ShareBox: Designing A Physical System to Support Resource Exchange in Local Communities

Matthew V. Law, Mor Naaman, and Nicola Dell
Information Science
The Jacobs Institute, Cornell Tech
[mvl24;naaman;nixdell]@cornell.edu

ABSTRACT
Indirect resource exchange (IRE), where individuals share physical items with one another but do not receive direct benefits (e.g. payment), has the potential to increase communities' access to resources, reduce consumption and waste, and bootstrap social ties. Although social technologies could play a key role in realizing this potential, significant barriers have emerged to the adoption of IRE services, including concerns related to trust, reciprocity, and coordination. To explore these issues, we designed and iterated on a concept called ShareBox, a system that enables IRE through a smart lockbox. We developed ShareBox as a technology probe following a set of design guidelines including: creating a physical-virtual system, enabling asynchronous and anonymous exchange, allowing for low-entry-barrier interactions, and emphasizing affordability and flexibility. We explore the benefits and trade-offs of these design guidelines through short deployments and semi-structured interviews with community members, and present findings that highlight both the potential and the remaining challenges of our design.

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H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

Author Keywords
Indirect resource exchange; sharing; sharing economy; technology probe

INTRODUCTION
What would it take for you to lend something valuable to a stranger? The terms sharing economy and collaborative consumption broadly refer to the sharing of goods, services, and information outside of traditional markets [5, 41, 65–67]. Driven by new and pervasive social technologies, sharing platforms have the potential to transform consumption, ownership, and access [4, 8, 30]. However, wide-scale adoption of markets for lending and borrowing physical items, which we call *Indirect Resource Exchange* (IRE) has proven elusive, even as such exchange holds great promise to benefit local communities.

Figure 1. ShareBox—a physical and virtual platform for borrowing and lending items in local communities—at one of the deployment sites.

Prior work has associated sharing of physical resources with various community benefits [22, 32], from reduced consumerism and consumption [1, 10], to increasing social solidarity and commitment to the community [52]. A number of platforms and projects have failed, however, to realize the vision of local item sharing [73]. Recent work has exposed gaps in motivations and significant challenges to engagement in these markets, including issues of interpersonal and systemic trust, safety and coordination obstacles, and difficulty achieving critical mass of users and goods [6, 38, 39, 46, 73].

This paper takes a design-driven approach to explore the potential of a physical-virtual sharing aid, the *ShareBox*. ShareBox attempts to alleviate some of the challenges to generalized exchange in a local community. ShareBox is a physical lockbox (see Figure 1) that is intended to be placed in a secure location, such as a building lobby, and that facilitates sharing between members of the community. Individuals in a community communicate anonymously with ShareBox via simple text messaging to share items and see what other items are shared. When a transaction occurs, ShareBox coordinates the exchange via an asynchronous handoff, with the shared item placed in the locked box by the lender and picked up from the box by the borrower. Combining the physical box with anonymous and asynchronous interactions, ShareBox follows

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a set of design guidelines in an attempt to address several key challenges for IRE identified in previous work, including trust and personal safety [15, 73, 76], difficulties in exchange coordination [30, 39], and a pressure to reciprocate that may deter people from participating [40], while probing behaviors around potential solutions related to or enabled by facilitating the physical handoff.

We describe our design guidelines, iterative design process, and findings from exploratory deployments with 31 users in three different communities. We draw on insights distilled from qualitative interviews to analyze our design choices, discussing how asynchronous exchange affects coordination, the impact of the physical-virtual nature of the system, and the effects of anonymity on perceived risk and expected social gains. We then discuss constructive design opportunities that result from our analysis, such as the need for increased scaffolding to support better coordination and a desire for hybrid models of anonymity that enable greater social interaction. Finally, we analyze our findings in the context of key concepts in market design [38, 64] and discuss implications for future iterations of ShareBox and other future sharing technologies.

BACKGROUND AND RELATED WORK

Our paper describes a system that addresses a gap in the sharing literature through the design of a physical-virtual platform that enables anonymous, asynchronous sharing in local communities. Our work explores how these affordances may address some of the challenges raised by previous work.

Peer-to-peer exchange has been a growing area of study in the sociology, economics, and HCI literatures. Building on social exchange theory [13], some recent literature has focused on three types of exchange: negotiated, reciprocal, and generalized exchange [12, 40, 52]. Molm et al. [52] provide a helpful factorization of these types across dimensions of reciprocity and direct benefit. Most relatedly, the authors distinguish forms of exchange that involve direct reciprocity (A gives to B, B gives to A) and generalized exchange which involves indirect reciprocity (A gives to B and is repaid by someone else in the community). Molm et al. further contend that generalized exchange is overwhelmingly better at increasing social solidarity, defined as levels of trust in others and in the community, regard for others in the community, a sense of unity, and commitment to the community. Sun et al. [73] more explicitly define IRE as generalized exchange in the context of physical resources. Even more specifically, for the purposes of this paper, we are primarily concerned with IRE markets of borrowing and lending, as opposed to donation or recommerce services like Freecycle [21] or Yerdle [81].

There have been attempts in academic and corporate settings to realize or study IRE markets through online platforms. For example, Kassi (now Sharetribe) was a university sharing platform for goods and services that enforced generalized reciprocity [70]. Ecomodo was an online platform that allowed users to search for and list items in trusted "sharing circles" [59]. Peerby is an inventory-less locally constrained application allowing email-based borrow requests [73]. Most of the corporate attempts have been discontinued or failed to achieve a wide user base. For example, Ecomodo is now defunct, and Peerby exploring a direct (via rental) model.

Recent work theorizes reasons for this level of attrition. Gaps in the motivations of platform designers and their users could account for differences between user interest and adoption [6]. Other research revealed barriers to adoption that concern trust and coordination issues [15, 73], which we attempt to directly address. More generally, Lampinen and Brown build on economic market theories [64] and map five key concepts (thickness, congestion, safety, stability, and repugnance) to challenges faced by peer exchange markets [38]. We discuss later in the paper how our design might interact with these concepts.

One of the features that we probe in our study is the potential ramifications of anonymity in exchange. The role of identity in peer-to-peer sharing economies has become a matter of critical relevance to the design of sharing platforms, especially as it regards bias and fair access. Recent work has discovered evidence of racial or gender biases reflected in evaluation and participation in platforms like TaskRabbit, Fiverr, and AirBnb [17, 27], and even sharing economies with egalitarian visions frequently exhibit barriers to participation that devalue or exclude certain demographics [68]. Indeed, digital sharing platforms that have been found to reflect or reinforce systemic biases have raised concerns about "virtual redlining" or the deterioration of Civil Rights [61, 63, 75, 76]. While some work has argued the best solution is to improve incomplete information to remove user reliance on prejudices [14], anonymity could plausibly remove the ability to discriminate. But anonymity has also been raised in studies of user behavior in sharing markets as a factor that can reduce levels of user accountability and trust [3, 18]. ShareBox was designed to allow us to study anonymity in the context of IRE, the mechanics of which we treat in detail in our design guidelines and discussion.

Our design supports IRE via a physical device, thus following in the footsteps of HCI and design work on installations in a public space. There is a rich literature on public installations and the social interactions that arise around them. For example, recent papers demonstrate the potential of synchronous physical or co-present interaction [2, 43, 54, 56, 79], asynchronous virtual interaction [19, 48, 78], and physical, asynchronous interaction [28, 69], while some systems have bridged multiple modalities [55, 80]. We believe that ShareBox, a design probe that enables sharing of physical items, exemplifies the last of these (physical and asynchronous).

SHAREBOX DESIGN GOALS AND GUIDELINES

The aforementioned difficulties with engagement forestalled the possibility of either using or building a fully-realized platform to study people's real-world sharing experiences. Instead, we adopted the methodology of technology probes [31], a technique founded and employed in participatory and experience-centered design approaches [16, 34, 35, 62]. Technology probes are typically not prototypes intended to test features, but simple and open-ended systems designed to observe user behavior in real-world settings and contexts.

In this work, we are interested in learning more about how physically mediating item handoffs could impact user perceptions and behaviors around local community IRE. We designed a technology probe to create the experience of sharing items with a local community through a physical platform. In particular, the physicality of the probe we deployed uniquely afforded us the opportunity to study user reactions to fully anonymous and asynchronous exchanges, exposing several unexpected challenges and advantages rooted in user experiences.

The design of our probe, called ShareBox, followed an iterative process in which we refined the system through a series of installations culminating in the deployments described in this paper. In creating ShareBox, we set out to uncover potential benefits and pitfalls surrounding plausible solutions to four important challenges identified in prior work as follows:

- **Reducing concerns regarding trust and personal safety** by engaging hyper-local communities. Item security is a potential issue in IRE markets, and personal safety has been raised as a significant concern in sharing transactions that require face-to-face interactions with strangers [15, 73, 76].
- **Easing coordination** by making the system asynchronous. The overhead associated with completing a peer-to-peer transaction can pose a significant barrier to engagement [30, 38] that eliminating in-person handoffs could reduce.
- **Reducing pressure to reciprocate** by making the interaction anonymous. Prior work has suggested that feelings of indebtedness may negatively impact participants' engagement and willingness to share [40] and we were interested in how anonymity might impact expectations of reciprocity.
- **Lowering the barriers to participation** via anonymity and by not having elaborate sign-up processes or restrictive system requirements.

Our desire to understand trade-offs around these design goals led to key guidelines that informed the implementation of our probe. Most importantly, ShareBox was designed as a **physical-virtual system**: a physical box that users interact with via a virtual (text-message-based) interface. The physical box is intended to be placed in a secure location like a building lobby. Each ShareBox is thus only accessed (physically and virtually) by members of a specified local community, lending the box its affiliation and associated trust. The secure box supports and manages an **asynchronous exchange**, removing the need for elaborate coordination: once a match is made between lender and borrower, the box virtually coordinates the exchange. The lender drops the item off in the box when convenient, and the box keeps it secure until the borrower picks it up, and vice versa. The box will only open for users who have a pending pickup or drop-off.

Further, we designed ShareBox with **low-entry-barrier interactions**. Individuals communicate with ShareBox using a text-based chatbot that facilitates borrowing and lending. The chatbot enables users to list items that they are willing to share or ask to borrow items that others have listed. Using text messages (SMS) as the interface allowed us to leverage the ubiquity of text-enabled phones and avoid forcing users to install a custom application.

ShareBox interactions were designed to be **anonymous**. The box mechanism allows transactions to occur asynchronously and anonymously, in a way that transactions requiring direct in-person exchange cannot. Our interest in anonymity is motivated both as an attempt to elicit general reciprocity instead of specific feelings of indebtedness [40] and for the potential to reduce barriers to participation associated with identity. In particular, due to our interest in sharing within local communities, our design provides *relation-based anonymity*, which allows people to share and interact anonymously with others somehow explicitly related to them, e.g. through proximity or social ties [45]. Certain types of relation-based anonymity have been associated with motivations to participate and benefits that reflect back on the underlying relations not typical of all forms of anonymity [44]. In our case, the relation underlying the system's anonymous ties takes the form of the community hosting the ShareBox.

Finally, we designed ShareBox to be **affordable and flexible** so it could potentially scale and be broadly accessible for many types of socioeconomically diverse communities. We also sought a simple, easily reproducible, and modifiable design to provide the kind of flexible research tool we envisioned in pursuing the development of a technology probe.

As a technology probe, we intended Sharebox to produce and capture the types of sharing experiences that we wished to study, and the manner in which we created these experiences formed an important part of the probe's design. As discussed, the deployment and bootstrapping of an active IRE platform and community are highly nontrivial, motivating this work. As a further complication, since borrowing is an as-needed activity, one might expect low-frequency transactions on an individual level even in a busy sharing community. When deploying our probe, we sought to simulate both an active sharing community and an actual transaction experience by (a) seeding the community inventory with items we identified as desirable through prior work and canvassing, and (b) asking new users to share items, which we subsequently requested to borrow over the course of the deployment. Both of these artifices were possible via the anonymous item listing and transactions afforded by our platform.

Design Process and Implementation

The realization of our technology probe resulted from two major cycles of prototyping, testing, and iteration. In the first, we developed the physical-virtual platform that composed the core of the technology probe, and in the second we refined the conversational chatbot that served as the primary facilitator and interface to our system. Concretely, with our design goals and guidelines as a starting point, we generated two conceptual artifacts for our probe through a series of brainstorming sessions, sketching, and user personas: a smart physical lockbox controlled by an SMS-chatbot that administered inventory and transactions through said box. We converged on the solution of a physical lockbox over alternatives such as a communal shelf or a door-to-door delivery system based on its simplicity, security, and flexibility. The choice of a chatbot was moti-

Figure 2. The physical form of the ShareBox probe evolved through several iterations. User- and community-driven modifications included the additions of a visible handle, lights, and sound to better indicate how and when to open the box, as well as changes to the dimensions, materials, and aesthetics of the box itself.

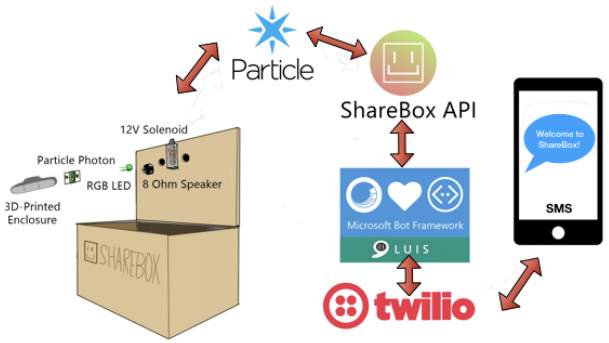

Figure 3. The ShareBox probe is comprised of a physical lockbox controlled by an SMS-driven chatbot. The lock is a simple solenoid interfaced via a Particle Photon through the Particle Cloud API, and the chatbot is built on Microsoft's Bot Framework, integrated with their LUIS parser and Twilio's SMS API. The ShareBox API exposes user, inventory, and transaction information.

vated by a desire to bridge concerns about availability and barriers to access that might arise in the installation of a phone application. In the same vein, we decided to use SMS as an ubiquitous, low-cost interface to maximize accessibility. Ultimately, the decision to use a smartbox together with a chatbot allowed us to build the probe cheaply and simply, while allowing any member of the community to interact with it without even needing to own a smartphone.

Prototyping of these artifacts in the first phase of development was an iterative process driven by repeated informal user testing. While remaining conceptually simple, the physical design of the box evolved through multiple versions to improve approachability, the physical legibility of unlocking the box, and its integration in the handoff process (see Figure 2). Among the improvements that emerged from early user feedback were the integration of a handle, signal light, and sound, to more clearly indicate how and when to open the box when the bot unlocked it. During this stage, a basic, menu-driven chatbot was developed to allow users to list items to share, request items to borrow, and carry out transactions with the box. Early user feedback on the chatbot drove our menu-driven design to involve fewer steps and give more explicit directions to account for user error and carrier delays. Although we originally designed a credit-based incentive system to encourage user participation, we removed this based on user misgivings and our focus on the core research questions.

At the conclusion of the first stage of development, we ran a user test with 11 users (eight female) and a small pilot deployment at two sites with another nine users. Participants in the user test were asked to initiate a borrow transaction with the bot that culminated in opening the box. The subsequent pilot was conducted by placing boxes in two public places in an attempt to capture more organic interactions than in the walkthroughs. We collected qualitative data by observing users and logging their interactions with the bot. We also allowed pilot users to directly send questions or comments to the researchers through the bot.

In the walkthroughs and pilot, despite the simplicity of the menu-driven chatbot interface, users expressed some confusion in navigating the dialogues, and annoyance at the verbosity of the text. During the pilot, we observed several instances where users struggled to complete one of the core actions because of incorrect wording or a misunderstanding. For example, one user used the feedback dialogue to ask about what items were available through the box and, instead of directly triggering a list of commands or available items, sent a message to the administrator.

From these deployments and feedback in the first stage, we inferred that the menu-driven chatbot, while functional, was too inflexible for real-world usage, both in terms of dialogue options and its ability to direct users to items that they were looking for. We therefore implemented instead a *conversational* chatbot that enabled more fluid interactions and handled variance in user item queries. Using the existing menu functions as a starting point, we developed a dialogue map in concert with internal user walkthroughs, followed by public demos with users and administrators at potential deployment sites. Feedback and interactions gathered from these demos helped us to hone the features exposed by the dialogue; for example, we integrated the ability for users to ask for borrowed items back and for the bot to naturally respond to user expressions of frustration or gratitude. We also developed a persona for the bot and refactored the dialogue map according to said persona in an attempt to make the bot more personable. Towards the end of the chatbot design process, we ran a usability test with 13 users on Amazon Mechanical Turk who worked through signing up, browsing the inventory, listing an item, and requesting an item from a demo version of the chatbot, with the goal of exposing any remaining pain points.

In its ultimate form, the ShareBox probe was implemented as a 45cm *x* 60cm *x* 45cm wooden box with a locking mechanism and a wifi-enabled controller (see Figure 3). The controller and locking mechanism consist of a solenoid driven by a Particle Photon, interfaced to the virtual chatbot via the Particle API [57, 58]. The box is constructed out of laser-cut wood panels with a 3D-printed lock enclosure that is easily reproducible. The total cost of parts is approximately US$100. The conversational chatbot is implemented using Microsoft's bot framework [49], with message parsing through Microsoft's Language Understanding Intelligent Service (LUIS) [50], and accessed via text messaging (SMS). Item queries are further filtered through an off-the-shelf implementation of word2vec [25, 26, 51, 60] trained on an Amazon product review dataset [47], in order to return semantically similar items, e.g. "mallet" for "hammer". Users send text messages to a community-specific number (relayed using the Twilio API [77]) to communicate with their community's box. An example ShareBox transaction is illustrated in Figure 4.

STUDY METHODS AND DEPLOYMENTS

We explored the efficacy of our design through preliminary deployments of ShareBox at three sites in New York City. The goals of these deployments were to probe participants' reactions to our design choices, understand how ShareBox may address potential challenges and barriers to IRE, and distill design implications for both ShareBox and future resource exchange systems. Our intentions aligned with the design of ShareBox as a probe developed to understand user needs and desires in a real-world setting. We hoped that, within the constraints of our design, users would have the freedom to define how they interact with the technology and other users.

It is worth noting that our deployments were limited in scope and duration by design. Larger and longer deployments will be necessary to expose stable attitudes towards the system and develop an understanding of natural transactions. However, we first need to ensure that the system design effectively fits the needs of target communities.

Procedure

Prior work on public interactive systems suggests that the dynamics of engagement can vary widely according to the nature of deployment sites, and that finding "champions" for a technology can prove a critical factor to success [2]. Accordingly, the deployments were conducted in collaboration with community partners at three research sites, selected for the differences we perceived between their underlying communities as well as enthusiasm and support that we received from stakeholders at each site. The first site was a small urban university campus in New York City, with a mix of faculty, graduate students, and staff, ranging in age from their early twenties to their late fifties. Here 30 users signed up to participate over a four-week installation. The second site was a high-rise apartment building with 136 units in an affluent neighborhood. This particular building had a relationship with a nearby hospital and many of the residents were researchers or medical professionals, typically in their late twenties or early thirties. Over a three-week installation, we recruited nine users at the apartment building. Finally, we partnered with a high-profile local bookstore in a commercial Brooklyn neighborhood that doubled as an event space with a bar. Here we recruited and spoke with five users, including undergraduate students, young professionals, and a parent, ranging from early twenties to middle-age, over a three-week installation.

At each site the ShareBox was placed in a secure location, easily accessible to members of the community. Each box was accompanied by signage that instructed users how to sign up. At each site, a researcher spent time standing by the box, explaining the project to community members, and helping them sign up for the study. We invited all users that we spoke with to participate in a 15-30 minute pre-deployment interview. In each interview, we walked participants through the basic interaction with the chatbot and asked them to list item(s) to share with the community. We made it very clear that they were under no obligation to do so at that time, and that any item they listed would be available to the community. This grounded the interview in actual behavior and afforded us a unique glimpse into participants' considerations and concerns when deciding what items (if any) they would offer to share. We probed user perceptions of ease of coordination and exchange, the physical box and its effect on trust, and anonymity and its consequences.

Over the course of the deployments, participants listed 42 items to share (21 at the campus, 20 at the apartment, and one at the bookstore). As discussed, due to the on-demand, need-based nature of borrowing, we did not anticipate a high volume of borrow requests from participants given the short duration of the deployments. Instead, we chose to simulate transactions in which we (the researchers) requested to borrow items that participants had offered to share. Due to the anonymity of the system, the requests looked to participants like actual, community requests to borrow their items, which allowed us to observe their responses to such requests in a real-world setting. We made a total of 28 requests, 12 of which were fulfilled and restored to their owners. Participants also independently borrowed four items; all were fulfilled, but one was never picked up by the borrower.

Finally, we conducted exit interviews with a subset of participants who were available to be interviewed after a few weeks of deployment. Each interview lasted between 15-30 minutes. We asked about participants' interactions with the ShareBox and their perceptions of the system and of other users. We performed 31 pre-deployment interviews with participants (19 female) across the three sites: 21 on the campus, and five each in the other locations. We performed exit interviews with 11 of the 31 participants (six female), all from the campus deployment. Participants were compensated up to $20 for preliminary and exit interviews. Audio recordings of each interview were transcribed and imported into ATLAS.ti [24] before being analyzed using thematic analysis [9]. We conducted several rounds of iterative coding to identify patterns and converge on appropriate themes. Examples of codes include *anonymity enables privacy*, *timing challenges*, and *item security concerns*. After several rounds of coding, we clustered the codes into larger, overarching themes that we used to organize the findings we present in the next section.

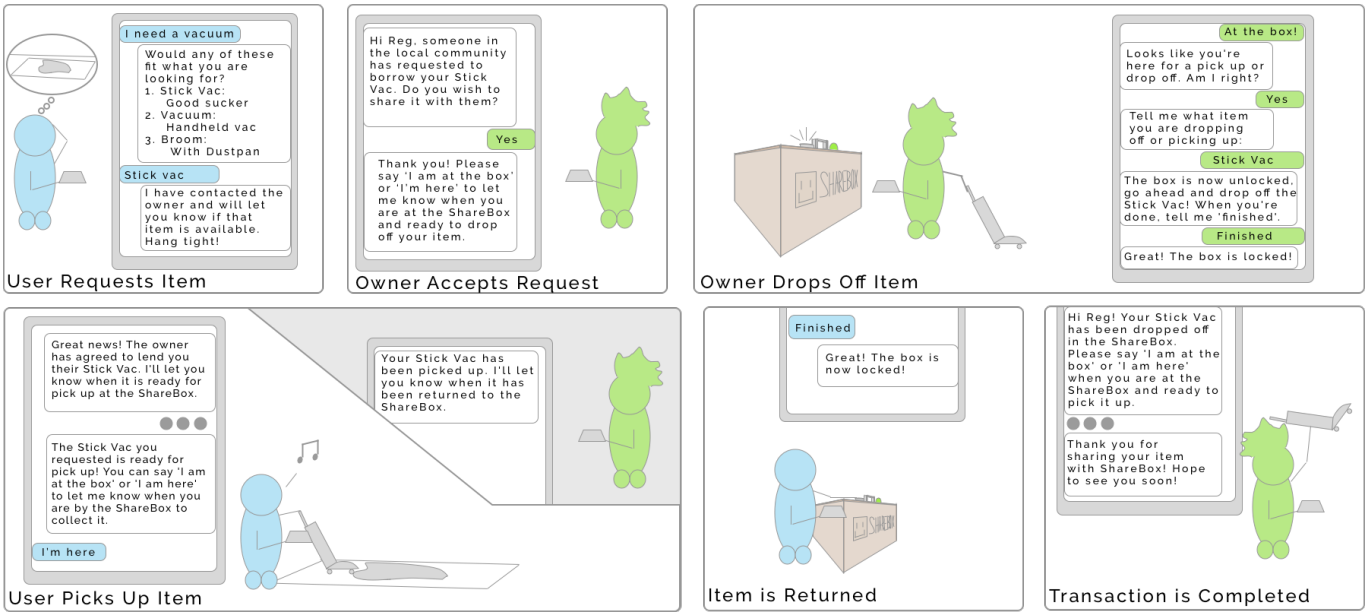

Figure 4. A sample borrow-and-lend transaction through ShareBox.

FINDINGS

Although we identified five main design goals for our probe (discussed above), the qualitative interview data that we collected was able to provide deep insights on only three of these goals, namely how **asynchronous exchange** affects coordination, the impact of the **physical-virtual system**, and the implications of **anonymity** on perceived risk and expected social gains. We discuss our plans for exploring the remaining two design goals (**low access barriers** and **system flexibility and affordability**) in future work. For clarity, participants quoted in our analysis below are labeled according to site they were at, where APT is the apartment building, BK the bookstore, and CMP the campus.

Asynchronous Exchange and Coordination

Participants generally appreciated the administrative and social convenience of asynchronous exchanges, but the open-ended timing of the exchange led to perceived or actual delays and sometimes hindered sharing. Eleven participants said that the convenience of being able to use the ShareBox to exchange items without needing to coordinate with another person was a factor in their willingness to list or actually lend out an item. Describing how the box affected her decision to accept a request to share her measuring tape, one participant said:

> *"...especially if you have to communicate with someone, you don't wanna be like, oh I'm free these days, are you free these times... going to a central spot to drop it off and they can pick it up on their own time... makes it easier for people to share something." (CMP-9)*

Another aspect of asynchronous exchange that participants appreciated was that they could avoid the discomfort involved in meeting a stranger. One participant told us,

> *"I'm a millennial. I don't want to have to talk to people... There's a comfort in knowing I don't have to interact with whoever is actually going to use it." (CMP-16)*

Another participant said that not meeting in person allowed her to assume the best about the person with whom she was sharing her items. For example, when her item was returned safely, she said,

> *"that [other] person has that sense of responsibility and they did it [returned the item safely] and then I'm grateful for that." (CMP-9)*

However, the open-ended timing of asynchronous handoffs also introduced complications. Two participants said they ignored or rejected requests for their items because they were away from the site and did not know the urgency of the request. A third agreed to lend her item but never got around to dropping it off. Seven participants requested more explicit scheduling, such as being able to specify how quickly the item was needed and how quickly it would be returned. In the apartment building, a lender dropped off an item and immediately texted the bot to query when she would get it back.

Physical Presence

The location of the ShareBox within the community and the physical, lockable, form factor positively impacted participants' perceived trust in the system and in other community members. The box's location projected a sense of security by reinforcing associations with access control and feelings of community affiliation. Further, the box itself conveyed safety both physically and symbolically. Fifteen participants said the location of the box played a key role in their willingness to list or share an item for reasons related to security or trust:

"Yeah because here, I trust the doorman. They are always here, it's closed. You know that people who get in are people with a key, or family." (APT-5)

The box's location also reinforced perceptions about the identity of the other anonymous users. Seven participants in the exit interviews felt confident their item had been requested by someone within their community, and two of the five residents of the apartment building explicitly predicted that other residents would borrow their items. This community assurance positively impacted participants' trust of both the system and other users of the system:

"...I feel like if their identity belongs to this organization, institution...the key difference is belongingness, their affiliation" (CMP-12).

However, this sense of *"belongingness"* was *not* a common theme among participants at the bookstore, possibly as a result of how they perceived the community around the store, which was described by one participant as a mesh of contrasts: homey closeness and outsiders, old and new. A patron explained:

"It doesn't feel very residential to me...people who are just coming in and going out and don't have a tie to this location necessarily...I would feel differently about sharing my stuff with tourists than I would with members of my community." (BK-1)

The physical design of the box also affected how people perceived transactions. Participants described how the affordance of being able to lock the box made them more comfortable to lend their item. A participant said,

"...the items inside are not visible unless you're sharing or getting an item back...there's like a safety aspect to it, the fact that it locks, that it's inaccessible unless you're doing those specific actions helps. I think even if the box was clear or something, that would be fine too." (CMP-9)

This notion was tested when three participants wanted to share items that did not to fit in the ShareBox (a folding chair, a small wagon, and a projector). When those items were requested, all three participants opted to leave the item close to, but outside of, the box. One described being anxious that she would lose her item or that someone would mistake it for a giveaway:

"This is my community, but I wouldn't describe what I felt as comfortable...I was uneasy. I did it partly out of my support for your research, and also because I told somebody I would lend it to them and then I didn't want to go back on my word." (CMP-6)

The same participant also suggested letting users add tags to large items to associate them with the box. One did in fact add a sticky note to mark an item. Moreover, although these larger items did not fit in the box, participants still felt that the physical box was very important. As one participant who shared an item that did not fit in the box described:

"I have to say, that sense of hearing the box unlocked and then hearing the box locked was cool and I was sorry that I couldn't put something [the larger item] in the box. I think the box matters. I don't know why because I didn't even get to put my [item] in the box. I felt like the presence of the box identified the thing there as a shared thing." (CMP-6)

Anonymity

Participants had conflicting opinions about anonymity: ten participants expressed support for anonymity while 14 expressed concerns. Our analysis reveals five themes that characterize participants' reasoning about anonymity: privacy, fairness, item security, reciprocity, and missed opportunities for social engagement. We now discuss each of these in turn.

Five participants wanted to preserve **personal privacy** when it came to shared items and transactions. As one participant put it, *"the less information strangers have about you the better" (CMP-5).*

Participants feared they would be judged by others based on the items they shared, borrowed, or the transactions they engaged in. One participant said:

"Well, at least you don't feel embarrassed to ask to borrow something from another person, so I think it's better if it's anonymous. You don't get embarrassed to lend something to another person and you don't get embarrassed to refuse to lend your stuff." (CMP-15)

One participant in a position of authority was concerned that having others associate certain items with her name might lead to unwanted personal interactions in the broader community. Conversely, at least two people specifically wanted their items to be associated with their names, possibly as means to establish social connections (discussed in greater detail below).

Another issue that emerged was the potential for anonymity to promote **fairness**. For example, a few participants suggested that anonymity would help to prevent discrimination when people choose to interact, either as a lender or a borrower:

"Say you get a text saying I need to borrow a drill. If it's anonymous, yes or no. You couldn't really know. If it's not anonymous, you could go, 'who's this person? I don't like the look of that person. I don't want to lend them my drill.' " (BK-1)

Other people had a different perspective, suggesting that the characteristics of the person borrowing their item would affect their choice of whether or not to lend it. One said,

"I think if you see very dirty people, you think, 'Okay, I'm not sharing my plates.' But if you see polite people and they will borrow a plate, you say, 'Of course.' " (APT-1)

Indeed, **item security** was a prominent concern, especially since the anonymity of the exchange increased uncertainty over the safety and return of items. One participant said,

"I guess the one thing you worry about is if you'll get your item back. Because tents or anything like that, those are relatively expensive. I'd be more likely to lend it out if I knew the person." (CMP-13)

Another participant went so far as to say that, without some guarantee of safety, *"it's not really worth sharing anything im-*

portant or useful" (CMP-18). Other participants were mindful that not all possible mishaps were malicious, which perversely might reduce the capacity of interpersonal trust to allay concerns about item security, as also reported by Sun et al. [73]. Many participants projected themselves onto the imagined behavior of potential borrowers. As one participant commented:

> *"I would feel more responsible as a borrower if it's not anonymous, if there's a name tag, if it shows the ownership, who it belongs to" (CMP-12).*

Twelve participants also perceived anonymity as a **barrier to social opportunities** that might otherwise arise from using the box. Participants pointed out that, if not for anonymity, sharing could provide opportunities to meet new people. One even compared ShareBox to a social media platform:

> *"I might put my camping stuff on it... I take pride in those hobbies, and so I would want to be known on this app as the camping guy. And then maybe ... if somebody wants to go on a trip, they'd be like 'Can we borrow your tent?' And I'd be like, 'Can I come?'... Boom, that's a cool connection." (CMP-13)*

Of course, not everyone felt this way. Five users felt that their items were more important than social connections or simply didn't care to know who borrowed their things, because they did not need or want to make friends through a sharing service:

> *"I don't really want to know ... exactly which apartment and the name. They use my things. I don't care." (APT-4)*

Finally, participants had different preferences about the limited (or generalized) **reciprocity** that resulted from anonymity. Participants worried that the feelings of gratitude or goodwill generated by transactions would be lost if people did not know who to direct them at. One said,

> *"So I guess I would prefer to know who is lending me things. Because if we are trying to create community, I would like to know who's the person who is sharing things with me." (APT-5)*

At the same time, three participants argued that even though the ShareBox service was anonymous, sharing contributed to building a general sense of community in a positive way:

> *"Social in a way when you're not actually meeting the person but you're doing something socially, is still community" (CMP-21).*

Building on this general sense of community, the anonymity of the service made it easier for people to see the ShareBox as a community resource. As one participant described:

> *"I think it's a communal thing, and I think it also builds relationships because, although this [service] is anonymous, it is, you know you never know when you need something. So you have a community where someone can offer it, then why not." (CMP-20)*

DISCUSSION

Our short-term deployments of the ShareBox probe, combined with participant interviews and analysis, suggested ways in which the system's unique affordances address key challenges in indirect exchange while also highlighting the difficulties that remain. We now discuss these findings in relation to the ShareBox design goals, drawing implications for the general design of IRE systems. We also analyze our findings in relation to key market design principles for HCI from Lampinen and Brown [38], who in turn build on Roth [64]. In particular, we focus on *congestion*, *safety*, *thickness*, and *repugnance*.

Benefits and Complications of Asynchronous Exchange

We find that the asynchronous nature of the exchange service provided by ShareBox was indeed effective in *easing coordination*, both perceived and actual, but some coordination challenges remain. The coordination challenge maps directly to the concepts of congestion [38] and market costs [30], wherein the market needs to enable efficient transactions. ShareBox's asynchronous dropoff reduces planning overhead and social friction, thus removing a significant burden. But we found that there was still significant uncertainty embedded in the process: timing for both the lend (when is the item available) and the borrow (when is it needed, when would it be returned), and details about the item and whether it can address the need. Discomfort expressed by participants around this uncertainty echoes prior work that suggests that loss of control over a resource discourages sharing [36], and uncertainties about timing and availability frustrate borrowers with unpredictable or urgent requests [30, 73]. Our future work will explore whether providing people with greater control and granularity over the timing of the exchange, such as increasing communication or giving items due dates and renewals, can reduce uncertainty and lag around asynchronous transactions.

Affordances and Constraints of Physicality

Both the physical form of the box and its location in a secure place within the community helped *reduce concerns about trust and safety* in the context of anonymous exchange, which Lampinen et al. argue is critical to the success of peer exchange markets [38]. The physical presence and access control provoked perceptions of community boundedness and affiliation, providing the foundation for a relation-based model of anonymity through participants' perceived proximity to, or presumed social ties with, other anonymous users. The importance of these factors evokes the concept of social presence, which sharing literature has previously associated with trust and participation [33], while the locked container provided an additional, palpable layer of trust. It should be noted, however, that this association between physically-constrained sharing and trust–with five users citing a preference for sharing in smaller communities–could nonetheless undermine the market's potential "thickness" [38] by limiting the number of potential users and shareable items. If, for the sake of trust, community sizes are fixed, then designers must resort to increasing participation within a community (i.e., getting more users or items shared) to ensure thickness.

Anonymity: Uncertainty, Safety, and Privacy

Perceptions around the safety aspects of the market were also negatively impacted by anonymity. By restricting information

available to users, anonymity clearly reduced the perceived safety of transactions, resulting in concerns about item security, even though users were only anonymous to each other, and not to the system itself. This recalls literature on user experiences in other anonymous social arenas, which have been associated with higher levels of negativity and need for moderation [37]. At the same time, we found that anonymity allowed people to participate while maintaining their sense of privacy. This is in line with previous results that suggest anonymity, and relation-based anonymity in particular, can increase comfort with self-disclosure [29, 44] and, in conjunction with asynchronicity, spur disinhibition [71]. Future study should explore ways to negotiate this tension, such as by allowing for less strict forms of anonymity, using pseudonyms, or providing some system-managed reputation and assurance. Other hybrid models of anonymity are also possible—precedent in other domains suggests personal or social opportunities may be afforded by selective disclosure or anonymity [23, 72], and users may, for example, gain from the opportunity to expose their identities for particular transactions.

One feature suggested by our participants is to allow borrowers to share information about their intended use of an item to improve safety and reduce uncertainty without sacrificing anonymity. Our findings here align with research in other exchanges, such as the need of participants in a mobile crowdsourcing workforce to learn about the motivation for tasks that they are performing [74].

Although several participants introspectively observed that removing the anonymity of ShareBox could cause them to be more discerning about those they would share with, some saw the inability to discriminate between other users as an impediment to participation at all. In fact, recent work on community commerce suggests that both exclusivity and perceived similarity are critical components of trust in transactions between strangers [53]. More broadly, some have argued the practical importance of bias in imputing meaning, but differentiate it from prejudice, which is ill-founded or socially harmful [11] (although inappropriate bias in peer-to-peer communities can be damaging for practical reasons as well [20]). Our findings suggest that relation-based anonymity may offer one path for designers to reconcile the sometimes conflicting goals of inclusiveness and establishing trust through the choice of a base community. Designers may design platforms around relations that satisfy both social and ethical imperatives but also provide sufficient comfort to support trust and engagement between anonymous strangers, achieving a sort of inclusiveness within exclusivity through relation-based anonymity.

Finding Social Opportunities in Third-Party Exchange

Given the one-sided nature and scope of behaviors exposed by our preliminary deployments, it is difficult to say whether anonymity coupled with asynchronous exchange was able to successfully reduce the *pressure to reciprocate*, although we can offer that in our interviews, indebtedness [40] was not raised as a consideration for avoiding borrowing or sharing. However, users worried that generalized reciprocity would not be enough of a driving force to encourage exchange over time and may reduce willingness to participate in the long term. At the same time, anonymity had other related social consequences. As participants observed, with mixed emotions, anonymity and asynchronism in tandem can stifle opportunities for social interactions by allowing people to avoid each other and avoid social contact. Averting social awkwardness for the sake of smoothness has been criticized for the potential of impersonal systems to permit painless exploitation or social de-skilling over time [42].

In general, designers should avoid making IRE systems seen as enabling social disconnect[1], which may contribute to the market being *"objected to by people who may not themselves experience any direct harm"*—the concept of repugnance [38]. Repugnance can hurt adoption and thickness of markets. While local peer-to-peer markets may be *"less prone to be deemed repugnant"* [38] there are also other reasons for people to resist such markets. For example, previous research identified attitudes regarding items that should not be requested [73], although we have not run into such attitudes in our study.

Our findings suggest a number of concrete design modifications that could potentially facilitate social connections and exchange while also allowing users to stay anonymous. For example, as hinted to above, ShareBox could allow users to selectively reveal themselves or adopt persistent identities through pseudonymns in an attempt to create richer social interactions, without encroaching on support for privacy and fairness by providing anonymity by default. Although not explored in our study, such "at-will" anonymity has been associated with improved social engagement in other forms of social technology [44]. It is also worth noting that, although potentially desirable, such direct connections between users may result in different unwanted outcomes. For example, multiple authors have discussed the dangers posed by disintermediation—where people transact directly while circumventing the market—potentially reducing safety and resulting in congestion [7, 38]. Disintermediation is especially likely in local communities where proximity or existing ties may make it easier to engage outside of the platform. Note that this is not inherently adverse to the vision of this work—if anything, ShareBox would like to make itself "disappear", supporting rich social connections and exchange with minimal technological intervention. Even in this vision, as one participant observed, ShareBox could play an important role in incorporating newcomers. Nevertheless, disintermediation may still be an issue if, for example, people end up focusing on selected relationships for exchange, or not listing items to share with the broader community.

Finally, the current study cannot conclusively suggest that ShareBox was effective in *reducing barriers for participation*. Although the SMS-based interface reduced the upfront cost of trying out the system (e.g. no need to install an app), linear text interactions made some tasks like browsing available items or listing multiple items cumbersome or repetitive, leading to such behavior as one user listing several items together as one. Thus, even if the low sign-up cost increases participation,

[1] Did anyone say "Bodega"? https://www.bostonglobe.com/opinion/2017/09/15/keep-your-hands-off-bodega-bodega/)

cumbersome interactions can reduce thickness by reducing the number of items that people offer. This tension suggests that a hybrid approach might be feasible by, for example, providing an optional app or website for browsing items or adding items.

CONCLUSION AND FUTURE WORK

This paper described a novel design for an IRE system technology probe combined with several preliminary qualitative deployments that allowed us to evaluate how key design goals and guidelines may help overcome known barriers for IRE in communities and the trade-offs therein. The study elicited valuable feedback to guide future designs of sharing applications. Although not a direct goal of our study, we posit that the closed residential and workplace/campus scenarios may be more promising for future large-scale or long-term installations, as well as other community centers such as schools or faith-based institutions. By contrast, more public venues like the bookstore may be less ideal.

Follow-up work should perform a longer-term longitudinal study that focuses on understanding detailed use over time. More extended deployments are necessary to expose new insights on what is required to sustain activity and increase participation in a community, as well as to develop a deeper understanding of the long-term effects on a community of indirect resource exchange. In particular, future work should address the rich design space around the role that a chatbot can and should play as a mediator in IRE, including the potential for more engaging interactions embodied through the physical system. Larger-scale study would also provide an opportunity to engage the design guidelines of affordability, flexibility and accessibility, evaluating how efforts to realize these play out across different communities. More generally, it is important for future study to explore the dynamics of sharing in different types of communities, such as in varied environments (suburban, urban, rural), or with socioeconomically or racially diverse communities.

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