Understanding Repair as a Creative Process of Everyday Design

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ABSTRACT
This paper presents the findings from an exploratory study that looks at how creativity plays a role in the repair and reuse of objects in the home. We are interested in a particular form of creativity that manifests in the everyday – what John Dewey [8] describes as a constant *doing* and *undergoing,* as we actively adjust to everyday situations. The goal of this study is to show evidence of repair as not only an act of restoration, but also as an act of creativity that entails the repurposing and resourcing of objects. This study is part of a larger research initiative known as the Everyday Design, where it is believed that everyone is a designer and that design is an ongoing activity that includes the repair, modification, and appropriation of design objects and systems. Furthermore, this study serves as baseline research for future investigations in how to inform the design of technologies whose lifecycle can be extended for various contexts of use through repair.

Author Keywords
Repair, reuse, everyday design, creativity, appropriation.

INTRODUCTION
This paper reports on a qualitative study that looks at understanding how creativity plays a role in the everyday repair of objects in the home. We see creativity as a phenomenon that occurs throughout our daily lives. We describe creativity as *resourceful* and *adaptive* actions that lead to unique design situations and systems. The goal of this research is to reconstruct the notion of *repair* as a creative process that serves an important role in the multiple lives of objects in the home.

This study is part of the larger study of Everyday Design. The aim of this research is to re-construct the ”user” as an ‘everyday designer,’ or someone who creatively ‘designs’ systems in by re-appropriating artifacts through *design-in-use* [27]. We believe that by understanding the evolution of artifacts and systems through the lens of repair (as a process of *design-in-use*), we can then begin to inform the design of interactive technologies that can be reused and appropriated to fit a variety of changing contexts and needs.

Understanding everyday repair in the home has relevant implications for interaction design, as we explore the fundamental barriers of objects’ physical attributes that either *compel* or *prohibit* the repair, reuse and/or appropriation of everyday technologies. We set out to answer the following three questions:

1. Is repair a creative process?
2. In what way does repair relate to appropriation?
3. How do acts of appropriation and repair fit within the context of Everyday Design – specifically as aspects/dimensions of design-in-use?

This paper outlines the current status of the project, as we describe the methods of our data collection (via a web survey) and the analysis of 30 responses. We describe our two methods of analysis. The first method entailed the development of an open-coding rubric for defining various states of repair, reuse and ‘digitality’ of the broken objects submitted. Our second method included an affinity analysis where patterns of repaired objects, particularly their physical attributes, were defined as part of an initial design framework for facilitating creative repair and appropriation. We conclude with a discussion of what implications this research has for the design of technology, and what challenges this poses for the interaction design community.

RELATED RESEARCH
There are several different areas of research that focus on understanding the reuse of objects to inform sustainable design practices. There are few, however, that focus on understanding repair as a creative process for informing the

design of more reusable and repurposeful technologies in the home.

Current research on repair is written in more general terms within the emerging discourse of Sustainable Interaction design (SID) [4]. Odom et al. look at why people keep certain objects as 'heirlooms' [17]. Huang et al. explore why people dispose, recycle and/or reuse technologies prone to obsolescence such as mobile phones [12]. These papers have made significant contributions in providing foundational theories for the development of sustainable design frameworks.

Work by Jung et al. looks at the materiality of digital artifacts with the aim of developing a taxonomy of digital material *qualities* for informing the design of technologies [15]. Here the authors also highlight the need to look more closely at the notion of *reconfigurability* – where technologies' software and hardware components can be easily broken down and assembled for different purposes of use through the addition and transformation of parts.

Industrial design initiatives look at designing for *disassembly* or *remanufacturing,* where manufactured objects are conceptualized with the end of their lifecycle in mind [18,21,23]. Frameworks related to remanufacturing include best practices around how to inform products' material design for facilitating transportation and disassembly processes [21]. Other frameworks look to inform business strategies by analyzing the rate of products technological innovation and their expected end of lifecycle [18].

Also related is Leah Buechley's work in understanding the role of DIY culture in the reuse and appropriation of technologies [5]. Buechley's research looks at *customization* as a key aspect of DIY culture, but also focuses on reuse and creativity as inherent characteristics of DIY practices. The goal of this workshop is to understand how thinking within Do-it-yourself communities can facilitate HCI design practices.

A key objective of our research is to understand repair as a creative practice that is strongly related to acts of appropriation. Designing for appropriation has become an emerging issue within the disciplines of interaction design and HCI. Literature pertaining to appropriation is found primarily within the contexts of the workplace [3,6,9] and the home [7,24,25]. Theories of designing for appropriation have also been discussed using ideas proposed by Heidegger, as well as in Activity Theory related frameworks like Instrumental genesis [16].

The arts have also been referenced as a realm in which acts of appropriation occur due to avant-gardism and the artist's pursuit of *authenticity* and *authorship* [10]. Senger, Höök and Gaver discuss the notion of *multiple interpretations* as a means of facilitating appropriation. They posit that *ambiguity* can compel more dynamic forms of interaction that go beyond usability and more towards explorative and creative activity [10,13,20].

Darinka Aguirre's work looks at applying the concept of *design for repurposing* as "an evolved design strategy that could help ease the negative environmental impacts in today's world." [1] This research proposes two checklists for informing small to large-scale businesses production processes. These frameworks serve as guidelines for best practices around the use of non-hazardous materials, as well as informing the design of affordances that lend themselves to repurposing.

Our own work under the rubric of Everyday Design has looked at the appropriation of artifacts and systems in the home, where we describe these processes as fundamental aspects of design-in-use [27]. We will discuss the parallels between the everyday design framework and the findings from this study further on in the paper. In the following section we outline our methods for data collection and data analysis.

METHODS

Data collection took place in the form of a qualitative survey that was distributed via email and Facebook. The goal of the survey was to gain insights into the processes by which people repair broken objects, as well as understand the reasons for why certain objects are kept and repaired. Another aspect of this study looked at uncovering the different kinds of values people attributed to objects that are broken, kept and repaired. Participants ranged from ages 20-67 years of age, with a range of different occupations including university students, a lawyer, designers, musicians, teachers, a dental hygienist, and a stay-at-home mom.

The survey population was composed of 50% female and 50% male participants, most of which were between ages 20-29. A total of p=30 responses were submitted with each participant including anywhere between 1-7 examples of repaired and/or broken objects from their home. The total number of objects submitted was n=87. Some of the responses were too vague to give a proper assessment, thus the total objects used in our data analysis came to 74.

The survey took place in two phases; the first phase asked participants the following three questions:

1. Do you have something that is broken but not thrown away?
2. Do you have something that is broken which you have repaired and is now more valuable (monetary or sentimental) and/or functions better than before?
3. Do you have something that is broken which you are still using or reusing in a new way?

Participants were also asked to include pictures of their broken items wherever possible. Photos were used as part of the analysis to determine the objects repair, type

(mechanical or digital) and reuse (we will discuss this further in the following section.) The second phase of the survey included follow up emails with participants in an attempt to elicit further information about how and why their objects were or weren't repaired.

The data collected from the survey responses was categorized into two sets. The first set quantified object types and the instances of repair present in each type. These were based on their *degree of repairability* and *degree of digitality,* and *degree of reusability*. The second data set is comprised of value-themes that resulted from an affinity analysis of the participants' submissions. The following two sections will describe each data set and the methods used to analyze them.

Defining Repairability, Digitality and Reusability Through Open-Coding

The first phase of data analysis entailed the development of an open code rubric for categorizing the repair of each object. The open-code included the following categories: *degree of repairability*, *degree of digitality* and the *degree of reusability*. Values for each of the three categories were developed through an iterative process lead by the principal researchers. In order to validate the rubric, two inter-raters assessed all 74 objects using the values defined in each category – first independently and then together to check for any discrepancies. Discrepancies between the open-codes were discussed until an overall agreement was reached.

For degree of repairability, objects were rated as one of the following values: (1) This object is not repaired and not usable; (2) This object is not repaired and is partially usable; (3) There is an attempt to repair this object and it is not usable; (4) There is an attempt to repair this object and it is partially usable; and lastly (5) This object is repaired and is fully usable.

Distinctions of all the objects' type, or *degree of digitality*, were defined, as we were particularly interested in finding examples of repaired digital objects and the processes that lead to their repair. An object's type was determined based on the following values: (1) This object is mechanical - it has no digital mechanisms; (2) This object has both mechanical and digital mechanisms; and finally (3) This object is digital - it only has digital mechanisms.

Objects were then assessed for their *degree of reusability* under the following rubric: (1) This object is no longer usable; (2) This object is used as it is originally intended/designed; and (3) This object is used with new intentions/functions.

By using this rubric, we set out to answer the following questions:

1. Are there visible differences amongst objects repaired versus those unrepaired? Reused or not reused? Repurposed or not repurposed?
2. What can any emerging patterns from the open-coding scheme say about creativity as part of everyday repair?

We describe the results our analysis in the following section.

Open-code Analysis: Results

Based on the open-coding scheme, we defined 64 objects as mechanical, 8 as digital and 2 as a combination of both mechanical and digital parts.

Out of the total digital objects submitted, 63% were assessed as "*not repaired, not usable*." These objects had completely stopped working and could not perform their intended function. The remaining 27% were deemed to be "*not repaired, partially usable;"* these technologies had parts of their hardware broken, but their software parts were still fully functioning.

Out of the total number of mechanical objects, 11% were assessed as *"not repaired, not usable,"* 28% were *"not repaired, still usable,"* 6% were *"repaired, not usable,"* 6% were *"repaired, partially usable,"* and lastly, 48% were *"repaired, fully usable."* Objects where no repairs were made and were no longer functional usually entailed electrical breaks that were beyond the participants' knowledge to fix. Objects where attempts of repair were made but still remained broken fell under the same circumstances where professional knowledge was required. Mechanical objects that were repaired to partial or full usability were simple in their material nature and thus easy to disassemble and put back together.

A particularly interesting outcome of the open-code analysis was the results for the instances of *reuse* of digital objects and mechanical objects. Out of the total digital objects, none of them were reused or repurposed. Conversely, out of all the mechanical objects, 56% were reused as they were originally intended (after their repair), and 31% were repurposed (as an outcome of repair). The implications of reuse in mechanical objects are discussed in more detail in our description of key attributes of repairable objects (See *Affinity Analysis*.)

In summary, it is somewhat unsurprising that a lower number of digital objects were repaired compared to those that were mechanical. This comparison gives evidence of a much larger phenomenon where not only mechanical objects are found to be more 'repairable' than digital objects, they also lend themselves to be more reusable. As an example, four participants described keeping their 'broken' iPods without any attempt to repair or reuse them in a different manner. It can be assumed that this is mainly due to the materials used in their manufacturing process (including hardware and software), which are difficult and often impossible to alter in any way. The value in comparing mechanical and digital objects' degrees of repairability and reusability gives evidence of the need for interaction design to reconsider how digital objects are

designed for instances of repair, which can lead to reuse and creative repurposing.

Affinity Analysis: Emerging Attributes of Repairable Objects

What do the findings from the open coding analysis mean for the repair of digital technologies? How can we make sense of the vast difference between digital and mechanical objects and their repairability? Or more pointedly, what can we learn from the creative repair of mechanical objects for informing the design of more reusable digital technologies? To try and answer these questions, we conducted an affinity analysis inspired by Huang and Truong's work in [12].

The affinity analysis entailed a thorough inspection of all 30 surveys where descriptions of broken objects and the process by which they were repaired were identified. These were used as direct quotes and were clustered into similar themed categories through the use of inductive open-coding. The pictures included by the participants also informed the development of these categories. We focused our analysis on the material qualities of the objects' hardware and their *influence* on repair and reuse. Three key material attributes of repair emerged from the analysis. They are described as follows:

1. ***Flexible materials*** – the ability of an object's parts to bend, twist and warp to accommodate its intended functions or entirely new ones.
2. ***Substitutable materials*** – the capacity of an object to be disassembled for the replacement of broken parts. These parts can be either made for it (standardized components), or jerry-rigged from other objects.
3. ***Salvageable materials*** – the ability to salvage broken items in order to create an entirely new structure or system. This has similar qualities to *flexible materials* but focuses more on the reclamation of parts for new contexts of use.

We believe these attributes can facilitate the creativity inherent in everyday design systems based on our observations of repair particular to mechanical objects. We discuss this further on in the paper (see *Discussion*). In the following section we describe each of the three material attributes and provide examples from the surveys.

Flexible Materials

Flexible materials are best described as an object's material ability to bend, twist and warp into new dimensions. The following examples all have some form of flexibility that have allowed their owners the ability to maintain their functionality, or repurpose them into something entirely new.

P19 gives an example of how he fixed the strap of his laptop bag by easily tying the ends together:

Figure 1. P19's shoulder bag with fixed strap

P19: *"The strap on my laptop bag is broken: the buckle continually comes undone and falls open (meaning the bag falls off my shoulder). It's been like that for at least a year. I 'fixed' it by tying a big knot in the strap above the buckle. So I haven't properly repaired it but the quick fix was good enough that it's lasted for a long time (even though the knot is kind of uncomfortable). I've been meaning to replace or repair the strap, but haven't gotten around to it."*

Flexible materials also allow for easy repurposing of the object entirely. P27 describes how she repurposed her necklace in two novel ways:

P27: *"[An] item that is broken and has new use as of recent is a leather necklace my baby cousin made me a few years ago. The 'pendant' part of it is a string of leather that has been twisted in a circle – kind of like a stove element – and the strap is just a simple long leather strap. The strap broke so now I'm using the strap to hold my curtains open. I glued a small safety pin behind the pendant and now it's a button (I collect buttons).*

In an example submitted by P22, she describes the repair of her old climbing rope by transforming it into a doormat:

P22: *"I have an old climbing rope that could be labeled as 'broken'. It's not suitable as a safety device while climbing anymore but I have woven it into a door mat/ rug and love it once again. (Though it is a very expensive rug). A lot of climbers turn their old ropes into rugs, I would assume that's because you invest a lot into that piece of equipment, both monetarily as well as in trust and care to make sure it functions properly. […] So I knew to make it into a rug from talking to other climbers about gear and caring for/ retiring it. Also it does function quite well as a rug. I think it would be nicer as a middle-of-the-room large area rug than a doormat (its not the easiest thing to clean/ shake out without needing to tinker with the shape a bit) and it does feel good on bare feet."*

The climbing rope is an exemplar of the simple properties flexible objects have, which allow their owners to easily alter (and creatively resource) their physical properties into forms that could serve their needs in alternative ways.

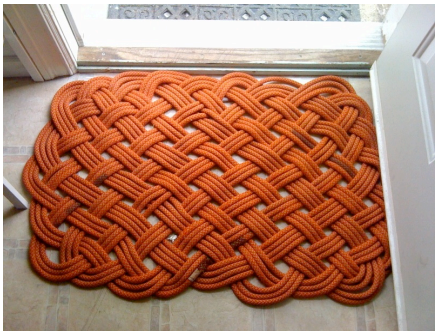

Figure 2. P22's climbing rope transformed into a doormat.

These examples highlight the ease with which people creatively reuse and repurpose their broken objects based on the flexibility inherent in the objects themselves. The materials found in these objects are typical, everyday resources that have a certain familiarity of use. Consequently, foreseeing solutions to their repair and/or other possible uses come almost as second nature through their design-in-use.

Substitutable Materials

Objects whose parts were easily substitutable facilitated repair by replacing and re-attaching other parts. In the examples that follow, each participant discusses how they were able to repair their objects resourcing other artifacts and systems with similar material qualities. P6 describes the repair of her sunglasses lens as the following:

P6: *[I repaired] my favorite pair of sunglasses that I got for $5. It was missing a screw at the time of purchase so I took a screw from another pair of sunglasses (as I didn't mind breaking it for this pair), and now it is all in one piece. I wear it whenever it's sunny while driving, even if it's not summer anymore. […] I took the screw from the brown ones at the top to put together the red ones. Unfortunately, the hinge of the red ones recently broke, and I really love this pair so I'm hoping to find one that's similar to screw on - or maybe go to a repair shop.*

Figure 3. P6's sunglasses repaired with a similar sunglasses' screw.

P6's repair is a common example of the substitutable qualities of common items such as screws, hooks and other adhesives. However, in the next examples P11 and P15 used alternative everyday materials for repairing their objects. These examples demonstrate the use of unobvious materials as resources for creative repair. Note that the flexibility of the materials used were easily adapted to serve the same functionality of the objects' broken parts.

A couple of years ago, P11 and her boyfriend were given a juicer as a housewarming gift. The juicer came broken; the waste collector had a crack in it and was rendered unusable. P11 explains that instead of replacing the juicer altogether, her boyfriend came up with an entirely new solution that proved more effective than the original waste collector.

P11: *The "waste collector" for our juicer broke, so [my boyfriend] put a plastic bag in its place to catch all the fruit spit-outs. It actually works pretty slick because we can just pull the bag off and toss it, without any clean up! I guess he originally tried to use the broken waste collector [only a man!] and shockingly it didn't work-- threw fruit chunks out all over the place. That's where the plastic bag idea came into his head. He did mention that it's great because it requires no clean up, and was nice and easy. The machine/unit part of the juicer has clamps that would attach the waste collector [you'd unattach it for washing purposes], so he just clamped the bag down in its place. Works like a dream.*

Figure 4. P11's juicer with new garbage bag waste collector.

P15 had a similar situation with his popcorn machine where the metal cover (also used for melting butter) went missing. He devised a solution that he describes as follows:

P15: *I have an old popcorn popper that I've had forever. It originally came with a little metal dish to melt butter in. The idea was that as the popcorn pops, the hot air runs under the dish and melts the butter. That dish has been missing for years. Instead, I have a sheet of aluminum foil over the hole where the dish goes. (If you don't cover the dish, the popcorn shoots out the hole and gets all over the kitchen.) In one sense, it's now less functional, since I have to melt the butter in the microwave. In another sense, I've fixed a safety problem: The dish would get darn hot, and I*

remember burning my fingers on it when I was little. I also don't remember why I decided to use tin foil on the popcorn popper. I remember trying to make popcorn once without the butter tray, and popcorn got all over the kitchen. Aluminum foil might have been the first thing I tried.

Figure 5. P15's popcorn popper with aluminum foil butter-dish replacement.

In both P11's and P15's repairs, we can see that their solutions take on characteristics that are similar to their broken counter-parts. The plastic bag is easily attached to the juicer and performs the same 'container' functions of the original waste collector. Similarly, P15's addition of his own aluminum foil cover takes on the same form as the missing butter dish.

A necessary aspect of substitutable materials is the simplicity of the object's form and function. As observed in the open-coding analysis, virtually all the digital objects had fairly rigid and complex structures making any kind of alteration impossible. There are still considerable challenges to facilitating the everyday repair of technologies whose software and hardware mechanisms are designed with built-in obsolescence. We submit, however, that designing with substitutable parts in mind is a viable place to start informing design practices.

In the following section we describe salvageable materials as a third attribute common to repairable objects. We describe salvageability as a key aspect for the creative repurposing of a broken object, and the degree to which its reuse depends on the presence of both flexible and substitutable parts.

Salvageable Materials

Many of the broken objects we observed were salvaged based on their perceived potential for reuse. An object's reclamation often resulted in the transformation of an object's physical properties towards new functionality – or creative repurposing. In the following examples, we make light of objects whose parts were transformed to create entirely new uses. We focus on the material attributes these objects embodied in facilitating their repair and inevitably, their appropriation.

P13 gives an example of a broken hockey stick in which its state of disrepair is used to function as two window stoppers:

Figure 6. P13's broken hockey stick used as window stoppers.

P13: *"I had a cracked hockey stick, which I cut into two, removing the cracked portion, to use as window stoppers for my own room window and my sister's, because our plastic built-in window "stoppers" broke. (Window "stopper" used to prevent a window from opening fully). I felt the hockey stick graphics were stylish to use as a window "stopper", then just any old piece of wood."*

In this case, the material structure of P13's broken hockey stick was seen as an effective solution for replacing his broken window stoppers. Both the simplicity of the hockey stick's form, as well as the structure of the windowsill itself allowed the two to comply with each other, thus creating an entirely new system. This illustrates the need for designing objects that are simple in their material nature in order to facilitate their reclamation for new contexts of use.

Similar to P13's hockey stick is P15's salvaged piece of plywood that his roommate cut too short when building a part of his desk. Instead of throwing the 'broken' piece of plywood out, P15 found another use for it:

Figure 7. P15's mis-cut piece of plywood reclaimed as a monitor stand.

P15: *"When my roommate got his desk, he went to Home Depot to get some plywood to make a keyboard tray, but he cut the plywood too small and couldn't use it. We kept the board around for months, for no particular reason. Then I*

got a monitor riser for my desk. Except my monitor has an enormous footprint and didn't fit on the riser. I ended up putting the mis-cut plywood between my monitor and the riser, and now the monitor is at the right height. (You can see the feet of the riser underneath the plywood.)"

The fact that P15 and his roommate had kept the piece of plywood around for 'no apparent reason' speaks to its implicit potential for future use. Again, we attribute this to the simple qualities of its form and the ease with which it substituted the monitor riser in its new context of use.

In summary, the emphasis we wish to draw from the examples shown is the need for flexible, substitutable, and salvageable materials in order to facilitate the creative processes inherent in repair. Furthermore, we stress the need for simplicity as an x-factor in the design of objects' physical materials – it is in the simplicity of form and function that the proposed attributes of repair hinge upon and that without, everyday repairs would less likely occur.

REPAIR, MODIFICATION OR APPROPRIATION?

Through the course of our analysis, we came across various examples of objects that didn't seem to fit the conventional sense of the term 'broken.' Objects that were considered 'repaired' also seemed to border on the line of being a modification. The example of the mis-cut piece of plywood had us reconsider broken to entail either of the following scenarios: (1) an object that is physically impaired (i.e. cracks, tears, dents, etc.), or (2) an object that no longer meets its *expected* functionality.

To illustrate our point further, we use P8's example of his 'broken' staircase and how some house renovations rendered it as an unusable space in his house:

P8: *I have a staircase that's been closed off and I wanted to use it as storage […] It used to be a functional staircase, but a new floor was added at the top of the staircase, blocking it off. So as a staircase, it no longer functions, and as a storage space, it's very difficult to use. So, sure, I could see [the staircase] as being 'broken.' […] A little creative re-engineering later, I re-built some Ikea storage units to work in the staircase.*

Was P8's staircase transformation into a storage space a repair or modification? Does a space actually break? At what point do we consider an object (or space) broken if only part of its functionality no longer works? Are the alterations of an unusable but fully intact object/space mean it's just been modified and not repaired? Are these situations then what we know as appropriation?

P8 considered his staircase 'broken' because it no longer functioned as a usable pathway for accessing the top floor to his apartment. We can also see the same issue with the mis-cut plywood – it was deemed broken because it could no longer fulfill its intended purpose as a keyboard tray. If a lack of functionality were a primary delineator for something being broken, would P15's monitor riser be considered broken since it could not hold his computer monitor? Is the addition of the plywood its appropriation and the addition to the riser a modification?

Figure 8. P8's 'broken' staircase reconfigured into storage space.

Given these questions, we believe there are strong correlations between repair and the appropriation of objects in the home. More specifically, we see the impairment of objects as an instigator of creativity that prompts home dwellers to think about alternative uses for their broken or unusable objects.

In the following section, we discuss these considerations within the larger context of our everyday design framework and how our proposed attributes of repair can contribute to our current research within Everyday design and its connection to appropriation.

DISCUSSION

Repair and Everyday Design

We see creative repair having direct parallels with previous observations from our Everyday Design studies [26,27,28]. As mentioned earlier, we describe "users" as a type of designer - someone who remakes and modifies artifacts and systems through the process of *design-in-use*. We argue that repair is also a form of design-in-use as people often explore alternative uses for objects that are deemed unusable or broken.

We recognize emerging synergies between the attributes of repair proposed in this paper and the everyday design frameworks previously published in [26,27,28]. In these papers we describe patterns of everyday design as acts of creativity and highlight the influence social dynamics have on the incremental adaptations of everyday design systems through *materiality* and *substitutability*. We will describe these parallels using the three key aspects of everyday design; these include *resourcefulness*, *adaptation*, and *quality)*, and the notion of *materiality-substitutability* as a

key factor for facilitating the social needs of everyday design systems in the home.

In [27] we described *resourcefulness* as the appropriation of artifacts and systems for serving new purposes in the home. We see flexible, substitutable and salvageable materials as key considerations that facilitate acts of resourcefulness. Resourceful behavior can be seen in the repair of P6's sunglasses, as she used another pair's screws to fix them. We also see resourceful behavior with P11's waste collector replacement using a plastic bag for her juicer, and with P15's use of aluminum foil to properly cover his popcorn popper. P15's reuse of his roommate's broken piece of plywood was also resourced as a platform for his monitor riser. What we wish to highlight here is that the need for repair often prompts resourceful actions that lead to creative outcomes that are unique in order to fit individuals' needs and situations.

In terms of *adaptation*, we see various manifestations of adapted objects in situations where parts of broken objects are changed and altered to serve new needs. This is particularly obvious with P22's climbing rope rug and P13's transformed hockey stick into a "window-stopper." Again, these adaptations are made possible through simple functional and physical properties of systems and artifacts.

We also see repair as a process of quality assurance that through design-in-use, compels people to explore and understand an object's materiality and its potential for reuse. *Quality* can be seen most prominently in examples where substitutions and reclamations were made with broken objects. As we describe in [26], *materiality-substitutability* as a necessary factor that extends the use of artifacts and systems by resourcing other objects and adapting them based on their simple functionality. We see this in the example of P11's use of a plastic bag for catching all the excess fruit parts from her juicer. This solution not only repaired the situation with the cracked waste collector, it also simplified the process of cleaning up. We can assume this system has a high degree of quality given P11's continual use of plastic bags when using her juicer.

Quality of an everyday design system, however, is subject to constant change and thus the success of a repair is always under scrutiny. We see quality as an integral part of repair, as people continually assess the degree to which they had met their own expectations, as well as those of others. A lack of quality perceived within a system can often lead to one of two scenarios; the object's disposal (as seen mostly with digital objects), or the adaptation of its broken parts through creative repair.

Given the conceptual overlaps between repair and the everyday design framework, we wish to reconstruct the notion of repair as a type of modification, and as a fundamental part of appropriation. More specifically, we see repair as a higher level of creativity that directly contributes further insights into the process of everyday design in the home. We recognize there's still more work to be done in making the distinctions clear between repair and appropriation. We intend to investigate these ideas further in future work. Ultimately, we hope this research offers provocative insights to current discourses around designing for appropriation and the inherent creativity of everyday designers.

Implications for Interaction Design

The physical attributes proposed in this paper help to describe the relationship between the creative actions of people imposed on the objects they use, and how the physical attributes of these objects facilitate their design-in-use – particularly in instances where repair is a consideration. As for the repair of digital technologies (or lack there of) that was evidenced by our open-code analysis, we see this as a prominent consideration for interaction design. Our analysis suggests that the simple nature of mechanical objects enable repair, though the presence of electronics and computational mechanisms in digital objects add further complexity that make adaptations and resourcefulness difficult. We advocate that designers use the framework of resourcefulness, adaptation and quality as a tool for anticipating a technology's design-in-use, coupled with the framework of physical attributes of repair for facilitating the appropriations made to systems in the home from a material standpoint. We can already learn from current DIY initiatives – particularly with "repair-hacks" who actively find ways of jerry-rigging technology towards new uses.

We see resourcefulness in the repair of more electronic-based objects that are made possible through the use of other flexible objects. As one example, an old expired credit card is used as reinforcements to repair this person's broken headphones (see *Figure 9)*. This person uses electrical tape as an adhesive for strengthening the overall structure. The headphones' are easily repaired using everyday materials like plastic form credit cards and tape. [19]

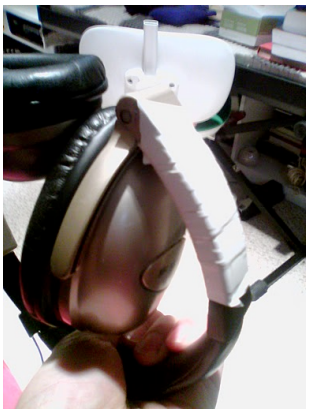

Figure 9: Headphone repair using expired credit cards and electrical tape.

(https://picasaweb.google.com/dmaranan/Jerryrigging?feat=flashalbum#5566932613349931330)

Adaptations of digital technologies are also prevalent in DIY communities. Binaebi Akah discusses the need for people to modify their technologies based on personal identity and through acts of appropriation [2]. She references the *Steampunk* movement as an example of how people make use of the steampunk aesthetic for presenting their personal identity through their technologies. We see glimpses of flexible and substitutable materials present in many of these modifications, which allow everyday people the ability to personalize their technologies based on their own preferences. In the example below, Jake von Slatt modified an old LCD display and keyboard to express the steampunk aesthetic [22].

Figure 10 This steampunk keyboard and monitor is made at the Steampunk Workshop (http://steampunkworkshop.com/lcd.shtml). Photo by Irish Typepad from flickr (http://www.flickr.com/photos/irisheyes/2505570986/#/photos/irisheyes/2505570986/lightbox/)

Lastly, *Hack A Day* (hackaday.com) is a blog dedicated to presenting various repaired and reused technologies of those who actively seek ways of repurposing them. We see seeking improvements in quality as an integral part of such communities, as people share how they've salvaged old electronics by finding other accessible parts that improve the way they work. As an example, this hack demonstrates an easy way of utilizing an old alarm clock LCD by using common electronic circuits and arduino (see *Figure 11*) [11]. The programming allows these readily available displays to be used in many new ways.

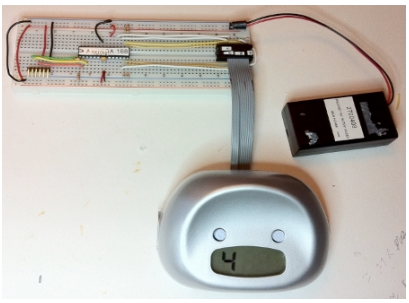

Figure 11: Repaired Alarm clock LCD using arduino and electronic wires. (http://hackaday.com/2011/02/10/driving-a-salvaged-lcd/)

In summary, there are clear directions for future investigations based on the findings presented in this paper. More research is needed for navigating through the challenges of implementing our proposed attributes of repair when designing complex digital technologies. We hope to continue our explorations by finding more examples of repaired and reused digital technologies in the home that can contribute further insights to the current list of repairable physical attributes. As a potential direction, we see the benefit in conducting ethnographic methods for observing the processes of repair in the home over a longer period of time and accounting for other factors that either instigate repair, or prevent it altogether..

CONCLUSION

This study demonstrates the need to consider repair as creative activity in the use, and reuse, of objects in the home. Based on the data collected in the surveys, it is clear that we can learn a lot from the material qualities of mechanical objects – specifically when considering the benefits of their inherent simplicity. Further research in this area can move us towards a framework of design that accommodates for creativity in situations where repair is needed – a scenario that is inevitable once the life of a technology ends.

In this paper we give evidence of the barriers to repairing digital technologies. We see the potential in considering how everyday designers operate as creative agents in the multiple 'lives' of objects – particularly in situations where repair entails the creative re-design of objects through resourceful and adaptive actions to meet new needs. This study also offers a different perspective on what we define as broken given the fine line between something that is no longer useful, or no longer usable. This has significant implications for interaction design, as designers accommodate for situations where repair is a viable option when it comes to the "end" of a technology's lifecycle – whether it means the end of its intended usefulness, or when its use may be appropriated in other ways.

Lastly, we see the need to incorporate flexible, substitutable and reclaimable attributes as key aspects of material use in the design of digital technologies, as inspired by our observations of mechanical objects and the ease with which our participants repaired and creatively reused them. We see this as a useful starting point and intend to investigate these factors further in future work.

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