Roaming Objects: Encoding Digital Histories of Use into Shared Objects and Tools

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ABSTRACT

An increasing number of non-profit groups and organizations have formed "libraries" of shared things to leverage the collaborative use of underutilized resources (e.g., power tools) for the benefit of local communities. Their key challenges are the transience and anonymity of their members, and how to nurture creative interactions among them. We designed and developed Roaming Objects, an interactive system aimed at supporting the capture and sharing of equipment-use experiences among these members. We deployed the system for two months in a tool-sharing cooperative to explore how it may help to address these challenges. We offer 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.

Author Keywords

Sharing Economy; Collaborative Consumption; Digital Histories; Tool-Use Experiences; Interaction Design.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

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. 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 [2]. Odom [35] 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: (i) 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; and (ii) to explore opportunities for designing interactive systems that positively shape people's relations to shared objects and to the broader social tool-sharing organization.

Through encoding and sharing digital histories of tool-use, our Roaming Objects system elicited a range of self-reflections across members of the tool-sharing cooperative – 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.

This paper makes two contributions. First, it describes the design of the Roaming Objects system and findings from an eight-week deployment study in a tool-sharing cooperative. Second, 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.

BACKGROUND AND RELATED WORK

Our work lies at the intersection of two principal research areas: (i) the sharing economy and (ii) research on digital possessions and histories of use.

The rapid development of non-ownership economic models, known as *collaborative consumption* [9] or "sharing economy", enables people to temporarily access and experience shared resources, such as housing, fertile land, and vehicles [2]. Interactive technologies and systems are often used to facilitate access to shared resources and provide efficient access to these resources for a monetary fee or another form of compensation [5]. Beyond well-known commercial enterprises such as Uber or Airbnb, an increasing amount of community groups and organizations have formed collections and libraries of shared things (e.g., tool and equipment coops) to leverage the collaborative use of various resources (e.g., woodworking spaces, fab labs). Scholz calls this emerging phenomenon *platform cooperativism* [42], where organizations within a local community prioritize environmental, social, and cultural values over economic gain. Platform cooperativism faces numerous issues, including lack of public awareness, sustaining long-term funding, competition with multinational corporations [42], transience among and anonymity of members of resource sharing organizations [2], and poor visibility of the work of their members and lack of accountability for shared resources [35].

Consumer behavior research has identified a number of motivations to take part in collaborative consumption, including altruistic [4, 20] social [21, 22], hedonic [6, 14], and economic motives [5, 18]. Prior work also emphasized the value of social ties and trust in sustaining online sharing communities [26], and outlined considerable challenges that can occur in terms of creating [29] and nurturing new instances of local organizations if social ties and trust are weak [26]. In light of this prior research, our work explores how the needs of multiple stakeholders (e.g., providers, volunteers and members) in a non-profit tool sharing cooperative can be supported through the design and study of an interactive system aimed at addressing these challenges.

Recent research in DIY communities [16, 24], including making [43] and urban farming [32], 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., [24, 32]). In fact, tool sharing often plays a supporting role in these communities [16], as it enables DIY practices at large [24]. 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) [1].

Today's smartphones make it easy to create, share, and review digital information and histories of our everyday objects. A growing amount of work is investigating how interactive systems can account for digital histories that capture everyday things and everyday experiences [7, 19]. One theme within this work has explored how *histories of use* [7] can catalyze strong attachment and perceived longevity [31]. Researchers have suggested that wear and patina resulting from everyday use can be represented digitally through material [12, 28, 31, 39, 40] and spatial [10] histories. Other work has explored how digital histories of individual and shared experiences can become valuable resources for self-reflection and social connection [30, 33, 37, 38], and prompt behavioral changes in people's everyday practices [23, 27, 41]. 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 has suggested both opportunities and challenges for designing interactive technologies and services to support the platform cooperatives. Our work aims to build on this prior research, to explore how interactive technologies can be leveraged to support capture and review of the digital experience with shared resources.

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 [17] and research through design [11, 45]. These approaches repeatedly demonstrated their value not only in understanding current user needs in a real-world setting, but also illustrated how designing new interactive systems and artifacts can address 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 the previous section) that examined how material and virtual possessions support and record interactions with individuals and groups, we identified three conceptually
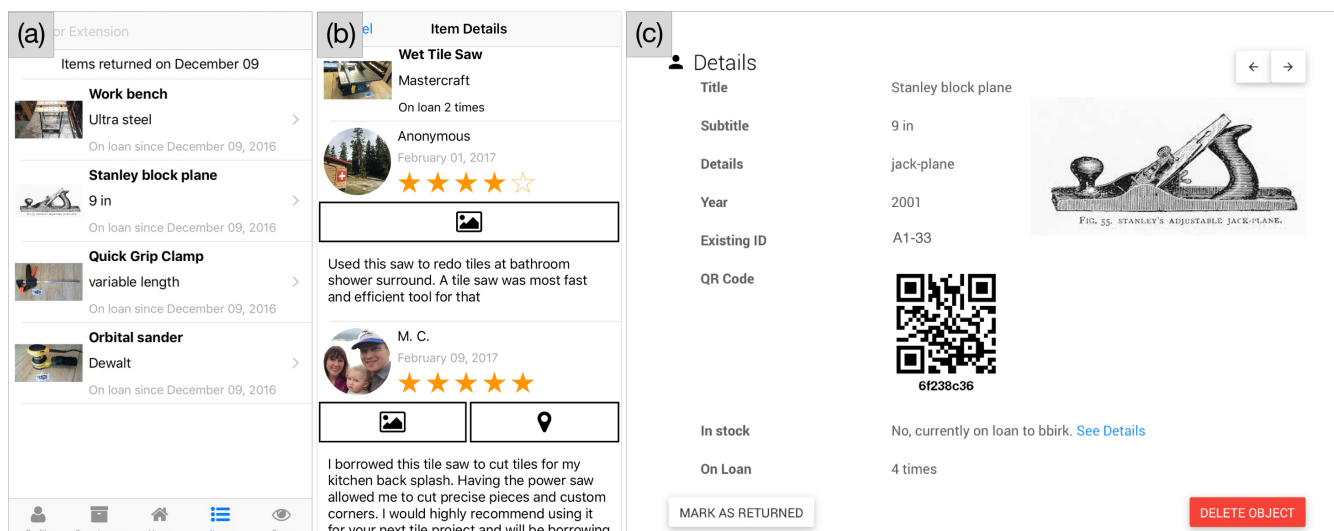
Figure 1. (a) the view of the companion app, which shows a list of currently borrowed items by the user; (b) the view of the item's profile as seen by the user; (c) the UI of the web-based inventory management system with details of a tool as seen by a volunteer

related, yet distinct design strategies that articulate how personal or social digital data could be valuably associated with physical objects: *accrual of metadata* [33], *tracking provenance* [19] and *collecting histories of use* [7]. 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 (http://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 [3].

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 [3, 19], 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 1b). An overview page shows the list of borrowed tools and their return date (Figure 1a). 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 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 1c) 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 [17] to explore how these experiences might shape sharing practices on individual and community levels.

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. The VTL cooperative has over 2000 tools in their possession and serves 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 [46]. 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 [8] to follow a volunteer at the checkout desk (Figure 2f). 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 illustrated well 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. 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 [13], 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 was ongoing and consisted of several stages. First, we used affinity diagramming [8] to understand the collected data thematically and to model connections and differences across participants. We held bi-weekly meetings first to

Figure 2. (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)

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. In the remainder of the paper, we use pseudonyms to describe study participants.

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 (Fig-

ure 2d). However, it was not sufficient 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 2e). 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 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.

Individual Level (Self-reflecting) 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 2b) or incomplete projects (Figure 2a), or described the process of making (Figure 2c).

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 on 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: "*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).

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 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 they look stuff online. You actually see it with a given tools that used in a process. I think it is pretty neat. There is a bit a curiosity how they did it. Would I do it differently?*" (Stefan, 40).

Archiving Histories of Use: Utilitarian & 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 artifacts. It would be great to review them back if I need.*" (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 interested 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.

Social (Community) Level Findings

Participants expressed a high interest in learning the previous history of items, and any associated story that it carried

along 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 as well.*" (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 that, 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 for reaching 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 to 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: "*I have uploaded a picture of the bevel grinding 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. It clearly shows what the drill is being used for: to make these particular holes in the bed base. You can see the* [final] *project. 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. Few 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, 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 the interacting with other members, and highlighted the importance of the new kinds of interactive systems, like Roaming Objects, to support and nurture the tool sharing community. In the following section, we provide further details about challenges and opportunities that participants raised over the course of the study.

Reflecting on and Beyond 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 "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 a 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, functional scope) provided in the application supported them to choose an appropriate tool. For example, Sunny, 24 describes 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 raised 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 ex-periences 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 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 2c); however, she could not hold the phone during the process of making to capture the whole experience. Including others to 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 can put my phone to record the process. My hands were busy when I was working on it. I almost need 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 1b) – when sharing their experiences. Most of the participants left the 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 1b). 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 in there, if I could make some kind of personal judgement in fairness to the people who 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 coops 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 has a rental-based. Like equipment rental stuff, like 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 whilst sharing them.

DISCUSSION AND IMPLICATIONS

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 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.

Addressing Challenges of Platform Cooperativism

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 [44]. 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 [24], or emphasized the inability to track outcomes from shared maker spaces [43].

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 platform coops 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 [15] 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 platform coops 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 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 [26].

These findings also suggest an opportunity for exploring how progressive self-disclosure could play a role in designing future systems that 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 [26]. 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 [2], and sustaining community growth.

New Opportunities for Digital Histories of Use
Roaming Objects aimed to mobilize and extend Odom et al.'s [33, 36] 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 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 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* [34] 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, high-

lights 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.

CONCLUSIONS AND FUTURE WORK
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 platform cooperativism. 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 examine wider interdisciplinary connections to politics of "sharing economy", as well as explore sharing practices around emergent local and "informal" economies of *personal* artifacts in a longitudinal study. Additionally, looking into the creation and management of pop-up inventories in a community context without any centralized organization will significantly increase the potential deployment areas, thus wider adoption, of the Roaming Objects system. Ultimately, we hope this study inspires future research into how interactive technologies can further support resource sharing associations (e.g., maker spaces) through capture, storage, and representation of the histories of use from sharing physical objects.

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