2) audience management; (3) motivations to share; (4) privacy and trust issues; and (5) user experience requirements. Using these dimensions, we described commonalities and differences

between sharing digital and physical artifacts across eight broad sharing practices (see Section 3.3.3). Finally, in this section, we reflected on this dichotomy and elicited a set of design implications for devising future sharing economy services.

As the next step, drawing on our empirically-extracted design implications, we present a design toolkit for sharing economy services. The toolkit covers the five aforementioned key design themes and for each, offers a set of actionable recommendations for designers to devise value-added services for the sharing economy. The toolkit also supplies each recommendation with an example of a user interface from an existing sharing platform or service that implements a given recommendation. In the next section, we describe our toolkit and present the insights from its two field deployments with design practitioners.

7.2 The Design Toolkit for Sharing Economy Services

Prior work in the HCI literature highlighted a key need to support designers in the sharing economy [Light and Miskelly, 2015], owing to the rapid proliferation of both profit-driven and non-profit forms of the sharing economy and the growing body of research knowledge in the area [Dillahunt et al., 2017]. However, design practitioners do not often adopt this type of research knowledge since they find it too abstract, too difficult to use, and too hard to locate [Norman, 2010; Roedl and Stolterman, 2013]. Driven by the goal to understand how designers of online sharing platforms and services could both improve existing sharing economy platforms and create new ones, we have sought inspiration in *translational resources* [Colusso et al., 2017] such as design toolkits, which have shown promise in effectively transferring knowledge between design research and practice [Deng et al., 2014].

We developed a 24-cards deck called the Sharing Economy Design Cards (SEDC), which provides domain-specific insights for designers on the diversity of shared content, users' motivations to share, audience management, privacy and trust issues, and user experience requirements – all in the context of the sharing economy. We initially deployed the cards with 16 design practitioners and sharing economy domain experts to gather their individual feedback on the content, possible applications, and usefulness of the cards for evaluating existing sharing economy services. We also deployed the cards in two design workshops with 5 participants each to explore their use in a collaborative setting. Our work addresses the following research questions:

1. What are opportunities and challenges when using the SEDC in a designer's creative process?
2. In which stages of the design process can the SEDC be used, and how?

We offer two main contributions. Firstly, we provide insights gathered in the context of two deployment settings of the cards (individual and group) and discuss how they help advance both design research and practice in the context of the sharing economy. Secondly, we present the SEDC themselves and the corresponding design methodology.

7.2.1 Background

Our work lies at the intersection of two principle research areas: (1) the socio-technical challenges of the sharing economy and (2) the design cards as a genre of design toolkits.

In Section 2.4, we reviewed the body of work that looked at the attendant challenges of different forms of the sharing economy. Of particular relevance to this study is a set of design strategies for better sustaining physical sharing practices in local communities and collectives [Light and Miskelly, 2015]. In light of this prior research, our work facilitates the transfer of knowledge from design research to design practice through cards – a familiar toolkit among practitioners – and explores their use within established design methods such as thinking aloud critique [Nielsen, 1994] and collaborative workshops [Halskov and Dalsgård, 2006].

Design cards have been created and evaluated in various contexts. To name a few, cards have been suggested to facilitate the conceptualization of Internet-of-Things applications [Mora et al., 2017], to raise awareness of emergent data protection regulations [Luger et al., 2015], to support the design of information systems for international justice [Logler et al., 2018] and to design interactive artifacts for ageing populations [Nicenboim et al., 2018]. Others targeted more abstract human qualities such as values [Friedman and Hendry, 2012], resourcefulness [Nicenboim et al., 2018], playfulness [Lucero and Arrasvuori, 2010], and creativity [Lucero et al., 2016] as part of the design process. We aim to extend these ideas in the context of the sharing economy.

Prior research showed that cards can support various design activities: understanding a phenomenon at hand [Colusso et al., 2018], collaborative [Friedman and Hendry, 2012] and playful ideation [Lucero and Arrasvuori, 2010], co-design (e.g., [Lucero et al., 2016]), formative evaluation of design concepts [Deng et al., 2014], and advocacy [Colusso et al., 2017]. In our work, we are interested in

understanding whether design cards can be also used in individual summative evaluation activities akin to heuristic evaluations to surface design issues with existing sharing economy platforms.

Prior work also outlined techniques aimed at better supporting designers and researchers to create their own design cards [Halskov and Dalsgård, 2006] and supporting materials such as design worksheets [Logler et al., 2018] and canvases [Mora et al., 2017] to guide cards' use. Drawing on these efforts, we developed a corresponding design methodology to facilitate design cards use in a collaborative setting.

In summary, prior research suggested various techniques and methods to apply design cards to support the creation of interactive systems within different application domains. Our work builds upon this prior research to explore how our SEDC can be leveraged in different stages of the design process, and in various settings (e.g., group and individual design activities), all in the context of the sharing economy.

7.2.2 Sharing Economy Design Cards

Drawing on the recent survey of the sharing economy in the computing literature [Dillahunt et al., 2017], and our own comparative review of technology-mediated sharing practices (see Section 3.3.3), we elicited a set of design recommendations to support designers with domain-specific knowledge. Given the difficulty of having this type of design research knowledge adapted by practitioners [Roedl and Stolterman, 2013], our goal was to aid designers in operationalizing the research knowledge in the context of sharing economy. The recent work of Colusso et al. [2017] calls for more practitioner-oriented translational resources, which could be used to engage designers to adapt the knowledge produced by design researchers in their practices. Following their work, we developed the SEDC and tailored them for service and UX design practitioners by providing actionable recommendations, genuine examples, and simplified search through keywords. We specifically chose the focus our research inquiry on design cards since this genre of design toolkits can provide an adequate level of details to inform the design (e.g., UI), and proved useful in combination to familiar design methodologies (e.g., the design sprint) [Colusso et al., 2018].

Figure 7.1 shows the face of one card (out of 24) in a SEDC deck as an example (plus 4 partially hidden cards). The full set is included in Annex B.

In terms of visual representation and layout, our cards were in part inspired by the Tiles IoT Toolkit [Mora et al., 2017] and the IDEO Method Cards (`https://www.ideo.com/post/method-cards`). Specifically, from the Tiles IoT

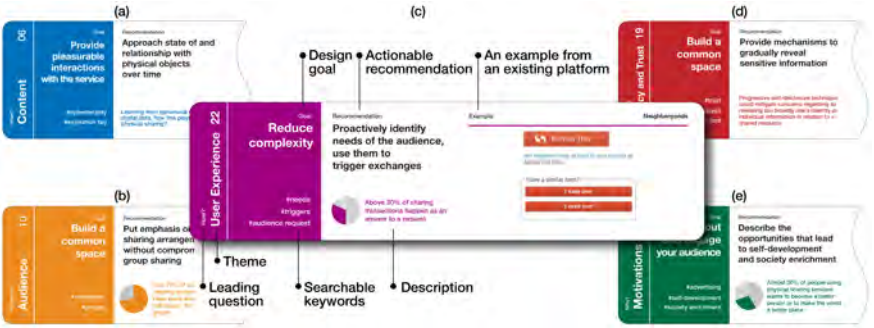


Figure 7.1. The SEDC examples for each theme: (a) Content; (b) Audience; (c) UX; (d) Privacy and Trust; (e) Motivations

Toolkit we took inspiration in distinctly-colored decks to ensure the ease of referencing, browsing and sorting cards, while from the IDEO Method Cards we were encouraged to add succinct descriptions to further inform and inspire designers. We adapted the structure of the cards from a mockup suggested by Colusso et al. [2017], which is grounded in their empirical research on design toolkits and based on multiple iterations with UX designers. Drawing on their most recent work on behavioral change cards [Colusso et al., 2018], we decided to include existing design examples in the form of screenshots of user interfaces, which were found extremely useful by their participants.

We have divided the front side of each card into seven "sections" (see Figure 7.1c), namely (1) a card's theme, (2) a leading question, (3) a design goal; (4) searchable keywords; (5) an actionable recommendation; (6) a detailed description; and (7) an example from an existing service. We have used bold and light typefaces to create a visual structure to the cards and to aid their readability. The **goal** and the **recommendation** are placed next to each other to quickly understand their relation among each other (following the Gestalt Law of Proximity). The **examples** have been chosen from existing sharing economy platforms and have been placed on the right side of the **recommendation**, offering its interpretation on the user interface level. We envision the cards to be printed in a minimum format of 10.6 by 2.8 inches with rounded corners to ensure comfortable use around a collaborative working area (e.g., a desk, a board). The back of each card has a recurrent pattern featuring the name of the theme on the correspondingly colored background.

The SEDC deck aims to explore design opportunities characterizing different angles of a sharing economy platform or service. The cards' themes were drawn

from a systematic literature review of technology-mediated sharing practices of both physical and digital artifacts (see Section 3.3). The deck details five themes (each represented with a colored suit, see Figure 7.1), which allow a designer to identify and describe specific characteristics of a service/tool at hand: **Content** (Blue), **Audience** (Orange), **Motivations** (Green), **Privacy and Trust** (Red), and **User Experience** (Purple). Themes set the foundation to answer a set of core sharing questions (see "Leading question" label on Figure 7.1). Namely, "What is being shared?", "To whom content is being shared?", "Why is the content being shared?" and "How is the sharing takes place?"

Note that the themes and the recommendations are neither exhaustive nor expected to be the orthogonal to each other. They are developed based on a qualitative account of 87 papers that studied technology-mediated sharing practices (see Section 7.1). However, to minimize this limitation, we have deployed the SEDC with a total of 26 participants to seek their feedback on the cards' content and to evaluate their use within designers' creative processes. Additionally, for each theme we have added a blank card, such that participants could formulate their own recommendation and suggest an example based on their own expertise.

7.2.3 Field Deployments

In order to understand the opportunities and difficulties using the SEDC in the designers' creative practices (RQ1), and to detail their use in different phases of the design process (RQ2), we conducted two user studies. We hypothesized that the SEDC can be used not only during early stages of the design, such as initial ideation or concept development (as suggested by the prior art), but also support the evaluation of existing platforms and tools with the goal to find usability issues and to improve overall user experience. What is more, we envisioned cards to be used during individual activities akin to heuristic critique or expert interviews, as well as in group design activities drawing on participatory [Bødker et al., 1995] and co-design [Sanders and Stappers, 2008] methodology. That is why we first conducted a study with individual participants, and then organized two collaborative workshops in a group setting. During both deployment settings, participants provided us their feedback on the cards, as well as reflected on their use. While our initial deployments did not explicitly engage with participants at their place of work [Roedl and Stolterman, 2013], we nonetheless see the value of adopting this approach to map this emergent design space. Wider dissemination of the cards marks a salient opportunity to further explore the extensibility of their value for professional design practice [Goodman et al., 2011].

Study 1: Individual Interviews

At the outset we individually engaged with 5 sharing economy domain experts and 11 design practitioners (16 people in total, 11 were female, all used sharing economy services actively) in semi-structured interviews. The average age of participants was 31.3 years old ($SD = 3.6$), they held various occupations including UX designer, graphic designer, interaction designer, start-up founder, academics (with backgrounds in statistics, sociology and economics) who conduct research in the sharing economy area. The participants' average job experience at the current position was 6.1 years ($SD = 4.6$). Most of our participants live in Western and Central Europe, five of them were from Argentina, one from China and one from the US. We particularly wanted to focus on non-US context since researchers suggested that those populations were less explored in the area of sharing economy [Dillahunt et al., 2017]. The goal of this deployment was twofold: (1) to elicit participants' professional reflections about the SEDC themselves and (2) to understand whether and how the cards can be used for evaluating an existing sharing economy platform that is most familiar to them.

The participants were initially recruited through our extensive professional networks; we then employed a snowball sampling strategy to reach out to more participants. We sent a PDF document featuring the SEDC deck and an introductory note (outlining the purpose of the interview) to participants a few days before the scheduled interview in order for them to get familiar with the cards. During the interview, we asked each participant to interpret at least two "specific" cards (we always picked different cards to ensure the coverage of the whole deck). We then inquired about one sharing economy service that participants have had the most experience with. Later, we engaged participants in a think aloud session [Nielsen, 1994]: using their offered interpretation, we asked them to reflect upon the sharing economy service they have selected. We challenged designers to discuss the content of a UX report with the goal to identify shortcomings and opportunity areas of this sharing economy service. For example, we asked them "How do you think the cards informed your conclusions?" For the five sharing economy experts we asked more detailed feedback on the content and the structure of the cards. For instance, we inquired "What aspect of the card (see Figure 7.1c) have you found most useful when thinking about this service?" and "What does that card (see Figure 7.1d) prompt you to do?" to elicit a critical reflection on a service at hand.

Each interview session lasted approximately 60 minutes, was audio recorded and transcribed verbatim. We conducted interviews either in person or over Skype and took extensive field notes; findings after each interview were captured

immediately in reflective field memos [Glaser and Strauss, 2009], which we reviewed throughout our analysis.

Study 2: Collaborative Workshops

In order to better understand the usage of the cards in group settings, we have organized two practitioner-oriented workshops, drawing upon collaborative design events such as the Inspiration Card Workshop [Halskov and Dalsgård, 2006] and design sprints [Knapp et al., 2016; Colusso et al., 2018]. Study participants were recruited by distributing a study invitation within various online communities, including user experience and front-end development meetup groups, local designers' Slack channels, email distribution lists, and through authors' social media accounts.

In total, 10 participants participated in our study. We conducted two 2-hour workshops with 5 participants each (see Figure 7.2). We tried to evenly distribute them based upon their background and work experience. Similar to Study 1, we recruited participants from both design and sharing economy communities. The average age of participants was 33.1 years ($SD = 8.4$), 6 of them were female. They all live in a Western European country and have worked at their current position for on average 6.0 years ($SD = 4.9$).

The goal of the workshops was to assess the potential value of the SEDC in the process of creating value-added sharing economy services. More specifically, we aimed to understand how and whether participants would find the card deck helpful when devising new sharing economy services. We adapted the Google

Figure 7.2. The Sharing Economy Design Sprint

design sprint format – that is mapping, sketching, deciding, and prototyping activities [Knapp et al., 2016] – since it is one of the most widely used approaches in professional practice and was familiar to our participants.

Sharing Economy Design Sprint In contrast to Study 1, participants were not able to spend much time reflecting on the SEDC. We specifically chose the sprint format as being close to industry demands, where designers have to make decisions within a limited time and with limited resources [Roedl and Stolterman, 2013]. We took inspiration from the Behavior Change Design Sprint process [Colusso et al., 2018], while modifying several activities that its authors found problematic. Figure 7.3a presents the input resources for the design sprint, namely: a design brief, the models of personas and a scenario. In addition to employing the SEDC, we developed three supporting templates: (1) a map canvas, (2) an idea template and (3) the prototype templates, which we have used during the sprint (see Figure 7.3b). All of these resources are included in Annex B.

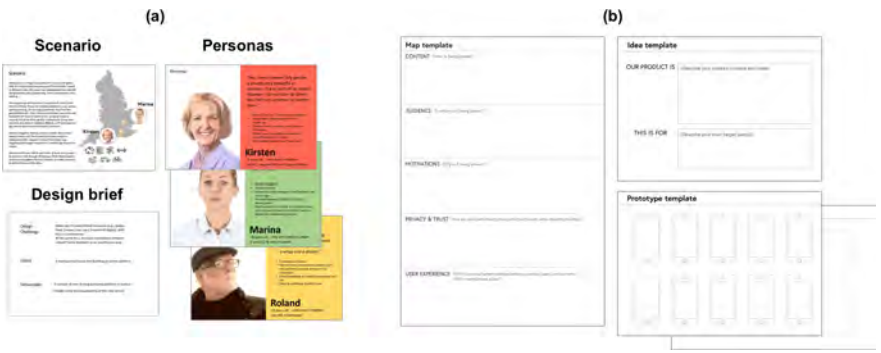


Figure 7.3. The Sharing Economy Design Sprint: (a) input materials; (b) worksheets

The Sharing Economy Design Sprint lasted for 120 minutes and contained eight individual and group activities (see Table 7.1). We video-recorded all sessions (see Figure 7.2) and then transcribed the parts that were relevant to our research questions. In addition to that, we took the field notes during the workshop and photographed the materials that participants produced during the sprint (see Figure 7.4d).

Nr.	Activity	Time (min)	Format	Resources
1	Introduction	25	Group	Sharing Economy Design Cards (SEDC)
2	Understanding	10	Group	Design Brief, Scenario, Personas
3	Mapping	10	Group	Map Canvas, SEDC (Themes & Questions)
4	Sketching	15	Individual	SEDC (Goal & Recommendation)
5	Deciding	15	Group	Idea Template
6	Prototyping	20	Individual/Group	Prototype Template, SEDC (Example)
7	Advocating	10	Group	All above
8	Reflecting	15	Individual	All above

Table 7.1. Activities of the Sharing Economy Design Sprint

Data Analysis

Our data analysis draws upon various sources from our fieldwork: participant observations from two workshops, analysis of the video data, participants' reports produced during the workshops, and semi-structured interviews. We used affinity diagramming [Beyer and Holtzblatt, 1997] to understand the collected data thematically and to model similarities and differences across participants. We followed an iterative process, going back and forth between the data, the researchers' notes, and the emerging structure of empirical categories, which we developed through recurrent reading of the material [Glaser and Strauss, 2009]. We also held meetings with researchers outside of the project to challenge our assumptions and to corroborate the themes. We distilled four sets of results that reveal at which stage of the design process, and how, the SEDC can be used in both individual and group activities. In the following section, we present examples that help capture these themes and support them with participants' quotes from both our studies. We use pseudonyms to describe study participants.

7.2.4 Findings

We elicited a range of reflections and reactions on the SEDC and their use from designers and sharing economy domain experts – from perceptions of the cards' usefulness, to considerations on the use of the cards in their own work, to prospective adaptation of the cards in different stages of service development process, to recommendations on how to improve the cards further.

Perceptions of the Cards

Our participants reflected on the structure of the cards and commented on each individual section with respect to its usefulness for their creative processes. Blanca, 30, while browsing a card, outlined the value of the **Recommendation** section for the designers:

> *"Recommendations are more specific than Goals, I found them more useful. What's in the Recommendation is a [set of] sub-goals that are often what a designer must deal with, it is more relevant for a designer. Connecting recommendations to big goals, as you have done, makes sense to me."*

This comment illustrates that the **Recommendation** worked as an instrument to achieve the **Goal**. Furthermore, Aubry and Emma noticed its reflective qualities. Emma, 31, further suggested to formulate it in the form of the question to trigger this process: *"because something poses a question on the card makes you think"*. Our participants felt that one of the most informative parts of a card was its **Description**.

> *"[This] statement (see **Description** on Figure 7.1c) suggests a study behind it. It feels trustworthy, it helps to convey the Goal "Reduce complexity". It felt bulletproof, it made me believe that this goal is useful, and that I should stick to it because there are studies showing that it works."* (Pierre)

This quote illustrates the value of statistical and other empirical information in the designer's activity when it comes to advocating their designs to a group of stakeholders. One of the most discussed section of the card was the **Example**. It not only served the purpose of stimulating alternative designs, but was also regarded as eye-catching, inspirational, and clarifying the content of the card at large. Rebecca, 26, reaffirmed the latter:

> *"Examples clarify a lot what the card is trying to say, they are really useful, especially because the example are things that people can understand – at least I understand what they refer to [...] They are good practices of products that achieve the goal."*

This quote refers to a practical example taken from a famous sharing economy service, which allowed the designers to relate the problem to their own work. It provided them both "legitimacy" and intuition that this UI pattern works in practice, hence could be considered reliable and trustworthy.

Danny, 31, proposed to use the **Keywords** section to allow searching for design patterns:

> *"I can see that search is a big problem for designers, they do not know where to look for those cards."*

In a handful of cases, the **Keywords** also acted as a signifier summarizing the whole content of the cards, especially in the collaborative activities during the sprint, when lots of workshop materials were on the table at the same time (see Figure 7.2).

The majority of our participants agreed that the **Motivation**, **Content**, and **Audience** themes of the cards were rather important at the initial stages of the development of new design concepts, while **User Experience** and **Privacy & Trust** would come at the later stages of the development. Conversely, Adam, 30, mentioned that some of the themes, such as **Privacy & Trust**, were often overlooked in the early stages of the design of a new service:

> *"Privacy is often left [out] in the design stage, usually the solution [architect] tries to add this at a later stage and designers don't think about it. [The card] (see Figure 7.1d) just reminds them that they have to bring this issue [up], which is very good."*

What is more, participants related the non-hierarchical structure of the themes with fluid boundaries among them:

> *"Maybe because I am an interaction designer, [when] thinking about UX, we extend it to all the other topics. Privacy & Trust, and Motivation are parts of my experience. It [may] not [be] the same for people with different background."* (Toby, 31).

This instance illustrates that the **UX** theme can be perceived as a broader umbrella that incorporate other dimensions. Gladys, 30, developed this idea:

> *"Some cards like [No.] 6 (see Figure 7.1a) and [No.] 21 share the same Goal "Provide pleasurable interactions", I think they can be combined and connected in different ways since there are some overlaps exists in them. One strategy, I think, is to make designers explore those connections and references while they are playing [the cards]"*

As a matter of fact, we observed that some of our workshop participants used several cards at once to sketch-out their ideas in order to meet the suggested "call to action". Refer to Figure 7.2, where two participants on the right have

several cards spread out around them during the prototyping exercise. Most of the participants agreed that the **Motivation** theme can be seen as a nucleus of any service design.

> *"The motivation in my opinion is most important to understand what you are really doing. I like a lot the emphasis on the desirable values, quality and convenience of the service. It is the core [...] it is what you are selling. If you don't have great value and a great way to engage [people] and [to] create social relationship based on reciprocity [...] these kinds of things are really crucial when it comes to a sharing economy platform [...] like authenticity in [the] case of Airbnb."* (Aubry, 30).

Notably in this instance, Aubry adapted the same vocabulary that we used in the cards, which suggests the informative and educational value of the card deck at large.

Collectively, these reflections illustrate how our participants attributed importance to the different sections of the SEDC, and how these provoked discussions on the fuzzy boundaries between the cards' thematic areas. Next, we provide further details about the challenges and opportunities participants raised within our two studies.

The Opportunities and Difficulties of Adapting Cards

Participants reflected upon the opportunities and difficulties of adapting our cards in their own creative processes, and saw a potential to use the design cards beyond the sharing economy. Participants discussed the value of the cards to support both existing and new instances of sharing economy services, and argued on the importance of looking beyond profit-driven aspirations.

> "*Sharing economy platforms are a rather new [phenomena]. There are many of them now – you pay and then get a service. The cards let a designer step back and look at the bigger picture, to slow down a bit and to think how we can improve [a service] in different ways beyond [an] economic [point of view]."* (Gladys, 30).

This quote illustrates the potential of the cards to mobilize the values of collaboration and participation – the cornerstones of platform cooperativism. Pierre, 37, argued that the content of the card could partially replace a human expert when it comes to acquiring the domain knowledge:

> *"I can imagine it is like a suggestion from an expert, instead of sitting and booking someone's time, I can use the cards and try to help myself as a designer without professional [domain expertise]."*

With reference to the challenges in adapting cards in the sprint format, Sarah, 42, explained that more time is required to process the **recommendations** given in the cards, which can be difficult in a high-paced design process:

> *"You have to be there, read a lot. It takes some time to understand. The [card's] Goal and [the] Example were more direct"* (see Figure 7.1c).

Another challenge that emerged from the data is related to the cards' **examples**.

> *"Those examples make me focus and comply to the goal in a way that may limit my imagination... [however] it may be good for those who struggle to interpret a goal."* (Pierre, 37).

This instance illustrates that even though the **examples** were regarded as very informative and clarifying, they also raised concerns of being too specific. Nevertheless, participants found them to be especially beneficial for less experienced designers or even non-designers. Similarly, the **Keywords** section of the cards helped non-designers to make sense of the cards, like in the case of Josepha, 35:

> *"The goal is a bit vague to me, the keywords helps you to clarify the goal. Without the keywords I would not know [how to interpret] the goal 'Reduce complexity' (see Figure 7.1c)."*

Several study participants suggested applications for the SEDC beyond the context of sharing economy. Given the broadly formulated cards' design goals and the themes, participants suggested their use in various areas, for instance product strategy, educational technology, e-commerce, games development, designing online platforms for fitness tracking and creating social media apps. Blanca, 30, explained:

> *"[Cards] provide some ideas for design goals that I should pay attention, [it] can be useful to incorporate those into interviews within my own field of work with users. [The] Goals are quite broad such as "Create value" for the sure, "Reduce complexity" (see e.g., Figure 7.1c). They are [also hold] true in my domain, that is e-commerce, as well when it comes to the user [research]."*

Worden, 32 also saw the value of cards in his teaching and research activities:

> *"Cards stimulate thinking of the practices and platforms in a systematic way, also it could be a good brainstorming tool even for researcher to coming up with new research ideas and projects."*

Collectively, these reflections help to anticipate designers' opportunities and challenges when using the cards in their creative processes. Furthermore, the SEDC provoked reflective thinking on possible applications of the cards in design of online platforms and services, where people share their personal digital information (e.g., captured from the wearable devices).

Serving Different Stages of a Design Process

From the participants observations and the video analysis, we have quickly discovered that our participants have used cards on the different stages of the sprint, as well during individual interviews. Morten, 33, outlined:

> *"First of all, it gives a quite nice overview on the different themes/factors that affect design of a service [as represented by] higher-level themes Content, Audience, Motivations etc as a bigger building blocks of the whole UX of the service. Also, by picking any of these cards up, you can use [it as] a checking point whether the particular recommendation is taken into account in the [current] design or even generating idea[s] for new features that the service does not yet have. I see value in both evaluation and designing new features."*

From our field data, we have elicited five main stages of the design process where the SEDC have been used including, namely: (1) focused brainstorming, (2) prototyping, (3) communicating, (4) refining, and (5) evaluating.

1. Focused Brainstorming The cards helped participants to initiate and engage in focused brainstorming sessions during the sprint. Participants were prompted by the cards' **Goal**, **Keywords** and **Recommendation** to start developing and discussing their ideas. Participants used not only individual cards to reflect upon their content, but also the combinations of cards looking for similar threads. Aubry, 30, explained:

> *"[I was] going deeper and deeper within a single goal per [theme] and expanded it to the extreme in order to see how this goal could be implemented on the Content, Audience, Privacy & Trust etc. That drives the design in all these different aspects. One can focus on one specific goal and that could be seen or interpreted [through] different layers [of] Content, Motivations, UX in order to build a coherent story."*

What is more, the SEDC guided participants brainstorming process by revealing the underlying domain-specific issues that designers may not be aware of.

> *"I think the cards could be used at the start of developing/designing a platform. They are easy to use and following them at early stages perhaps could contribute quicker to the [overall project] success. People behind the platform should be informed about those issues [the] cards bring up."* (Dacie, 35).

This instance demonstrates the value of the cards in revealing the prospective challenges that designers may want to anticipate in the context of sharing economy.

2. Prototyping and Sketching As expected, the cards were widely used during sketching and prototyping activities. In particular, the cards' **Goal** and **Recommendation** part was useful to quickly outline some ideas on the post-it notes during the sprint, while the **Example** parts were heavily used during creating low-fidelity prototypes to flesh out some ideas from the existing platforms and services. Toby, 31, explained:

> *"I think in the prototyping phase, they were particularly useful. I think the Example [part] was one of that gave us more insights, more inspirations to draw something"*

Figure 7.2 on page 185 shows the participants during the prototyping phase; some participant worked in pairs, while others reviewed the cards individually to develop their designs.

3. Communicating Both interview participants, as well as the workshop participants, found beneficial to use the cards to advocate their designs to their colleagues or to a group of stakeholders. Emma, 31, detailed how the **Description** part of the card was crucial during this phase:

> *"I also like images and a little stats that you have here in the card (see **Description** on Figure 7.1c). That is the one of the first things that we mentioned because if you are going to present to your client, which is a new startup, [in] this deliverable, you can use these cards as a kind of give yourself some credibility, advocating particular design [decisions]."*

4. Refining Figure 7.4a shows how participants used the cards to refine and evaluate their own design concepts. In this particular figure, Diana, 35, explained:

> *"The features I added here thanks to the cards were the donate [option], age selection and storytelling."*

What is more, participants reported that cards helped them to understand some design issues that they had not earlier anticipated. Jehanna, 31, explained:

> *"The card (see Figure 7.1d) helped me to notice a problem I didn't take into consideration [. . .]. Even though I didn't find a solution to the issue just now, the card helped me to approach the problem."*

5. Evaluating The majority of our participants agreed that the cards can be used as a guiding tool to evaluate the existing platforms and services. Like in the case of Delora, 32:

> *"I see these card deck as a guidebook. For me as an owner of the [sharing economy] service facing some issues with community-building cards provide some ideas to identify particular issues with my audiences. I found for instance, in [the card No.] 12 (see Figure 7.1e), [the] goal 'Reach out and engage your audience' helpful and [the card] provides a clear recommendation how to [attend] it."*

This instance illustrates that the SEDC can perceived as a checklist featuring best practices, which can be cross-checked against platforms' designs. Morten, 33, provided further detail:

> *"For example, picking out one of these cards and checking that the goal is already designed/implemented in the service or there will be more work to do. Also after that moving to the right side of the card (see **Example** on Figure 7.1c) and checking some concrete examples how to manifest these kind of goals to the UI level."*

The SEDC facilitated our participants to identify existing design flaws, Julie, 27, mentioned:

> *"I believe Airbnb are doing quite the opposite to what the card recommends, here [this card] (see Figure 7.1c) suggests to identify the needs of the users and to trigger things to improve the service with them, but I don't receive good recommendations of things I'm interested in. I just opened the app and I don't see any of the places I searched before, they [Airbnb] show me these fancy houses I'm not going to rent because they are too expensive."*

Furthermore, the cards offered potential design solutions for those problems:

> *"For an average user, it is hard to say often whether [rating] 4.2 is good or bad. Airbnb could provide some contextual information, such as average ratings in certain city, explain what this rating mean. Like if you click on "Accuracy", it can be described for those who opt-in to learn more about it."* (Worden, 32).

In addition to that, the SEDC provided necessary resources to our participants to develop the protocols for future user studies as in the case of Blanca, 30:

> *"If you want to understand how people perceive a platform it makes total sense to me [using the cards], it gives me good examples of what to ask and what you should not miss [...] if you need to focus on the Content, you need all the Examples and all the Recommendations of those [...] it helps you to go straight to the point."*

Finally, several participants contemplated that the cards can be used to structure their design feedback and critique.

> *"I do not have to think about the process. The card is a hint for me to use within my expert feedback. The colored [themes] are helping me to structure my thoughts and the overall documentation from different perspectives. There are some ready-made suggestions that I can communicate to a client. It provides me a certain confidence, even [when it comes] to naming sections of the report."* (Pierre, 37).

Collectively, these reflections confirm that the cards could be used in the different stages of the design process from assisting in initial ideation sessions to facilitating the reporting to the stakeholders. In what immediately follows, we detail how the SEDC played out in different stages of the service/platform design.

Developing Design Material Using the Cards

From the collected data, we have observed that the SEDC can generate various design materials to create or improve a service. Our Study 1 participants used the cards to inform the structure and the content of a UX report including user flows, customer journey maps, and propose adjustments to the UI. Pierre, 37, detailed this while evaluating an existing platform:

> *"I have built up a state-map of functions to decompose the UI into the basic functions of different components and I am trying to find inconsistencies between certain [application] logics, which failed [within a service], and [to spot any] misleading components."*

Furthermore, Bobby, 33, elaborated that he used the cards to uncover platform shortcomings and to support their reporting:

> *"I guess a good way to show it would be [. . .] to take the card (see Figure 7.1c) and replace the example with the exact block from [our own service]. If I can do that, then we have to be doing things right, but if the example doesn't fit, that means we're failing in this aspect."*

During Study 2, participants used the cards to develop concrete service designs. For example, Figure 7.4d shows the filled idea template (and corresponding prototyping templates), which describes a design concept of a local toy bank and its target audiences, namely parents and orphanages. Specifically, the participants proposed an online service that would support the renting and sharing of

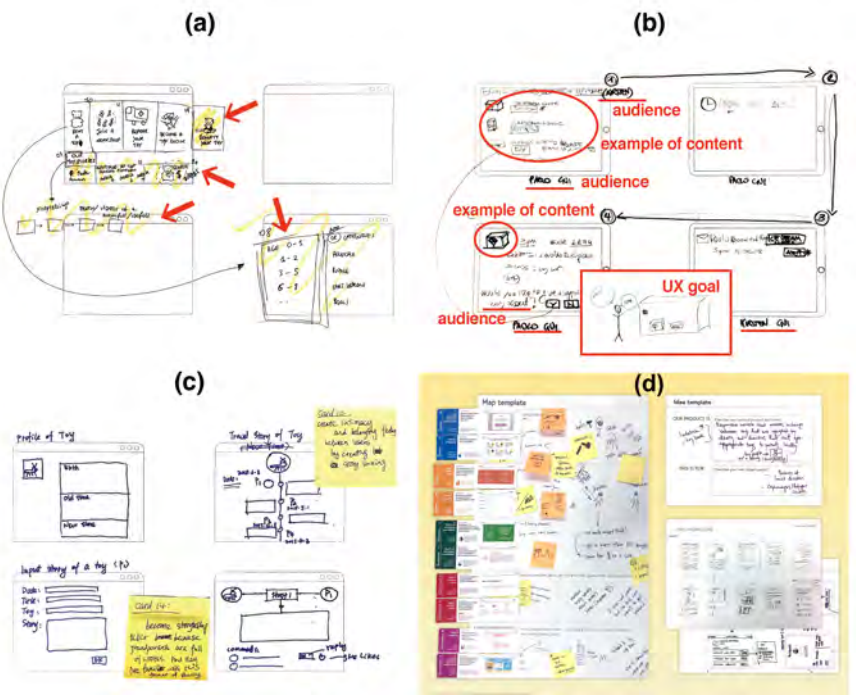


Figure 7.4. Design materials produced at the sprint: (a) value-added features based on the cards highlighted in yellow with red arrows; (b) user flows, examples of content, target audiences, and UX goals; (c) wireframes and their relation to the cards; (d) an example of a final concept

upcycled toys. The cards not only facilitated the generation of various concepts, but also served to develop and to refine the ideas on the user interface level (see highlighted content on Figure 7.4a). The cards also helped participants mindfully attend to the design goal by incorporating new functionalities, such as storytelling, or attending to the emotional aspects of belonging and intimacy. In particular, Figure 7.4c illustrates how Amy placed the explanatory notes next to her prototypes, summarizing the role of a particular card in her design decisions. In this instance, Amy demonstrated her interpretation (on the UI level) of the card's **Goal** "Build a common space" (see Figure 7.1b) for platform's users by affording them to create personal stories and to link them to the shared toys. Sarah illustrated (see Figure 7.4b) how the cards helped her to not only establish the UX goals of the service (e.g., enhance sociability), but also assisted her in the process of wireframing, establishing an interactive flow, and the creation of examples of the shared artifacts and the target audiences for it, stemming from the **Content** and **Audience** themes of the cards.

Collectively, these reflections help to demonstrate how the cards were instrumental in different parts of a design process: from detailing nuances at the present design idea, to fostering interactive scenarios, to helping to identify and report design flaws in existing sharing economy services.

7.2.5 Supporting the Design Processes

Our findings show that the SEDC enabled speculation on the role of the UX in the service development, provided hands-on guidance on different parts of the design process, facilitated creating new design material to inform the decision-making, and enabled speculation on future-looking opportunities of cards' use beyond devising sharing economy services. In what immediately follows, we discuss how the SEDC help advance the design practice and design research in the context of sharing economy.

Despite our work focusing on studying designers in design workshops outside of their usual place of practice, we have ensured that the exercises we have performed with designers are situated around their core activities at work, that is collaboration and communication [Roedl and Stolterman, 2013]. Those activities were implicitly included in the stages of the design sprint, namely Deciding and Advocating phases (see Table 7.1). In the Deciding phase, participants have to synthesize their design ideas, establish a group consensus, and eventually pick 1–2 design alternatives, while in the Advocating phase the participants were required to advocate their designs to the set of (imagined) stakeholders. While numerous prior studies of design cards (e.g., [Lucero and Arrasvuori, 2010; Mora

et al., 2017]) have actively supported the divergence steps of the design process, our research highlights key value in better enabling convergence activities.

Following recent work of Colusso et al. [2018], we have adapted the design sprint process in our Study 2 in the context of the sharing economy. While, several of our participants felt that more time is required to reflect upon cards' **recommendations**, we specifically chose this high-paced approach to account for the ongoing issues of limited time and resources during the design process, which practitioners face in the real-life product development projects [Roedl and Stolterman, 2013]. To address this concern, we believe that exposing the cards to participants prior to any design activity can be beneficial. Therefore, in order to ensure we would receive adequate feedback on the cards' content, we have accommodated an individual activity with designers and sharing economy experts in Study 1. In contrast to prior work [Colusso et al., 2018], where participants were struggled to reflect on theoretical frames brought by the design cards, this time-unbound activity allowed us to elicit deeper reflections on the sharing economy concepts.

Our findings revealed that some of the design ideas that emerged during the sprint were attributed to the continuous interaction among participants (see Figure 7.2). Yet, similarly to [Colusso et al., 2018], our participants were able to further advance and expand their designs using the cards' **examples** and **recommendations** (see Figure 7.4a).

Finally, individual uses of design toolkits, such as cards, are rarely described in the design research literature, perhaps due to the collaborative nature of the design process at large. Friedman and Hendry [2012] suggested that card-based design toolkits can be used as "an analytic technique tool", which our research supports and helps extend through an empirical case. Our SEDC were used not only in supporting groupwork to create new design concepts of sharing economy services, but also in the individual activity akin to expert critique to identify design issues of the existing sharing economy platforms.

7.2.6 Designing for Sharing Economy Services and Beyond

The SEDC extended and mobilized design strategies suggested by Light and Miskelly [2015], which aim to promote different dimensions of sustainability in sharing and exchange communities: environmental, social and economic. In particular, they highlighted the importance of the community cohesion as a pre-requisite to bring these strands together. Similarly, Delora and other participants discussed aspects tied to community-building while reviewing the cards. In this, they acknowledged that the **recommendations** that our cards provide, prompted

them to approach the problem from a new angle they had not yet anticipated. We have also incorporated the **User Experience** dimension as one of the cards' themes in the service of supporting community engagement early in the design process. With the rapid emergence of personal and mobile technologies, we envision that designers of future platforms for resource sharing communities and cooperatives may want to revisit the role of the UX in their value proposition. While some platforms co-ops (e.g., Stocksy, FairMondo) offer mobile-tailored (i.e., responsive) website designs to access their services, they are hardly competitive to design-driven sharing economy organizations with significant resources, such as Airbnb. Perhaps focusing on clearly communicating their commitments to cultural and community values (see Section 7.1) at different points of interaction with a platform may be beneficial to engage and retain users.

Our findings revealed that the SEDC can also be successful to surface opportunities for incorporating added privacy dimensions in the design process, known as "privacy by design" (e.g., [Cavoukian, 2013]), which is often overlooked in the early stages of product development, as highlighted by Adam. Participants also regarded that understanding the motivation behind the service is a prerequisite to start any design process. While researchers have struggled to engage designers to see the motivation behind the design briefs during the sprint [Colusso et al., 2018], we enabled participants to consider the **Motivation** theme early in the process. This worked not only to generate empathy among our participants in the given design challenge, but also to provide scaffolding for participants to detail their designs with reference to the various motives to participate in the sharing economy.

Looking at the particular distinction among profit-driven and non-profit approaches of the sharing economy [Light and Miskelly, 2015], the SEDC can productively support designers in exploring this space from different perspectives. For example, Gladys, while evaluating a profit-driven bike sharing service, mentioned that the SEDC encouraged her to reconsider the value of social ties through reciprocity, cooperation and participation. For non-profit organizations, the SEDC illustrated design opportunities to address the attendant challenges of platform co-ops – most notably to improve trust within their communities and supporting online platforms [Lampinen et al., 2015, 2013]. Following prior research highlighting specific characteristics of local and global context of the sharing economy [Light and Miskelly, 2015], our work highlights the need for future empirical research to examine the role of platform design (e.g., functionalities and their enabling mechanisms) in greater detail.

Ultimately, our findings suggested that the breadth of themes covered in the card deck may be applied to various social sharing platforms (e.g., Endomondo for

sharing personal workout data). This suggests an opportunity for future work to explore the extensibility of the cards to different, yet related areas of the sharing economy such as e-commerce, or online sharing services and apps.

7.2.7 Comparing the Design Cards with Other Design Toolkits

Similar to other design cards, the SEDC enabled creative thinking [Lucero et al., 2016; Mora et al., 2017], engaged non-experts in generating domain-specific ideas [Luger et al., 2015; Mora et al., 2017], facilitated prototyping [Halskov and Dalsgård, 2006; Lucero and Arrasvuori, 2010], and described previously unknown concepts [Colusso et al., 2018; Luger et al., 2015]. Following existing card-based approaches to facilitate the design exploration in particular application domains (e.g., Internet-of-Things [Mora et al., 2017], data privacy [Luger et al., 2015], behavioral change technologies [Colusso et al., 2018]), our design of the SEDC integrated domain-specific knowledge to inform and inspire the design process. The SEDC surfaced ongoing challenges in the emerging sharing economy design space and provided actionable recommendations on how to address them. We see this as a main differentiator across other all-purpose design toolkits (e.g., `platformdesigntoolkit.com`) and broader approaches to design research (e.g., qualitative contextual inquiries). The SEDC incorporated both a "what-to" and "how-to" toolkit, which offers concrete frames of references to help designers (like Gladys and Pierre, see page 190) navigate specifics of the sharing economy and to enable them to develop their ideas in this space. This can be especially beneficial to actual design teams, which often have to deal with practical challenges, such as working within limited time and resources [Roedl and Stolterman, 2013].

In contrast to many card-based design toolkits (see e.g., [Wölfel and Merritt, 2013] for a review), the SEDC provided examples of interface designs of existing successful online sharing (economy) platforms. Pierre, along with few other participants, explicitly mentioned that while such examples may limit designer's imagination, they nevertheless offer clarification and interpretation of the design goal, which can be particularly valuable for junior designers. These findings suggest an opportunity for exploring how those inspirational examples could play a role in supporting designers' creativity in professional practice [Kulkarni et al., 2014].

The SEDC can be seen akin to platform-specific interface guidelines (e.g., Apple Human Interface Guidelines), as they feature a great level of detail and can be considered as self-contained design instruments [Luger et al., 2015]. Many of our participants described and used them as "checklists", which can particularly be useful in evaluating existing sharing economy platforms and services. We

see the SEDC as translational resources [Colusso et al., 2017] that can facilitate knowledge transfer between design research and design practice [Deng et al., 2014] by offering the adequate amount of detail tailored to different stages of the design process.

7.2.8 Conclusion and Future Work

This study offers two main contributions. Firstly, it presents the Sharing Economy Design Cards and the corresponding framework for their use in a collaborative workshop. Secondly, it provides insights and findings that surfaced during the two deployment settings of the cards with 26 participants, and discusses how they help advance the design practice and design research in the context of sharing economy. Our participants have found cards useful not only in collaborative activities to create new sharing economy design concepts, but also in individual activities to provide structured design critique on the well-known existing platforms. Moreover, we demonstrated that the SEDC can be suitable for the different stages of the design process: from initial ideation, to prototyping and evaluating designs, to reporting them to the stakeholders.

Wider dissemination of the SEDC would allow us to explore their applications in industry-based projects, which have longer timespans and real-life constraints. Future research could incorporate a particular methodological lens to analyze the use of the cards in designers' creative processes such as theories of social practices. This will not only help better grounding this work in the designers' processes at their place of work, but may also offer deeper insights of the design space in the context of sharing economy. Ultimately, to further validate the usefulness of the SEDC for platform design or evaluation, one can conduct a controlled experiment where one group of designers (an experimental group) would have access to the card deck, while the other group (a control group) would not. Even though many factors could contribute to the creativity of the designers (e.g., a collaboration between peers), the yielded findings could potentially provide stronger evidence for the utility and value of our cards.

7.3 Summary

This chapter *investigates how designers can specifically support technology-mediated physical sharing practices in the context of the sharing economy* **(G3)**. In particular, reflecting upon the results of our empirical study of technology-mediated sharing practices (see Section 3.3), we elicited a set of design recommendations for

sharing economy services. Based upon these reccomendations, we developed and partially validated the Sharing Economy Design Cards, a design toolkit for sharing economy services.

At the outset, drawing on both our mapping of the sharing economy design space, as well as a comprehensive account of the commonalities and differences between digital and physical sharing practices (see Section 3.3.3), we formulated a set of design implications for devising novel sharing economy services and platforms. Specifically, we offered design strategies to *leverage the dual nature* of the shared content (i.e., a physical artifact and corresponding layers of digital metadata) in the sharing economy, we provided ideas how to *adjust levels of self-disclosure* throughout the course of a sharing transaction, and we urged platform designers to *actively communicate* pro-social benefits of the sharing economy services they are building. Furthermore, we emphasized the importance of the nuanced *mechanisms to improve trust* within resource sharing communities and their supporting online platforms, as well as discussed the value of *operationalizing sharing triggers* to improve user experience with a sharing economy service.

Drawing on these design implications, we developed the Sharing Economy Design Cards. The cards can be seen as a "what-to" and "how-to" toolkit that provides domain-specific recommendations for UX and service designers to aid the developement of their ideas in the context of the sharing economy. The deck consists of 24 cards that are organized into five key design themes – **Content**, **Audience**, **Motivations**, **Privacy and Trust**, and **User Experience**. Each card is divided into seven sections (see Figure 7.1): (1) a card's theme; (2) a leading question; (3) a design goal; (4) searchable keywords; (5) an actionable recommendation; (6) a detailed description; and (7) an UI example from an existing service. We deployed our design cards with 26 participants and discussed how they can be used in individual activities (e.g., to facilitate structured design critique akin to an expert evaluation of existing sharing economy services), as well as in collaborative workshops (e.g., to create original sharing economy design concepts in a group setting). We additionally developed and field-tested a corresponding design methodology for the cards' use in a collaborative workshop. Our findings suggested that the cards, owing to their thematic composition and their structure, can effectively support both the divergence steps of the design process (e.g., exercise designers creativity based on cards' broad design goals and themes), as well as better enabling convergence activities (e.g., refine a specific design concept through cards' action-driven recommendations). In particular, we demonstrated how the cards can be a versatile design tool suitable for the different stages of the design process: from initial ideation and sketching, to prototyping and evaluating designs, to communicating and advocating them to

the stakeholders, to identifying and reporting design flaws in existing sharing economy platforms. Ultimately, the cards were not only instrumental in creating new design material to inform decision-making in a group setting, but also enabled speculation on future-looking opportunities of their use beyond devising sharing economy services.

In the next chapter, we reflect upon the research contributions of this thesis by situating the findings from this chapter and others in the context of our original research goals. We also outline the limitations of our approach and discuss directions for future work.

Chapter 8

Conclusions and Future Work

This dissertation explored the design space of novel technology-mediated sharing practices in two emergent sharing domains: (1) the domain of personal activity tracking; (2) the domain of sharing economy services. The goal of this final chapter is to offer concluding remarks on the work we conducted in this thesis. We first provide summaries of the research problems we addressed and discuss the completed research goals that form our research contributions. Furthermore, we outline the limitations of our approach. Ultimately, we describe two future avenues for interaction design research in the context of the sharing economy that can build upon this dissertation.

In Chapter 1, we identified the main motivation for our work – an overarching problem of understanding how the design of networked and interactive technologies could adequately address the challenge of information oversharing and the challenge of under-sharing of physical resources in two aforementioned domains. In order to approach this challenge, we formulated three research problems that we addressed in our thesis:

(P1) With the absence of a comprehensive account of novel content sharing practices, it is difficult to characterize the specific role of mobile and wearable technologies in supporting *digital sharing enabled by the advent of personal activity tracking.*

(P2) It remains difficult to describe nuanced design characteristics for interactive technologies to support *physical sharing practices in the context of sharing economy services.*

(P3) We do not know how designers of online sharing platforms and services can support physical sharing practices in the context of the sharing economy.

8.1 Contribution Summary

The main goal of our research was to understand current practices of sharing personal digital and physical possessions, and to uncover corresponding end-user needs and concerns across novel technology-mediated sharing practices, in order to map the design space for user experience design to support emergent and future sharing needs.

In this thesis, we addressed the three aforementioned problems with the completion of the corresponding research goals (G1-G3). We outline those goals below and summarize the steps we took to attend to them while describing their particular research contributions to the field of HCI, interaction design research, and, more specifically the design technology for sharing.

(G1) **Provide a comprehensive account of common digital sharing practices stemming from the advent of personal activity tracking.**

We achieved this goal by conducting an online questionnaire of 246 individuals to examine their novel content sharing practices, stemming from personal activity tracking, and contextual interviews with 45 participants to elicit their sharing needs and concerns in the prototypical context of outdoor sports. We analyzed the findings using quantitative and qualitative analysis approaches and synthesized the insights with the related work. The completion of **G1** presents two major research contributions:

— *A descriptive mapping of novel content sharing practices online*. In Chapter 4, we presented peoples' practices of sharing (1) music preferences and playlists; (2) travel plans and trip details; (3) details of physical exercises and sports activity; (4) digital representation and contextual metadata about real-world items such as rooms and vehicles; (5) virtual artifacts in video games and virtual social worlds and (6) personal culinary and dietary preferences. We systematically identified and compared content items that are being shared across various audiences, as well as elicited the examples of actual online services that enable sharing of novel types of content. We subsequently illustrated the limitations of these services and tools, and outlined the common privacy concerns that frame novel content sharing practices. Ultimately, we empirically extracted a set of factors that influence device preference when accessing supporting sharing services, and revealed that desktop interfaces of those services in contrast to their mobile counterparts are often considered more efficient and easy to use – both for sharing, and access control tasks (i.e., privacy).

— *A set of insights on supporting digital sharing practices of co-located leisure skiers*. In Chapter 5, we examined in-depth how mobile and wearable technologies

could support digital sharing practices of leisure skiers. We initially identified their information sharing needs before, during and after the activity. We discovered that skiers often share location information, media content and reference information about ski resorts (e.g., amount and types of hazards in the area) within co-located groups. Following contextual and participatory design processes, we extracted the design requirements for an interactive system to support skiers sharing practices and subsequently designed, developed and deployed SkiAR, a wearable augmented reality system for sharing personalized content on ski resort maps. We offered prospective critical reflections on how the SkiAR system (a) supported skiers' group planning and decision-making in situ; (b) afforded adequate interactions utilizing envisioned wearable high-tech skiwear; (c) enabled collection and sharing activity-related content within a group. Finally, we introduced two interaction design concepts for in situ content sharing systems that could support decision-making encounters within and beyond the context of outdoor sports: (1) *points-of-interaction* i.e., the location where actual group decisions are taken, and (2) the *temporal aspects of interactions*, the fact that those interactions are often time-constrained.

The completion of **G1** also presents an additional, yet still important, contribution:

— *A proof-of-concept for remotely-located sharers*. In Chapter 5, in order to further our understanding of the variety of novel shared content types stemming from personal activity tracking, we looked at biophysical and emotional data. Nowadays, this data can be relatively easily gathered from the widespread personal wearable devices (e.g., fitness trackers, smartwatches) and, subsequently, shared online. We selected the context of movie-viewing with distance-separated families/couples to meaningfully leverage sharing of these types of data. We designed and developed Movie+, an interactive prototype that allows one to create and share emotional fingerprints of a recently viewed video clip or a movie with family members and friends. We offered a set of considerations for a prototype's field deployment to uncover the social end experiential effects of sharing emotional fingerprints.

(G2) **Describe nuanced design characteristics for interactive technologies to support physical sharing practices in the context of the sharing economy.**

We completed this goal by conducting two field studies. In the first study, we employed the empirical sampling method and analyzed individual practices of sharing everyday purchases of 71 participants. In the second study, we conducted

an ethnographically-inspired qualitative inquiry into tool sharing practices of one resource sharing cooperative with a view to eliciting their ongoing organizational challenges and informing the design of an interactive system to approach those challenges. We interviewed 16 active co-op members and employed an open coding technique to analyze the results and synthesized them within the related work. The completion of **G2** presents two major research contributions:

— *A descriptive account of sharing practices of everyday purchases.* In Chapter 6, stemming from a month-long diary study of everyday purchase sharing routines, we identified the most shared categories of everyday purchases. We illustrated that sharing purchases typically happens within domestic environments among close family members and friends. In addition to that, we computationally determined that overall purchase satisfaction positively affects its sharing. Delving further into this relationship, we elicited motivational and experiential aspects of sharing purchases spanning hedonic, eudaimonic and environmental factors of everyday consumption. Ultimately, we articulated a set of user experience design considerations for future persuasive technologies that aim to support purchase sharing.

— *A set of design recommendations for interactive technologies to support resource sharing communities.* In Chapter 6, we established a case study with the Vancouver Tool Library (VTL), a tool sharing cooperative. We identified the co-op's three emergent organizational challenges: (1) the large degree of members' anonymity, (2) poor visibility of members' work, and (3) the lack of accountability for shared resources. We empirically demonstrated that those challenges can be partially addressed through capturing and sharing members' tool-use experiences. We designed and developed Roaming Objects, a mobile application that afforded the creation and sharing of such experiences. We subsequently deployed the Roaming Objects app at the VTL for two months to elicit a range of self-reflections across members of the VTL on how digital narratives could shape their reactions to shared objects (e.g., tools) and to the broader social tool-sharing organization. Drawing on the field deployment, we elicited a set of design recommendations to support physical sharing practices within resource-sharing communities. Namely, (1) the *progressive self-disclosure* technique may have a potential to de-anonymize the community membership; (2) accrued *experiential histories of use* not only increased visibility of largely unseen members' practices, but also became useful indicators for timely tools maintenance and for required inventory updates (thus helping in overall accountability of the tools among volunteers and members); and (3) *dynamic thing-story assemblages* opened opportunities for adapting Roaming Objects beyond tool-sharing communities for virtually any resource sharing collectives where physical things change many hands over time.

The completion of **G2** also presents an additional, yet important, contribution:
— *A proof-of-concept for supporting informal economies of personal artifacts.*

Building upon the design considerations from the deployment of the Roaming Objects system at the VTL, we looked beyond resource sharing organizations and explored the context of informal economies of personal artifacts (e.g., sharing/renting a pair of skies through an online platform to an unknown peer). Following the review of the relevant literature, we identified two attendant challenges of such online communities: (1) issues of trust within the community members and the supporting online platforms and (2) difficulties with dealing with a growing number of intermediaries (e.g., a payment processing company, an insurance, a bank), especially when the goods are not adequately delivered/returned. For this purpose, we designed and developed "Just Share It", a mobile application that, firstly, aims to engender trust within the community and the online platform through implementing a reputation review mechanism on a transparent and immutable blockchain ledger, and, secondly, offers a prospective solution for disintermediation by utilizing an escrow property of emergent smart contracting technologies. We discussed the future-looking opportunities for a field-deployment of our system and reflected upon the use of blockchain ecosystems as a resource for the design technologies within the context of the sharing economy.

(G3) **Investigate how designers can specifically support technology-mediated physical sharing practices in the context of the sharing economy.**

We completed this goal by conducting a literature survey of technology-mediated sharing practices, 16 expert interviews on contemporary sharing economy services, and a set of qualitative studies (individual interviews and creative collaborative workshops) with a total of 26 designers and sharing economy domain experts. The completion of **G3** presents two major research contributions:

— *A mapping of the design space between physical and digital sharing practices.*
In Chapter 2, we systematically reviewed prior work that broadly covered various technology-mediated sharing practices spanning from file sharing to sharing physical things in the context of the sharing economy. We additionally recruited 16 design practitioners and sharing economy domain experts for qualitative interviews to discuss specific socio-technical and design challenges of contemporary sharing economy services. In Chapter 3, based upon both the synthesis from our empirical review of the literature, and experts' reflections and reactions, we elicited five key design themes of technology-mediated sharing practices: (1) the diversity of shared content; (2) audience management; (3) motivations to share; (4) privacy and trust issues; and (5) user experience requirements. These key

themes, along with detailed sub-themes (see Figure 3.3) constitute 13 sharing dimensions that can be used as a common frame of reference for researchers and designers who are investigating this emergent space. Using these dimensions, we outlined nuanced commonalities and differences among the digital and physical sharing spheres.

— *A set of design implications, a design toolkit, and a method for the creation and evaluation of sharing economy services.* In Chapter 7, building upon the dichotomy between physical and digital sharing practices identified in Chapter 3, we subsequently formulated a set of design implications for devising novel sharing economy services and platforms. Drawing on the elicited design implications, we designed the Sharing Economy Design Cards, a "what-to" and "how-to" design toolkit for the sharing economy. We also developed a corresponding design methodology for the card's use in collaborative settings. We then partially validated our cards with 26 design practitioners and sharing economy domain experts in individual and group activities. We articulated that our cards can be seen as a versatile tool to help designers to navigate specifics of the sharing economy, and to develop their ideas in this space by offering the adequate amount of detail needed at both divergence and convergence steps of the design process – from initial ideation and sketching, to prototyping and evaluating designs, to communicating and advocating them to the stakeholders, to evaluating existing sharing economy platforms. On the whole, we highlighted the cards' usefulness not only in collaborative activities to create new sharing economy design concepts, but also in individual activities to provide a structured design critique on the well-known existing platforms. Ultimately, the cards enabled speculation on future-looking opportunities of their use beyond devising sharing economy services.

8.2 Limitations

In this section, we would like to acknowledge several limitations of our research.

The first limitation relates to the malleable concept of *sharing* that often means too many different things and touches various aspects of our lives (see Chapter 2). Therefore, this polysemic nature of the phenomenon makes it hard to generalize our findings. Drawing on the work of the media and communication scholarship (e.g., [John, 2017; Kennedy, 2015]), in Chapter 3, we framed sharing based upon its communicative and distributive logics, as well as upon the medium where the sharing takes place – digital ephemera or the real world. We contextualized this phenomenon within two emergent sharing domains: (1) the domain of personal activity tracking and (2) the domain of sharing economy services. We argued

how these two domains are interconnected owing to a mediating online platform that often governs the interactions among a sharer and a sharee, and the *dual* nature of the shared content within sharing economy services (see Chapter 7). We subsequently presented how the challenges of one domain are inherently related to the other one, and how they can be characterized within five key design concepts/ themes – (1) shared **content**, (2) target **audiences**, (2) **motivations** to share, (3) aspects of **privacy and trust**, (5) and **user experience**. Future research should look at how these concepts could be situated, adapted, and extended in newly emergent sharing practices, for example, sharing digital possessions in virtual social worlds, or machine-to-machine information sharing in an IoT environment, as well as in "traditional" offline sharing practices such as of sharing physical things within neighbors or sharing emotions between people at large.

Secondly, while throughout our thesis we looked at the different sharing *practices*, we acknowledge the moderate use of the actual theories of social practices described in Chapter 3. These theories were fundamental in framing our research questions and informing the design of our empirical studies, albeit we have adopted their ideas only partially. In our thesis, we drew upon the work of Kennedy [2018], who offered an understanding of sharing practice as a composition of three inter-related elements: *materiality*, *symbolic values* and *competences* (see Chapter 3). These elements helped to form the basis of our core sharing questions and informed the above-mentioned key design concepts, namely (a) shared **content** that addressed the question "What is being shared?" exploring the *materiality* element; (b) **motivations** to share that exploit the *symbolic values* component of a practice by eliciting sharing meanings and aspirations and attending to the question "Why sharing takes place?"; and (c) **user experience** inquiring "How sharing takes place?" speaking to the *competences*. What is more, we offered an interpretation of how the elements from Kennedy's framework [2018] could be adapted beyond networked cultures towards technology-mediated sharing practices in the context of collaborative consumption. Specifically, we provided a common frame of reference for design research and design practice through systematically mapping the sharing economy design space, and formulated a set of specific design recommendations (e.g., in the form of the Sharing Economy Design Cards) for devising new instances of sharing economy services and platforms. Leveraging these theoretical underpinnings of sharing, we then designed, developed and deployed several technological prototypes to partially validate and extend our assumptions about sharing through a set of field studies.

In addition to that, we followed a practice-oriented approach to research exploring everydayness and ubiquity of sharing practices [Kennedy, 2015], rather than explicitly engaging in a prescriptivist debate about what counts as sharing and

what is not. In turn, HCI researchers demonstrated that in generative approaches to design *a practice* could be used as a unit of analysis [Wakkary et al., 2013] as well as a unit of design [Kuijer et al., 2008]. Note that in these approaches people have a peripheral role as carriers of practice. Consequently, we made an informed decision to follow user-centered design approach, instead of designing for practices, in order to ensure that people remain at the center of a design process and their sharing needs and concerns are adequately accounted for.

The third limitation relates to the choice of the methodology. The qualitative research approaches that we widely employed in our thesis have an inherent limitation of being hard to generalize to different populations. Therefore, despite the rich and descriptive accounts we developed within two emergent sharing domains, our findings should be interpreted with caution. Nevertheless, the very nature of these methods allowed us to describe in great detail and depth peoples' sharing practices within a given context. In addition to that, in Chapters 4 and 5, we complemented our findings with quantitative research methods in order to determine causal relationships between different elements that constitute sharing in their respective contexts. Furthermore, responding to the call of Dillahunt et al. [2017], we developed several interactive prototypes to support sharing practices of individual and groups within two emergent sharing domains leveraging a system-building tradition of HCI. Nonetheless, more varied methods of research are needed to establish a holistic understanding of technology-mediated sharing practices within the context of the sharing economy.

Ultimately, a further limitation of this work is related to the diversity and the composition of participants in our studies. The work presented in this thesis often recruited young and tech-savvy participants from middle-class backgrounds who live and work in an industrialized Western country (mostly from North America and Europe). On the one hand, these populations represent the actual users of technology-mediated sharing services and tools well, on the other hand, it is important to acknowledge that sharing practices and routines could be different in various cultural, geographic and demographic contexts. Therefore, future research should look at the technology-mediated sharing practices of participants with different socio-economic backgrounds, ages, and beyond Western culture.

8.3 Future Work

This dissertation presents a building block for researchers and designers who interested in further exploring technology-mediated sharing practices. Throughout this dissertation, we suggested new areas for future research and practice

initiatives in the HCI and interaction design communities. In particular, in what immediately follows, we outline two opportunities for future work in the context of the sharing economy.

8.3.1 Local Economies of Personal Artifacts

Building upon the findings from our study of tool-sharing practices in the Vancouver Tool Library (see Section 6.2), we outlined the need to further support the design of platforms and tools for non-profit approaches to the sharing economy (e.g., local resource sharing associations and grassroots initiatives) in order to ensure the sustainable development and growth of their respective communities. Specifically, we see the value in exploring how information technologies can support the sharing of underutilized personal physical artifacts (e.g., tools, household items, sports equipment) within local communities.

Throughout our research on alternative models of the sharing economy, we came across a sharing community Pumpipumpe (`pumpipumpe.ch`), which was founded in Bern (Switzerland) in 2012. The community provides a set of stickers that can be put on a mailbox to let neighbors know what household items one is willing to share. Being a "low-tech" solution, the service does not specify how the sharing of those items would be arranged – it is up to the individuals to agree upon terms of use and arrangements for an item's return. The pre-defined images on the stickers vary from common household items (e.g., a bike-pump) and tools (e.g., a drill), to rarely used kitchen appliances (e.g., a pasta maker), to typical Swiss cookware such as fondue sets. One can design their own sticker as well, in case none from the standard set match. Currently, its online service offers only a simple search interface, including an online map of participating households. There is no monetary compensation explicitly designed and endorsed by the platform.

In 2014, Pumpipumpe formalized their legal status in Switzerland as a non-profit association. The goal of the association is to provide awareness of conscious re-use of peoples' underutilized personal possessions while supporting face-to-face encounters of neighbors. The association is run entirely by volunteers to support day-to-day operations of the association. All revenues collected from the sale of the sticker-sets (5 Swiss Francs/Euros for a set of 40) covers the printing and shipping costs. This rather simple idea quickly gained popularity outside Switzerland. Now, nearly 20 000 households participate worldwide. Pumpipumpe is an interesting example of a sharing economy service that promotes trust, encourages sustainable consumption, facilitates social encounters and fosters the development of local communities.

Nonetheless, when we initially approached the association in 2018, we quickly realized that they have very little knowledge of the actual practices, needs, and concerns of the participating individuals and households. Apart from the name, the address and the type of ordered stickers, the community membership was largely unknown and anonymous to the association. As a result of that, the association faced growing concerns regarding their future activities in order to adequately support and serve their members' needs.

Therefore in our future work, we would like to create a comprehensive ethnographic account of physical sharing practices of local economies of personal artifacts in a prototypical resource sharing community, such as Pumpipumpe. In particular, we would like to explore *what* people are currently sharing/renting from their personal possessions, and understand the conditions and circumstances of *how* these exchanges are performed. In addition to that, we would like to compare and contrast these sharing practices and routines with our field-work conducted at the Vancouver Tool Library (VTL), see Chapter 6.

We expect that resource sharing practices within neighbors would be different from the ones in the VTL, owing to the following important distinctions among them: (a) the individual or family-ownership of household items in contrast to collective ownership in the VTL; (b) the processes of borrowing items are self-organized in contrast to the established practices at the VTL (e.g., tools check-out at a counter with a presence of a volunteer); (c) the underlying meaning of sharing resources (e.g., tools) in the neighborhoods generally aimed towards straightening social connection and community resilience instead of various motives of participation in well-established cooperatives such as the VTL (e.g., to learn a new tool, engage in a personal project); (d) intricate use of ICT within informal resource sharing communities in comparison to the centralized infrastructure (e.g., inventory software) at the VTL.

Ultimately, through contextual and participatory design approaches, we will collect a set of user requirements for a local sharing economy platform in order to support the community's operations and address their emergent challenges.

8.3.2 Trust Accrual in Online Resource Sharing Communities

A further research avenue that immediately appeared from our dissertation is the growing concerns of trust within the peers and the supporting online platforms in the context of the sharing economy in general and within the online rental or swapping platforms for physical goods in particular. In Section 6.3, we described the design of a mobile sharing system to connect lenders and borrowers using blockchain-based technologies. We argued that these technologies may

help (1) to engender trust within an online exchange platform by keeping an immutable record of peers' reputations/ratings on transparent distributed ledger and (2) to reduce the number of intermediaries when dealing with potential disputes. For example, smart contracting technologies could offer a platform for conflict resolution in order to settle occurred disagreements between a lender and a borrower regarding the state of a shared item (e.g., broken returns).

We envision deploying our system into an existing online resource sharing community (e.g., Peerby) in order to validate our assumptions. This will not only allow us to elicit aspects of perceived trust within a sharing platform and to examine the role of blockchain technologies in trust accrual, but also to identify challenges and opportunities related to the experiences of the use of a blockchain-based system in the context of the sharing economy. In this effort, we particularly like to set the following questions: "How can technology interventions facilitate or inhibit trust within a community and within a supporting platform?", "What are users' perceptions of trust enabled by the smart contracting technologies within a sharing economy community?" Ultimately, we hope this work inspires future research to look at how blockchain-based technologies can further support physical sharing practices in an IoT future, where everyday things (e.g., an IoT-enabled pair of skis) are controlled by a machine agent, and thus have their own decision-making capabilities and power to execute smart contracts.

8.4 Final Remarks

This dissertation supported the design for technology-mediated sharing practices using empirical research methods. It has identified the set of differences and commonalities between sharing digital and physical artifacts. It has also in-depth examined and articulated novel sharing practices and routines within two domains: (1) the personal activity tracking and (2) the sharing economy. What is more, we designed, developed and field-tested several technological prototypes to elicit how interactive technologies may support the novel sharing practices in those domains with the view to informing the design of tools and services to address emergent and future peoples' sharing needs. In addition to that, we offered a design toolkit and a method for the sharing economy targeted design practitioners to assess and improve current and future sharing services and to engender user experience with such systems.

Ultimately, we discussed the complexity of the sharing phenomenon and illustrated the existence of an obscure boundary between digital and physical sharing, drawing upon the ideas from the social sciences. Our work was informed by schol-

arship in several domains, including consumer behavior research, communication and media sciences, sociology, privacy research, human-computer interaction, and interaction design. Therefore, we believe that taking this cross-disciplinary perspective, this thesis contributed new empirical knowledge on the design technologies for sharing. We hope that this dissertation can be seen as a building block for the HCI and interaction design researchers and practitioners to further explore intricate nuances of sharing across digital ephemera and the real world. We also believe that this dissertation provided a set of necessary references (e.g., the key design themes for technology-mediated sharing practices) to allow future research to investigate how new technologies, such as augmented and virtual realities, can further shape our perceptions and practices of everyday sharing among people and ubiquitous computational artifacts.

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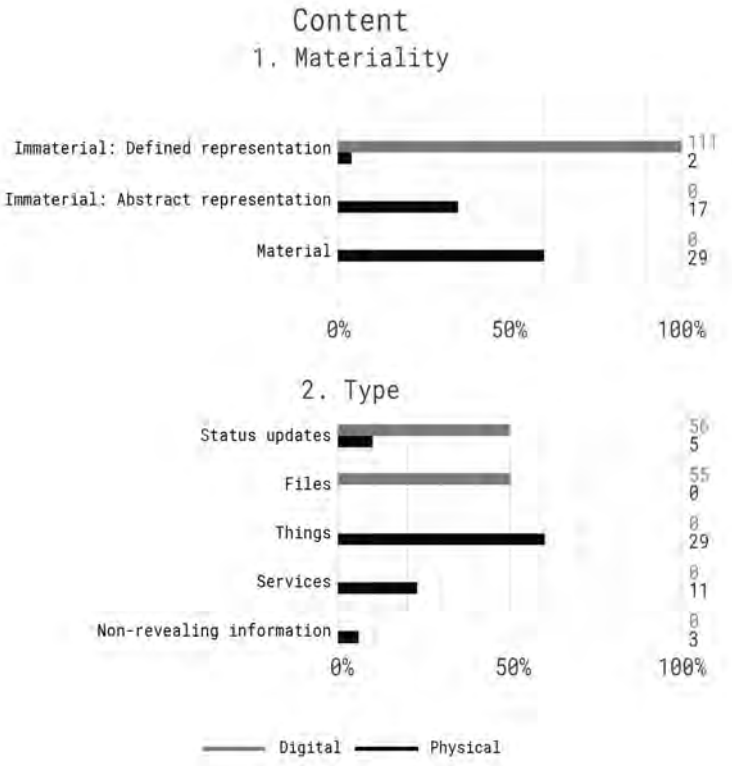
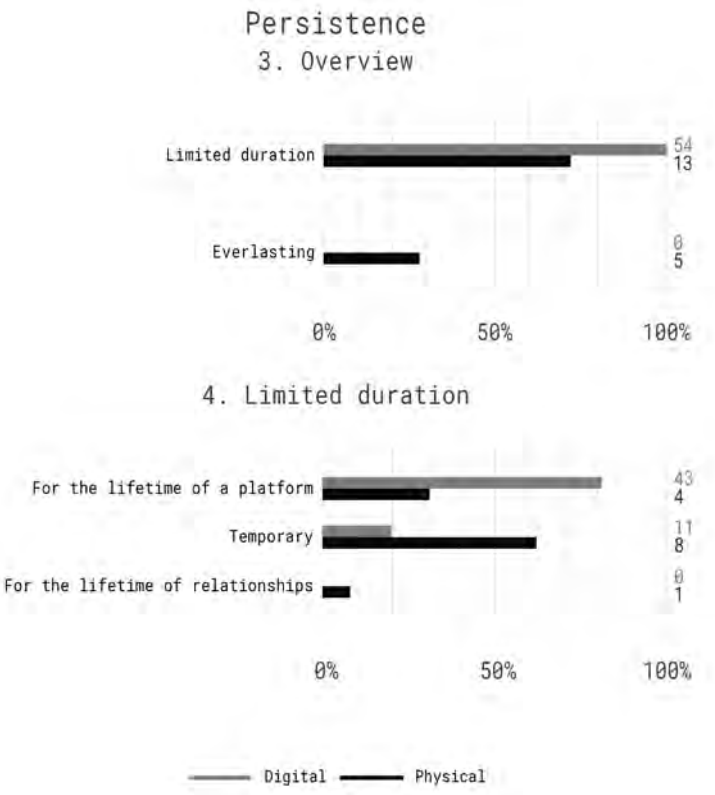
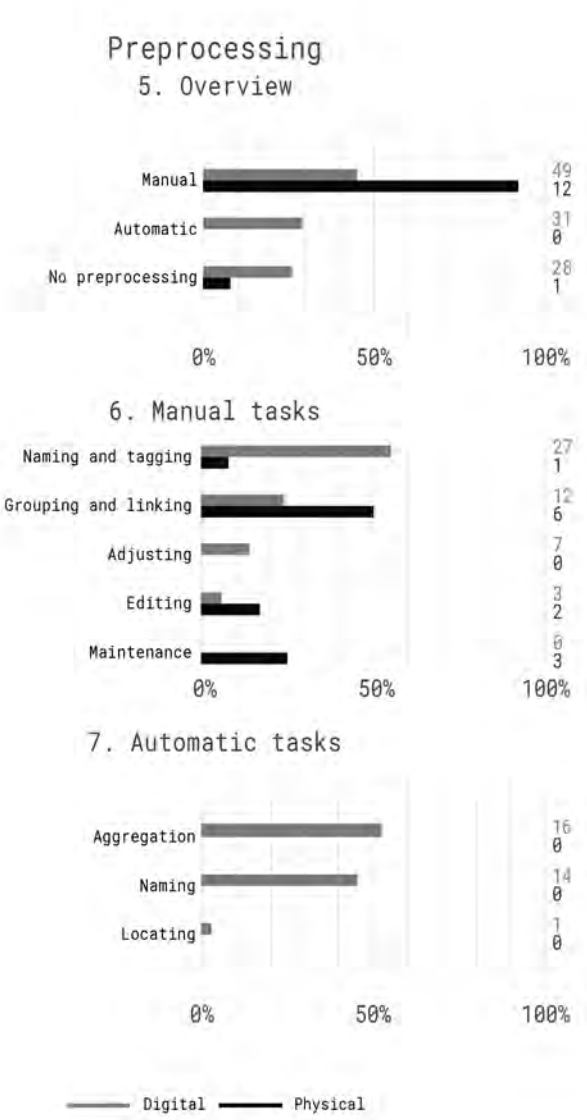
Appendix A

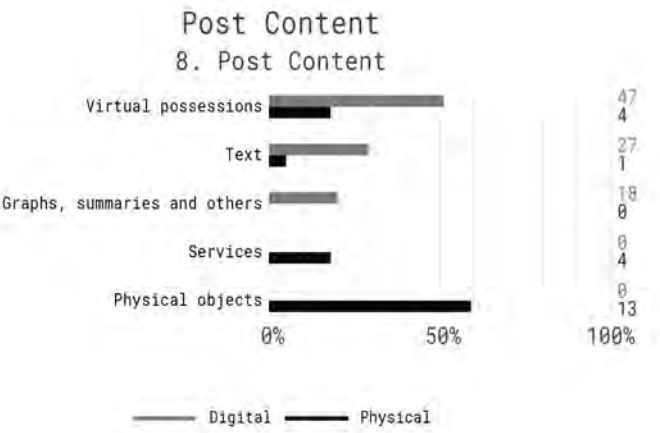
Materials from Technology-Mediated Sharing Literature Survey

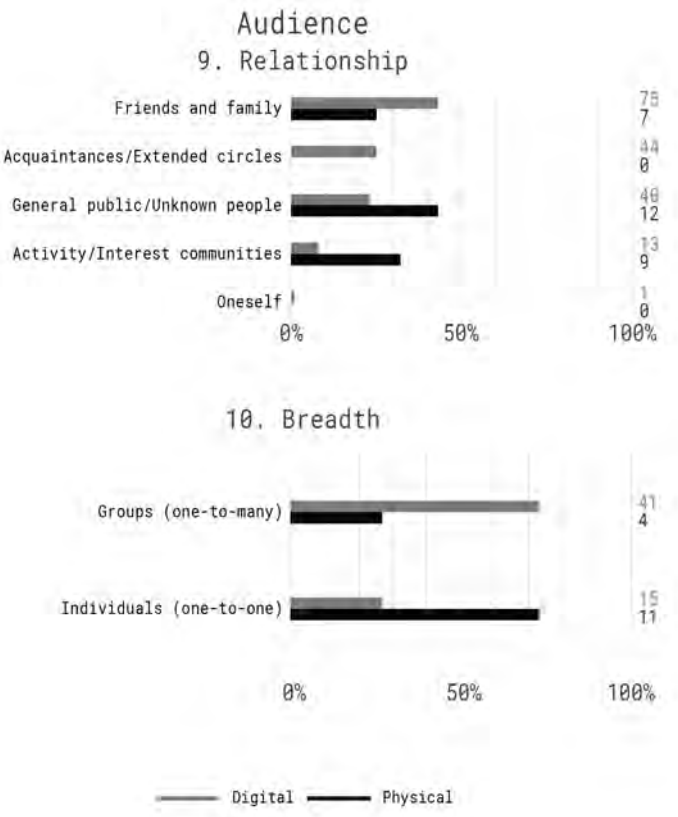
This annex includes the results of the content analysis for technology-mediated sharing literature survey described in Section 3.3.3. This set of figures shows distinctive groups describing one aspect of sharing (e.g., "sharing for self-expression") with aggregated absolute and relative code counts for each group within both digital and physical sharing contexts. Absolute values describe how many codes of a given group we have encountered in our data corpus (see value labels on the right side of each chart below). Relative values (represented in percentages in the charts below) were calculated as the sum of the absolute values of a category within a sharing sphere (i.e., digital or physical), over the number of groups in the category.


Content
1. Materiality
Immaterial: Defined representation
111
2
Immaterial: Abstract representation
0
17
Material
0
29
0%
50%
100%
2. Type
Status updates
56
5
Files
55
0
Things
0
29
Services
0
11
Non-revealing information
0
3
0%
50%
100%
Digital
Physical

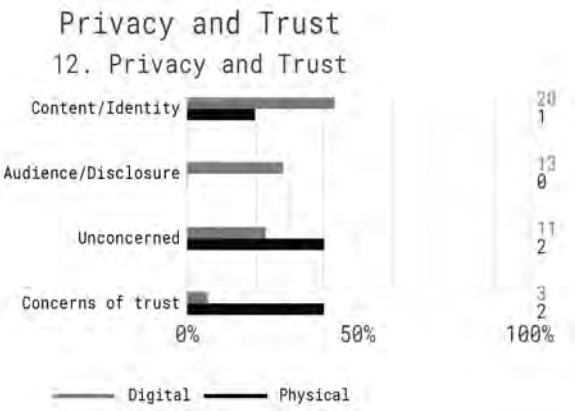

Persistence
3. Overview
Limited duration
54
13
Everlasting
0
5
0%
50%
100%
4. Limited duration
For the lifetime of a platform
43
4
Temporary
11
8
For the lifetime of relationships
0
1
0%
50%
100%
Digital
Physical

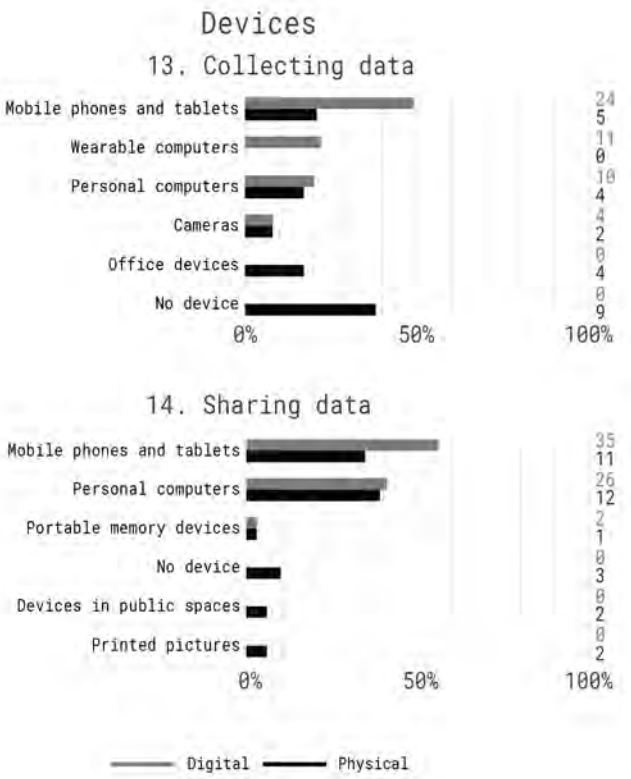

Preprocessing
5. Overview
Manual
Automatic
No preprocessing
49
12
31
0
28
1
0%
50%
100%
6. Manual tasks
Naming and tagging
Grouping and linking
Adjusting
Editing
Maintenance
27
1
12
6
7
0
3
2
0
3
0%
50%
100%
7. Automatic tasks
Aggregation
Naming
Locating
16
0
14
0
1
0
0%
50%
100%
Digital
Physical

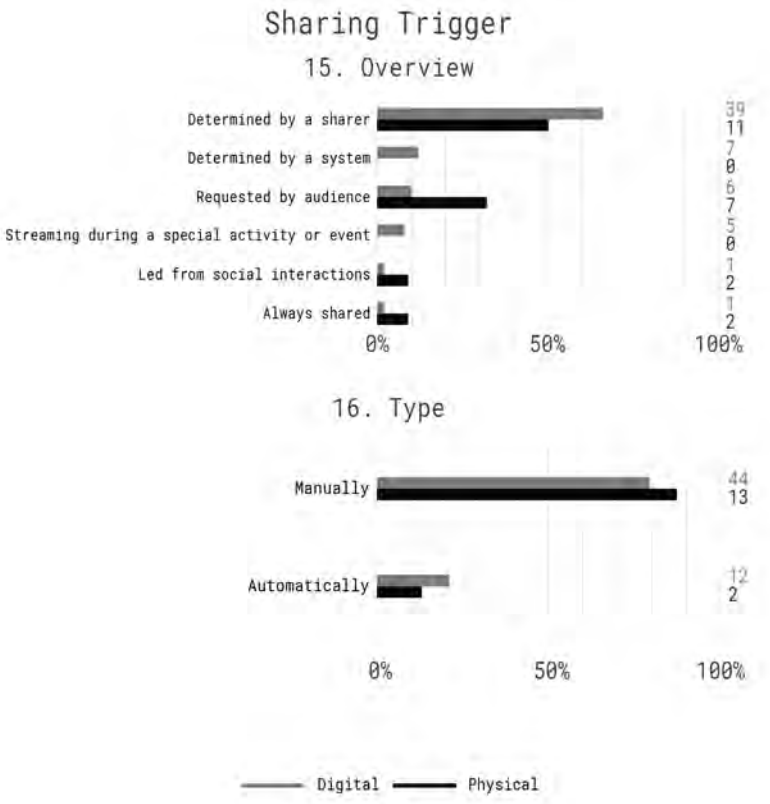

Post Content
8. Post Content
Virtual possessions
Text
Graphs, summaries and others
Services
Physical objects
47
4
27
1
18
0
0
4
0
13
0%
50%
100%
Digital
Physical


Audience
9. Relationship
Friends and family
Acquaintances/Extended circles
General public/Unknown people
Activity/Interest communities
Oneself
78
7
44
0
40
12
13
9
1
0
0%
50%
100%
10. Breadth
Groups (one-to-many)
Individuals (one-to-one)
41
4
15
11
0%
50%
100%
Digital
Physical


Motivations
11. Motivations
Self-expression and enjoyment
Social connection
Self-presentation, reputation and power
Society enrichment and self-development
Altruism and empathy
Get payment/service and convenience
Social influence
Safety
0%
50%
100%
35
1
34
3
31
1
14
8
10
2
10
12
9
2
2
0
Digital
Physical


Privacy and Trust
12. Privacy and Trust
Content/Identity
Audience/Disclosure
Unconcerned
Concerns of trust
20
1
13
0
11
2
3
2
0%
50%
100%
Digital
Physical


Devices
13. Collecting data
Mobile phones and tablets
Wearable computers
Personal computers
Cameras
Office devices
No device
24
5
11
0
10
4
4
2
0
4
0
9
0%
50%
100%
14. Sharing data
Mobile phones and tablets
Personal computers
Portable memory devices
No device
Devices in public spaces
Printed pictures
35
11
26
12
2
1
0
3
0
2
0
2
0%
50%
100%
Digital
Physical


Sharing Trigger
15. Overview
Determined by a sharer
Determined by a system
Requested by audience
Streaming during a special activity or event
Led from social interactions
Always shared
39
11
7
0
6
7
5
0
1
2
1
2
0%
50%
100%
16. Type
Manually
Automatically
44
13
12
2
0%
50%
100%
Digital
Physical

Appendix B

Materials from the Sharing Economy Design Cards project

This annex includes the supplementary materials for the project described in Section 7.2:

1. The Sharing Economy Design Cards Deck. The print-ready version is hosted at `http://sharing.inf.usi.ch/sedc/01-Sharing%20Economy%20Design%20Cards-A4-2018.pdf`
2. The Sharing Economy Design Sprint input materials: a prototypical scenario, a design brief and a set of personas.
3. The Sharing Economy Design Sprint auxiliary materials: a map template, an idea template, three prototype templates.

01

What? Content

Goal

Reduce complexity

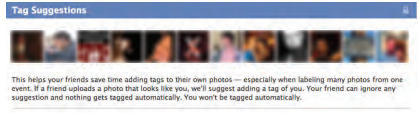
#manual tasks
#data preprocessing
#automation

Recommendation

Alleviate burdens of pre-sharing tasks without automating pleasant tasks

In more than 90% of the cases users of "sharing economy" services manually need to perform some data preprocessing tasks prior to sharing

Example **Facebook**



02

What? Content

Goal

Reduce complexity

#maintenance
#manual tasks
#preprocessing

Recommendation

Establish procedures for accountability

Every fourth task in handling a shared resource in "sharing economy" services is related to maintenance or repair

Example **Zipcar**

03

What? Content

Goal

Provide pleasurable interactions with the service

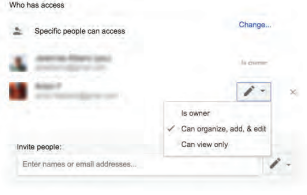
#ownership
#access control

Recommendation

Be transparent with regard to ownership of shared objects

Sharing may complicate the sense of ownership and control; communicate this information clearly to the users to avoid any confusions

Example **Google Drive**



04 What? Content

Goal

Create value for the user

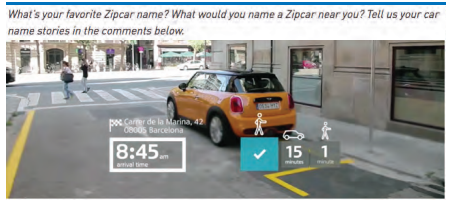
#digital stories
#motional value
#augmented reality
#bridging digital & physical

Recommendation

Allow users to enhance physical objects with digital content

Augmenting physical items with digital content may enhance their emotional value, which could facilitate attachments to the objects and improve identification with them

Example — **Zipcar/MINI**



05 What? Content

Goal

Build a common space

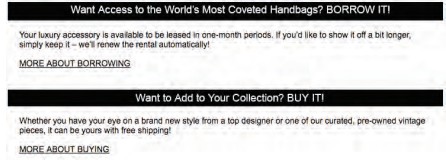
#persistence
#everlasting
#limited duration

Recommendation

Extend control of a shared resource for temporal shares, consider changes in ownership for gifts

More than 70% of the times, physical artifacts are shared for a limited amount of time, the rest are everlasting shares

Example — **Bag Borrow Or Steal**



06 What? Content

Goal

Provide pleasurable interactions with the service

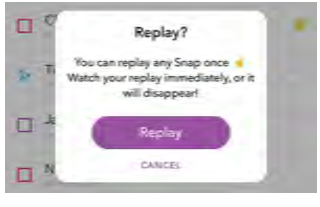
#ephemerality
#expiration tag

Recommendation

Approach state of and relationship with physical objects over time

Learning from ephemeral quality of digital data, how this plays out for physical sharing?

Example — **Snapchat**



07

What?
Content

Goal
Create value for the user

#content
#communication
#distribution
#users feedback

Recommendation
Explore post content and evaluate how users experience it

Post content refers to the actual information being delivered and communicated about a shared object; various channels to distribute this information can be perceived differently by the end-users

Example
Playstation

PS4™

PRE-ORDER DOWNLOAD

PRE-ORDER DISC

What?
Content

Goal

Recommendation

Example

What?
Content

Goal

Recommendation

Example

08

To whom? Audience

Goal

Reduce complexity

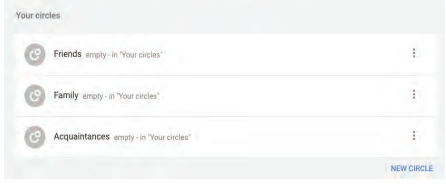
#disclosures
#grouping
#audience management

Recommendation

Develop the audience management tools to reach different circles

Allow self-presentation for different communities and circles, such as friends and family, communities of interest, and strangers

Example — Google+



09

To whom? Audience

Goal

Build a common space

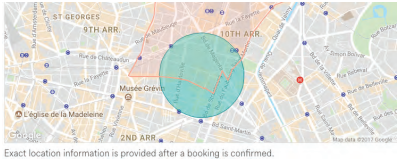
#strangers
#privacy
#sensitive content

Recommendation

Keep a balance between the sufficient level of disclosed information and an adequate level of privacy for sensitive content when sharing with strangers

Over 40% of exchanges in "sharing economy" services happen between strangers

Example — Airbnb



Exact location information is provided after a booking is confirmed.

10

To whom? Audience

Goal

Build a common space

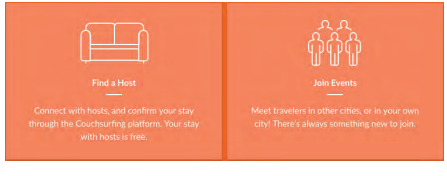
#individuals
#groups

Recommendation

Put emphasis on 1 to 1 sharing arrangements without compromising group sharing

Over 70% of exchanges in "sharing economy" services takes place among two individuals, the rest among groups

Example — Couchsurfing



Audience

To whom?

Goal

Recommendation

Example

Audience

To whom?

Goal

Recommendation

Example

Audience

To whom?

Goal

Recommendation

Example

Why? Motivations 11

Goal

Reach out and engage your audience

#core message
#practicality
#convenience

Recommendation

Emphasize and clearly describe the value, practicality and convenience of the service

More than 40% of users that engage in "sharing economy" services counts on monetary or non-monetary compensation

Example — **Zipcar**

Why? Motivations 12

Goal

Reach out and engage your audience

#advertising
#self-development
#society enrichment

Recommendation

Describe the opportunities that lead to self-development and society enrichment

Almost 30% of people using physical sharing services wants to become a better person or to make the world a better place

Example — **Couchsurfing**

1. Share Your Life

Couchsurfing is about sharing your life, your experiences, your journey, your home, your extra almonds or a majestic sunset. We believe that the spirit of generosity, when applied liberally, has the power to profoundly change the world.

Why? Motivations 13

Goal

Reach out and engage your audience

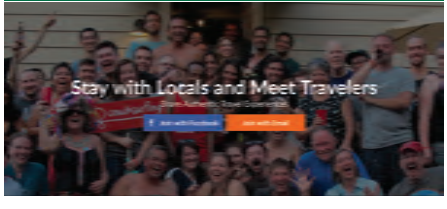
#promoting
#social relationships

Recommendation

Create and maintain social relationships

10% of the users that engage in physical sharing seeks to create new connections and maintain existing ones

Example — **Couchsurfing**



Why?
Motivations
14

Goal
Reach out and engage your audience

#reciprocity
#advertising

Recommendation
Emphasize reciprocity to drive sharing

Social influence affects sharing behavior, reciprocity is the common example of social influence

Example
Couchsurfing

Become a host

Give back and open your home to travelers. Learn about a new culture first-hand or practice a language. Make the world a little smaller; a little friendlier.

Why?
Motivations
15

Goal
Reach out and engage your audience

#user role
#advertising
#engagement

Recommendation
Encourage users to participate in diverse ways

Getting people on board is one of the main challenges when creating a new service; buyers can also act as sellers, hosts can become guests

Example
Couchsurfing

Discover Amazing People

Couchsurfers open their homes and share their lives. Connect and be inspired.

Find a Host

Connect with hosts, and confirm your stay through the Couchsurfing platform. Your stay with hosts is free.

Why?
Motivations

Goal

Recommendation

Example

To whom? Privacy and Trust 16

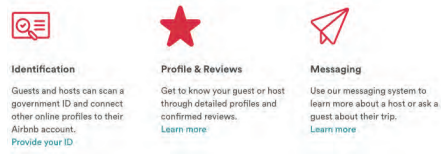
Goal
Build a common space

#trust
#engagement

Recommendation
Provide features to build trust among users, focus on potential exchange partners

Approximately 40% of people that participate in "sharing economy" services looks for trust in their exchange partners

Example — Airbnb



To whom? Privacy and Trust 17

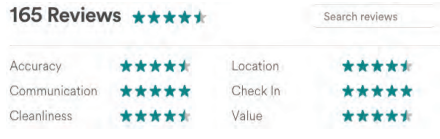
Goal
Build a common space

#trust
#reviews
#communication

Recommendation
Show attributes of successful exchanges

To create trust between users effectively visualize summaries of transactions. Provide contextual information for interpreting the ratings and reviews.

Example — Airbnb



To whom? Privacy and Trust 18

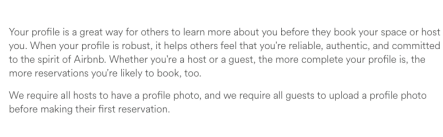
Goal
Build a common space

#anonymity
#undesired audiences

Recommendation
Offer reasonable alternatives for anonymous usage

People are worried to disclose information to unknown public, especially to anonymous users; eliminate those worries

Example — Airbnb



19

Privacy and Trust

To whom?

Goal

Build a common space

#trust
#disclosures
#sensitive content

Recommendation

Provide mechanisms to gradually reveal sensitive information

Progressive self-disclosure technique could mitigate concerns regarding to revealing too broadly one's identity or individual information in relation to a shared resource

Example

Airbnb

What is a House Manual?

Your House Manual explains features of your listing, such as how to turn on the hot water heater or where they can find an extra blanket. Guests receive this information once they've confirmed a reservation—it isn't included on a listing page.

Privacy and Trust

To whom?

Goal

Recommendation

Example

Privacy and Trust

To whom?

Goal

Recommendation

Example

How? User Experience 20

Goal

Provide pleasurable interactions with the service

#mobile
#desktop
#devices
#interactions

Recommendation

Ensure consistent representation for mobile and desktop platforms

Personal computers (desktops, laptops) are slightly more used to access to and interact with a sharing service

Example — **Dropbox**

Install the Dropbox app on your devices

1. Download the desktop app on your computer.
2. Get the free Dropbox mobile app on your smartphone or tablet.

How? User Experience 21

Goal

Provide pleasurable interactions with the service

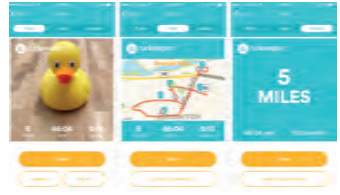
#devices
#capturing
#collecting
#interactions

Recommendation

Explore opportunities to share from the same devices that capture an experience

Users often use different devices for data collection and sharing, incorporating these tasks in a single device may improve the overall sharing experience

Example — **Runkeeper**



How? User Experience 22

Goal

Reduce complexity

#needs
#triggers
#audience request

Recommendation

Proactively identify needs of the audience, use them to trigger exchanges

Above 30% of sharing transactions happen as an answer to a request

Example — **Neighborgoods**

How?
User Experience 23
Goal
Reduce complexity
#triggers
#automatic
Recommendation
Automate sharing based on user needs and available infrastructure
Almost 90% of transactions in "sharing economy" services requires manual approval; however, automation in that space looks promising
Example
Airbnb
Instant Book
Book without waiting for the host to respond
$41 per night
How?
User Experience 24
Goal
Build a common space
#engagement
#indebtedness
Recommendation
Redirect feelings of indebtedness towards positive and participatory outcomes
Users may feel indebted after an exchange (especially in non-monetary transactions) owing to social norms, emphasize social benefits of sharing
Example
Wikipedia
Now is the time we ask
PayPal
How?
User Experience
Goal
Recommendation
Example

Scenario

Kirsten lives in a huge house alone for 3 years in Brighton after her husband passed away and all her children moved to different cities. She enjoys her independent everyday life doing hobbies such as gardening, home improvement, and knitting.

The huge house still has lots of unused stuff, which is left from her family. There are 3 empty bedrooms, a car, various sports gear (e.g., ski-touring equipment), toys form her grandchildren etc. From time to time Kirsten uses son's and husband's DIY tools to work on her personal creative projects and to do some garden maintenance. Every now and then she asks her neighbor, Roland, a DIY enthusiast to get advices about tools and how to use them.

Kirsten's daughter, Marina, lives in London. She worries about Kirsten a bit. She knows that Kirsten loves her independent life, however the fact that Kirsten was diagnosed with slight rheumatism 3 months ago leaves her unrest.

Marina and Kirsten talk to each other at least once a week by phone or chat through WhatsApp. While Marina wants to have more updates from her mother, she does not want to bother Kirsten all the time.

Design Challenge	Make use of underutilized resources (e.g., spaces, tools, houses, toys, cars, household objects, skills etc) in a community. At the same time, increase connections between remote family members in an unobtrusive way.
Client	A startup which looks into building an online platform
Deliverable	A concept of new sharing economy platform or service. Include some key visualizations of the new service

Personas

"Yes, I am a tinkerer. My garden is always very beautiful in summer. I try to do it all by myself. However, I do not dare to climb into the trees anymore to shorten them."

- ✓ Walks 20 km for 1-2 hours everyday alone
- ✓ Diagnosed as rheumatoid arthritis 3 month ago
- ✓ Contacts family members with phone or WhatsApp
- ✓ Collect ideas for garden improvement using Pinterest on her tablet
- ✓ Her husband passed away 3 years ago

Kirsten

72 years old Lives alone in Brighton

son (42), daughter (40) and 4 grand children

"I have had a nightmare that Kirsten fell from a ladder while gardening and was not able to call for help. "

- ✓ Kirsten's daughter
- ✓ A school teacher
- ✓ Moved to London because of her husband's job 3 years ago.
- ✓ Stressed between childcare and career development
- ✓ Worries about her mother and wants to have more connection with her but don't want to disturb her independent lifestyle

Marina

40 years old Lives with family in London
2 sons (12, 8) and a husband

"I do some volunteering here and there. I feel good about it. I have time, energy and a dream."

- ✓ A neighbor of Kirsten
- ✓ Retired from a professional carpenter, but still sometimes provide services in his community
- ✓ Great knowledge on material processing and DIY
- ✓ Want to contribute his skills more

Roland

69 years old Lives alone in Brighton
Son (43) in Edinburgh

Map template

CONTENT What is being shared?

AUDIENCE To whom is it being shared?

MOTIVATIONS Why is it being shared?

PRIVACY & TRUST How do users feel about privacy and trust issues when deciding to share?

USER EXPERIENCE How to provide better relations among a service, users, and contents when sharing takes place?

Idea template

OUR PRODUCT IS (Describe your product concept and name)

THIS IS FOR (Describe your main target user(s))

Prototype template

Prototype template

Prototype template