

Design Analysis: Understanding E-waste Recycling by Generation Y

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ABSTRACT

This paper aims to understand e-waste recycling behavior of Generation Y. It presents a pilot study that explores this generation's e-waste recycling practices, their attitudes towards e-waste recycling, and the barriers to e-waste recycling. The findings reveal the complexity of the actual e-waste recycling behavior, many participants in this study hold a positive attitude towards e-waste recycling, yet there is a shortage of convenient recycling options and e-waste recycling information. Based on the Motivation-Opportunity-Abilities model, this paper also uncovers the decision-making process involved in each recycling action. We use these findings to present a preliminary analysis of design implications to provoke design ideas and services that support e-waste recycling, and discuss our further research direction.

Keywords

E-waste, recycling, recycling behavior, recycling action, attitude, design.

1. INTRODUCTION

Over the last decade, the electronics industry has achieved remarkable success in developing a mass consumer market for computers, cell phones, and other personal electronic equipment. Planned obsolescence, a policy of deliberately planning or designing a product with a limited useful life [33], has caused people to discard their electronics at a much faster pace than ever before. Moreover, interaction design and human-computer interaction (HCI) community have contributed to making electronics more efficient, usable, and enjoyable [24]. As a consequence of these technological advances, many types of electronic goods reach obsolescence fairly quickly and are quite often destined to end up in a landfill. The primary concerns of this ever-increasing volume of electronic waste (e-waste) are the waste

of valuable resources, such as copper, aluminum and gold, which can be extracted and recycled into new manufactured products, and the presence of toxins that are harmful to health and the environment, such as lead, mercury and cadmium, when the electronic goods are dumped in a landfill or when they are improperly dismantled.

In the field of ecological design, several so-called eco-efficient strategies have been put forward to reduce the environmental impact of discarded products. Recycling of used products is one important contribution toward sustainability. However, electronic waste recycling has a relatively short history so that the recycling rate is very low. Part of the problem is that "the developing patchwork of programs ranging from infrequent municipal or retailer collection events and manufacturer mail-back services, to charitable donation programs and fee-for-service operations" [6]. But users' participation is another critical factor for the success of e-waste recycling. Therefore, it is necessary to understand users' actual willingness, attitude and experiences towards e-waste recycling for designing and developing more effective e-waste recycling programs, infrastructure and services.

In his paper, Sustainable Interaction Design: Invention and Disposal, Renewal and Reuse [2], Blevins advocates a critical design perspective or an ethical design stance in which interaction designers have a heightened awareness of the environmental impact of their design enterprise [35]. We argue that the expertise and design of both design and HCI communities should and can be leveraged to find ways to encourage and support users to recycle more e-waste.

As a first step towards this goal, this paper tries to understand the e-waste recycling behavior of Generation Y through answering the following questions:

- What is e-waste recycling behavior?
- What is the characteristic of e-waste recycling behavior?
- What are users' attitudes towards e-waste recycling?
- What are the barriers to recycling when they want to recycle their e-waste?

Generation Y, typically those born between 1977 and 2003 [31] already outnumber the baby boomer generation and have become the largest demographic group [16, 31]. Recent studies identify several core behavior attributes of this generation. They are more comfortable working with technologies than previous generations

[23], demand constant connectivity to high-speed Internet [10, 31], are able to perform multitasking activities simultaneously [10, 23, 31], and anxiously await and purchase the newest technology devices [10, 16]. Given these characteristics, this population has the potential to generate massive amounts of e-waste and is worthy of study from the standpoint of e-waste recycling. Hanks, etc. [16] also present a study of this generation, yet focus on their attitudes towards sustainability and the material effects of interactive technologies.

The remainder of this paper is organized as follows. First, we offer a review of prior work related to recycling. We then report the participants, research method and findings. After that, we use the Motivation-Opportunity-Abilities model as a theoretical lens to understand the complexity of the actual e-waste recycling behavior and discuss findings. The paper ends up with implications of the findings.

2. RELATED WORK

Wikipedia defines recycling as “the reprocessing of old materials into new products, with the aim of preventing the waste of potentially useful materials, reducing the consumption of fresh raw materials, reducing energy usage, reducing air and water pollution by reducing the need for conventional waste disposal, and lowering greenhouse gas emissions as compared to virgin production” [36]. This definition emphasizes the processes of recovering materials from waste and translating these materials into new products. In fact, recycling is a complicated system including several different working procedures in which various stakeholders are involved. For example, the likely stakeholders in an electronics recycling system would include: electronics designers and manufacturers, retailers, electronics consumers, e-waste generators, collection agencies, haulers, consolidators, processors, government and so on. Hence, a large number of research projects have been conducted to study recycling from various perspectives. And there are three main research directions: determinants of recycling behavior, digital or non-digital recycling containers design, and development and evaluation of waste processing technology. These researches have the same goal that is to promote the development and success of the whole recycling system.

The literatures on understanding the determinants of recycling behavior hold most of the recycling research. And most of them focus on household recycling behavior with respect to traditional commodities such as glass, paper, plastic, and tin. Each discipline focuses on the influence of different variables on recycling. For example, economists often look at monetary rewards [32]. Sociologists study social pressures [4]. Legal researchers look at the effects of legal mechanisms such as mandatory recycling laws [14]. No matter what determinants researchers study on, broadly speaking, two different kinds of approaches are used to understand users’ recycling behavior: (1) behavior is viewed mainly as a function of internal factors, such as environmental attitude [21], environmental knowledge [12, 14], personal norms [20, 27], habits [9], and demographics [3] and (2) behavior is largely a product of external factors, like monetary rewards [32], social influences [8, 21], laws and regulations [14], and so on. Some recent studies tend to adopt both approaches to investigate the influence of internal and external factors on recycling behavior [22, 26]. But they don’t explore the relationship between internal factors and external variables in any depth. The common research methods in these studies are usually based on empirical

survey and quantitative analysis, such as using variance analysis and multiple regression analysis to explore the relation between variables and recycling behavior.

A limited amount of research has focused on recycling containers design. As environmental issues have become more active targets of research within interaction design and HCI, several new, pleasing and unobtrusive technologies have been developed to encourage and facilitate recycling behavior in public places. Boujarwah, etc. present a web-supported vending machine for school uniforms recycling by automating the exchange between parents and minimizing the work necessary to donate and obtain second-hand school uniforms in [5]. Holstius, etc. put out a living plant display, and its robotic counterpart in a cafeteria between pairs of trash and recycling containers. They aim to create a robotic analogue that mimics phototropic behavior to provide feedback about recycling and waste disposal [15]. Louw and Forlizzi draw on pervasive computing approaches to develop an interactive exhibit about recycling for the Pittsburgh Children’s Museum. They believe that it is through active play that children construct recycling knowledge [17].

Several studies have described various waste processing technologies, such as electric conductivity-based separation [7] and density-based separation [7], which can be used to remove or sort recyclable materials from solid waste to reduce the amount of material requiring disposal. However, there is a controversy around the application of these technologies focusing on whether the benefits outweigh the costs. Thus, some research presents a framework for evaluating the economic performance of these technologies [11].

2.1 Discussion

Despite considerable research attempting to identify different factors significantly related with participation in recycling schemes and investigating the correlation between these factors and recycling, there has been little concern to understand recycling behavior from a qualitative perspective, especially for e-waste recycling, resulting in an important gap in the literature. Furthermore, the factors identified consist of internal variables about users and external variables with respect to social environment, but don’t include the factors from the artifacts, which are and will be recycled. In research on recycling traditional products, such as aluminum cans, once the can is emptied, the user is faced with three options—filling it with other things, throw-away or recycle, so the effect of the artifact itself on recycling behavior is not crucial. But the recycling of digital artifacts is more complicated and more determinants are involved in. This paper aims to address the gap through this study and the use of the Motivation-Opportunity-Ability (MOA) model, a mature theory that helps frame and interpret the research results.

2.1.1 Research Goal

It should be made clear that our goal in this paper is not to validate the MOA model or propose new models and theories for explaining e-waste recycling behavior. Rather, our goal is to draw on this model in order to explain findings as means to better understand the actual e-waste recycling behavior and to inform design practices and further study.

3. PARTICIPANTS AND METHOD

In an attempt to answer the questions mentioned above, we undertook a pilot study of students in Simon Fraser University

during November 2010. The students were between the ages of 18 and 33, which locates them in the Y generation.

Based on course enrollment lists, 312 students received an e-mail that contained a description of the goal of the survey and a brief and simple questionnaire. Of the surveys sent out, 36 useable surveys were returned, with no attempt made to contact non-respondents. About 64% of the respondents were male, and about 42% of the respondents were graduate students.

The survey was comprised of two parts. The first part was to explore students' e-waste recycling attitudes and e-waste recycling practices through asking the following questions:

- What do you do with old electronics that you no longer use, such as televisions, microwaves, remote controls, electronic toys, wireless devices, iPods, digital cameras, game controllers and so on?
- Have you ever recycled old electronics?
- Do you want to recycle old electronics?

In this survey, we didn't use the term "e-waste" in the questions to avoid misunderstandings of its meaning. And we also gave examples of digital technologies that students frequently use in their daily life to help participants recall their past experiences of e-waste disposal easily.

According to the different replies of participants in the first part, the questions in the second part were not the same for every respondent but focused on the reasons motivating their particular recycling behavior.

3.1 Data Analysis

The initial step of analyses was reading all of the feedback. Then we "fractured" the data and rearranged them into three categories, which were e-waste recycling experience, attitude towards e-waste recycling and disposition ways of e-waste, to facilitate comparison between the data in the same category and finding relationship among the data in different categories. Next, we used respondents' own words to describe the theme of each category. Based on the comparison among the different descriptions of the same theme, we classified the descriptions into different subcategories. After that, we tried to identify the relationship among these three categories. Figure 1 is one example that used respondents' feedbacks to describe their attitudes towards e-waste recycling and these descriptions were classified into different subcategories. The light and dark grey areas represented the respondents who reported having e-waste recycling experience, but through different ways. The final step was theoretical analyses of these findings tailed to the question what is the characteristic of actual e-waste recycling behavior and what is the design implications.

4. FINDINGS

4.1 The Confusion of E-waste Recycling Behavior

The confusion of e-waste recycling behavior emerged in examining the answers of the question "Have you ever recycled old electronics?" From respondents' descriptions, we found the term "recycling" when applied to e-waste often meant various and different sets of actions.

According to respondents' feedbacks, nineteen students (52% of all respondents) reported having at least one time of e-waste

recycling. However, they differed in the definition of e-waste recycling actions. Eleven of them claimed "recycling action" was to take the e-waste to a recycle depot:

"I have twice recycled broken or bad quality old TV's by taking them to the recycle depot. TV's are neutral there in that they don't pay you, but you don't pay them either...like you pay the dump to drop things off." (P3)

Others extended this definition to a scope including passing the e-waste on to other people, donating the e-waste to some organizations, and selling the e-waste online:

"No, not officially recycled. Only handed digital technologies down (like iPods)." (P1)

This confusion likely reflects the lack of established knowledge and services for what to do with old technology. And it is worthwhile to briefly clarify the different kinds of e-waste recycling that occur, as they may have different practical implications for designing recycling services and collection infrastructures. In 1987, Schiffer, an archaeologist, explained the cultural and natural formation processes of the archaeological record in his famous book, *Formation Processes of the Archaeological Record* [28]. He also distinguished four kinds of artifacts' reuse processes that delayed transformation of materials from systemic to archaeological context. Our summary of the e-waste recycling types and meanings is based on Schiffer's classification of the reuse processes and careful analyses of respondents' treatments on e-waste.

- Lateral cycling means "transfer of object from one user to another; use/function remains the same [28]." In this study, lateral cycling of e-waste was a common occurrence, and it can happen through both informal and formal means, and both with and without the exchange of money. For example, a boy gives his old iPod to his girlfriend, or donates an old digital camera to the Salvation Army, or sells a used computer on eBay.
- Re-manufacture of artifacts (often broken) means using them as the primary raw material in another manufacturing process for new and different purpose. In our research, re-manufacture of e-waste took place when respondents brought the broken or bad quality e-waste to a recycling center where the scrap value of e-waste was extracted through disassembly.
- Secondary use means repurposing a used object without remanufacture, for example, taking an old iPod and using it as a flash drive. Because secondary use of e-waste depends on users' knowledge of technologies to some extent, it only came up in four respondents' reports of this study.
- Conservation means preserving objects for emotional value and future use. As with lateral cycling, this concept frequently surfaced explicitly in our survey.
- Repair means restoring the broken objects to sound condition. Because the repair of digital artifacts needs professional skills, people usually have the broken artifacts repaired. So respondents in this study didn't mention this concept.

Negative	Ambiguous	Positive						
		Positive attitude with negative arguments					Positive attitude	Positive attitude with positive arguments
		Rewarding	Convenience	Information	Artifacts' condition	Others		
P6: If I could, I would.	P14: Yes, of course. Recently I saw an advertisement in future shop that says if we bring some particular items, we can give a discount for purchasing some of the laptops. I think it is a great idea, and I hope to see more companies doing that.	P1: Yes. I wish there were easier ways to do so.	P9: Yes. I wish I knew where to recycle or have outdated digital artifacts repurposed or reused.	P4: If I can deem them as having 'no use', then they end up being recycled (as above), though if I figure that I can still make use of them, or that others may be able to make use of them - they will be repurposed or passed on to another party.	P8: Yes, I really would like to recycle them if there is any possibility.	P5: Yes, I would like to.	P3: Yes. I have a lot of old dead batteries lying around that I should probably figure out how to recycle or where to drop off for disposal.	
P15: Maybe	P29: Definitely. Especially since large corporations have started to encourage recycling electronics by rewarding consumers with gift cards for bringing in old electronics, etc.	P2: Yes, if there was more access to this it would be great.	P10: I have tried to recycle digital artifacts in the past; however, I have found it difficult to find places to appropriately dispose of the object.	P13: Yes, but I'm not always sure where to take them. And sometimes I like to keep them if I think they might come in handy later.	P25: Yes! I think my bed is not big enough to hold them under any more!!	P34: Yes.	P17: Yes I do want to. The whole capitalist society and planned obsolescence has generated a lot of waste and the paradigm should be shifted.	
P20: Depend. If recycle guys does charge me like environmental fee, I will do it.		P7: Yes, I do. But it's very annoying to find place that would take digital artifact. Sadly, the Canadian government doesn't make it easy for us.	P11: Yes, if there's a convenient to reach where I can recycle them, of course I would recycle them.			P12: Not really, I haven't thought about it.	P16: Yes, I do. Wish it were easier and available everywhere.	P30: Yes! In fact, I have an old UPS/ power bar I need to get rid of safely...
P22: If it is easy and rewarding enough, yes, otherwise might be simpler to just throw them out.	P28: I would love to. With materials recycled and reused, things can be sustainable and potentially cost less. Unless it costs us money to do so, then it would be contrary.	P18: Yes! If I knew of a convenient way to recycle e-waste I would pay to do it. It bugs me that they're hanging around when they could be either used by someone else or reclaimed.	P21: Yes. I want to recycle a bunch of stuff, like an old computer, and CDs, cables, empty ink cartridges. Credit cards get outdated often. I know eventually even my toaster will break, and I want to dispose of it properly when that happens, but whether I will or not, I can't say.	P24: Yes. Now that you bring it up, I would like to recycle them.	P32: Yeah, I guess. If it's big and bulky, it's a nuisance to leave it around. Not only that, but it's difficult to locate a recycling plant that accepts electronics. Honestly, I'm lazy as heck, so I might not end up recycling that often.			P23: Yes. Actually I have considered this problem for a long time. If we can make a good use of bottles and cans, then we must be able to gain much more from old computers, etc. I do not mind to buy new ones made out of recycled materials either. It is not just a government thing or a manufacturing one side relay. if people care, it must be easy to show that environment, economics and enjoyment do share some commons in sustainability .
P12: Not really, I haven't thought about it.		P31: Yes. If a system to recycle electronics was more common, I'd gladly participate.	P26: I want to recycle those outdated digital artifacts. Recycling helps to reduce pollution.					
P28: I would love to. With materials recycled and reused, things can be sustainable and potentially cost less. Unless it costs us money to do so, then it would be contrary.			P27: Yes, I try to do everything in my power to recycle old electronics. It is for the benefit of our living environment, and our future generations.					
			P33: if I know where to send them to then sure					P35: Yes definitely! In society today we use so many electronics, and the constant disposing of them would not be good for the sustainability of our world.

Reported having brought e-waste to a recycling depot
 Reported having e-waste recycling experience through other ways

Figure 1. One example of data analyses----attitudes towards e-waste recycling.

Depending on this definition of recycling and students' reports, twenty-seven respondents have participated in e-waste recycling but in different ways.

4.2 The Complexity of Actual E-waste Recycling Behavior at the Individual Level

According to the definition and classification of e-waste recycling actions above, we reexamined the data and sorted respondents' disposition ways towards e-waste into the first four categories of recycling actions (see figure 2). We found e-waste recycling was a complicated and multiple selection process at the individuals' level. Except seven respondents, others adopted several different ways to deal with their e-waste: "When I was a child, I'd take appliances apart piece by piece to see how they worked underneath. For modern technology, I either give away or sell outdated models (e.g. iPod) if possible. Sometimes I keep technologies and repurpose them (e.g. old mp3 player is now an USB flash drive). Old cell phones I return to the company I purchased them from, where they are then given to those in need.

I don't like throwing technology away, so if all else fails, it collects dust in my basement." (P9)

It is interesting that some of the respondents recycled their e-waste in a systematic way and their choices of recycling ways are intentional and under volitional control: "Typically, if it's still usable, I sell it online. If it's too hard to sell or it's too old, but still usable, I donate it to the Salvation Army. There are a few old electronic devices in my room that has sentimental values to me that I keep." (P17)

4.3 Attitudes toward E-waste Recycling and the Barriers to Recycling

Thirty respondents (about 83% of all respondents) clearly expressed a positive attitude toward e-waste recycling (see figure 3). However, among them, only five students explicitly conveyed their active concern and reflection about the e-waste recycling and the environmental problem after expressing their attitude towards recycling:

“Yes. Actually I have considered this problem for a long time. If we can make a good use of disposed bottles and cans, then we must be able to reuse or recycle outdated electronics. I do not mind to buy new ones made out of recycled materials either. Recycling is not just government or manufacturer’s responsibility but also the duty of consumers. If people care, it must be easy to show that environment, economics and enjoyment do share some commons in sustainability.” (P23)

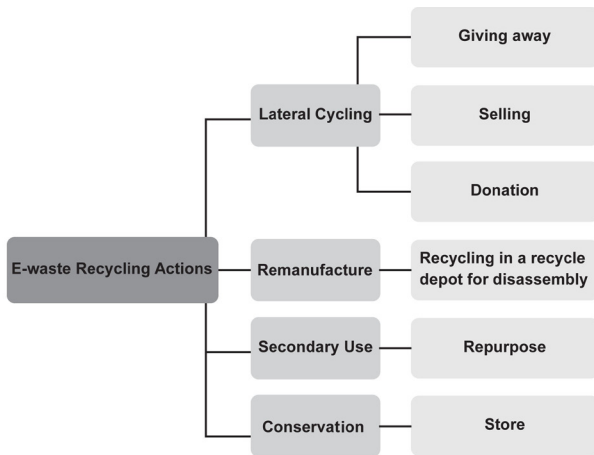


Figure 2. Sorting respondents’ disposition ways towards e-waste.

Twenty respondents presenting their positive attitudes towards e-waste recycling were immediately followed by negative arguments. Seven of them hoped there were convenient ways to deal with e-waste. And for these seven students, recycling may be seen as connected with a large amount of practical nuisance:

“Yes! If I knew of a convenient way to recycle e-waste I would pay to do it. It bugs me that they're hanging around when they could be either used by someone else or reclaimed.” (P18)

Seven of these twenty respondents thought information about the recycling depots was scarce and the implicit implication of their expression was if they knew where to recycle, they would do it: “Yes. I wish I knew where to recycle or have outdated digital artifacts repurposed or reused.”(P9)

Apart from these thirty participants, others (six participants) had ambiguous attitudes towards e-waste recycling. Among them, one student said he had never thought about it and three participants argued whether they participated in recycling depended on the cost or financial rewarding of their behavior.

5. UNDERSTANDING THE COMPLEXITY OF E-WASTE RECYCLING BEHAVIOR

In this section, we will first briefly introduce the Motivation-Opportunity-Abilities model and then use it to explain the complexity of e-waste recycling behavior and finally build the MOA model of e-waste recycling of this pilot study.

The MOA model (see Figure 3) was first proposed by consumer behavior researchers within the context of information processing theory [19]. This model has been successfully employed to explain a wide array of behaviors such as consumer choice [18], firm-level decision making [34], and social capital activation [1]. In 1995, Ölander and Thøgersen [25] applied this model in

environmental domain to understand consumer behavior with an environmental impact. The important structural feature of this model is its attempt to integrate motivation, habitual and contextual factors into a single model of pro-environmental behavior and it overcomes the internal-external dichotomy which is the shortcoming of most existing literature related to recycling behavior.

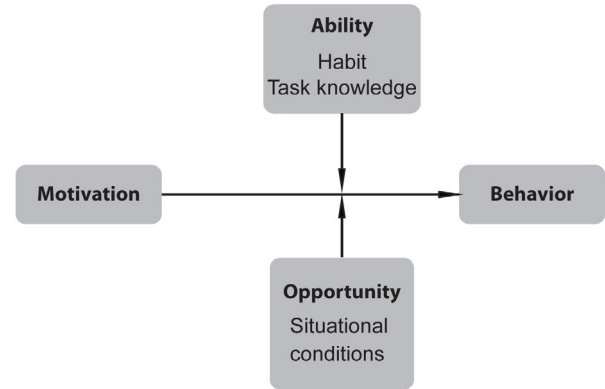


Figure 3. The motivation-opportunity-ability model [19].

5.1 Why Users Adopt Different Recycling Actions towards Different Target Objects?

According the MOA model, behavior can be considered as an interactive product of psychological factors, ability and contextual factors. In the e-waste recycling context, these three factors correlate each other to form an integrated recycling action system. In other words, each type of recycling action is determined by all of them.

And the happening process of each recycling action stays the same. But, for the same user, if his/her ability remains unchanged over a period of time, and the recycling infrastructure is also the same, his/her recycling actions will be determined by the motivation and the objects. In many recycling cases, the target objects will always be changing. As a result, the user will choose the suitable action depending on the situation. So, for users, the actual choice of recycling action can be considered as a decision-making process.

5.2 Building the MOA Model of E-waste Recycling of this Study

Based on the MOA model, the findings mentioned above and limited respondents’ description of the reasons for their recycling actions, we identify some kinds of motivation of different e-waste recycling actions, the e-waste recycling ability and the opportunity and build the MOA model of e-waste recycling of this pilot study (see figure 4).

5.2.1 Motivation

Motivation is “commonly viewed as a force that directs individuals toward goals” [13].

Emotional connection. Two participants who reported keeping most of their old stuff explained their actions:

“I think this is partly because I found it very hard to throw thing away that are mine and that I've used for a period of time. Although it's become useless, it still carries some memories. Besides, I would like to think that I will ever use them for

something useful. Second part is that I really like to see very old digital artifacts, such as old vinyl records of my dad. And although our old broken remote controls have a complete different feeling and quality, maybe they will once become nostalgic.” (P6)

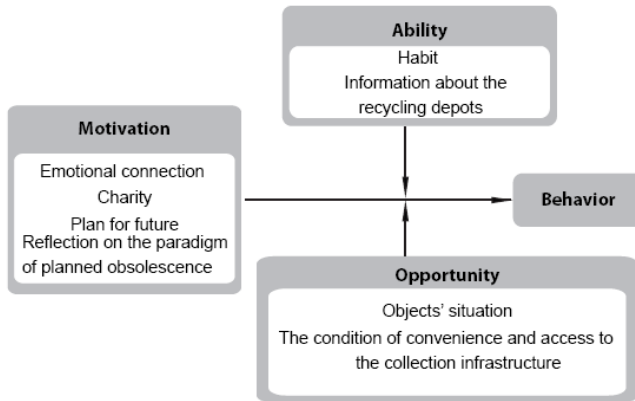


Figure 4. The MOA model of e-waste recycling of this study

Plan for future. One participant who regularly tended to hand on to all his technologies reasoned: “... Often the item in question hasn't been used because I just haven't had any projects or need for its functionality. For example, I retain a menagerie of old MIDI music devices, which have served a purpose at various times in the past. I know that I will re-engage in musical endeavors in the future that will use these devices. Therefore they would be retained for later.” (P4)

Reflection on the paradigm of planned obsolescence. One participant who sent the most elaborate report among all the respondents interpreted his actions: “I keep old things because I think it is ridiculous how often new technology and new versions of the same technology come out these days that cause people to completely upgrade their stuff and throw away the old stuff. It causes so much technology to be used for such a short time. Also, because manufactures know this, now they can get away with just making shoddy products that would break after a certain time anyway.” (P3)

Charity. Two participants explained why they gave the old but useful technologies to other people:

“It is also nice to be able to give something to my younger siblings. They are happy with it because they are even farther behind than most people in Canada in buying new technology. I don't think that's a bad thing, it's just the way they live. So, I gave my old cell phone to my brother and it was his first cell phone. I gave my old camera to my youngest sister and she was very happy for it. Since I was getting a new camera, it was much better than throwing the old one away. It still worked, so why throw it away? I also gave my GameCube to my younger siblings when I got a Wii.” (P3)

5.2.2 Ability

Ability is “the extent to which users have the necessary resources to make an outcome happen” [13]. In the model outlined in figure 3, two dimensions of the users' ability to e-waste recycling were included: habit and task knowledge. In the survey of this study, one participant attributed his environmental behavior to his habit: “Well the main reason is just that I was raised by my parents to reduce, reuse, and recycle. If I can reduce the amount of garbage I

generate, then I do it. If they can recycle my TV by using some of the parts for something useful or at least properly dividing the parts to cause the least damage to the environment then I am all for it.” (P3)

Task knowledge is about how to perform the act to reach the goal. As mentioned in the attitude section, some respondents argued the problem of e-waste recycling started with the lack of information about the location of the recycling depot. So, information about the recycling depots is the task knowledge in this study.

5.2.3 Opportunity

Opportunity reflects “the extent to which a situation is conducive to achieving a desired outcome” [13]. Besides depending on personal abilities, the execution of intended behavior depends on conditions external to the actor that facilitate or hamper the activity [29, 30]. The external condition of e-waste recycling in this study is determined by two factors. One is the convenience and access to the e-waste collection infrastructure. It was mentioned by many respondents of this study in the attitude section. And it also has been studied as main factor in increasing recycling participation in lots of researches and results indicated that large numbers of people would take pro-environmental actions if they have access to a convenient way of doing so [14].

Another important factor is the technologies' situation including its type and its usefulness to users. One participant detailed his different recycling experience to emphasize this factor: “I guess my reasoning depends highly on the artifact, its condition, and its usefulness to others. A few examples: I've sold an old CRT monitor to a recycler because I knew none of my friends or family would want it (it was outdated), and because I knew a place that offered \$35 for old monitors. I passed a cell phone on to a friend because it was still perfectly good, but I had to stop using it because I changed providers and the technology was incompatible (CDMA/GSM). I gave my old laptop (iBook G4) to my wife because I had upgraded but it was still in good shape, and it meets her needs (web, email, photos). It's still going strong after nearly 7 years of use. I gave an old stereo to Value Village because it was outdated and hadn't been used in probably 6 years. It was also bulky. However, I thought it might be useful for parts or for someone with less disposable income. So I don't know if there's a common thread in those examples. All I can say is it depends on each case.” (P18)

6. DISCUSSION

Since large amounts of electronic products have been manufactured, the huge consumption of materials and improper waste treatment are causing massive damages to the environment. According to our study, the majority of surveyed students are willing to recycle their e-waste, but there is a general lack of knowledge of where the e-waste can be recycled properly and an expectation of convenient ways to recycle outdated electronics. Even so, most of them use different recycling actions that belong to the categories of lateral cycling, secondary use and conservation practices, to deal with their e-waste, which uncovers that the actual e-waste recycling behavior is surprisingly complicated. Although many of them are confused with the recycling definition, some students still have their own systematic recycling ways and show strong ability in managing their e-waste. There are also some students showing active concerns about the prospects of e-waste recycling.

Admittedly, our study has potential limitations. The important one is response rate (11.5%) bias may limit the generalizability of the study. And another one is the study relied too heavily on respondents' descriptions of their own e-waste recycling behavior, which may differ from their actual recycling practices. Even so, the findings of this study still provide useful information with regard to actual e-waste recycling attitude and behavior. As designers, we consider these findings through the lens of design. The implications we discuss here are part of data analyses and we view them as preliminary design implications. We hope the findings above and these preliminary design implications can be creatively appropriated by other designers. Moreover, for us, the findings of this pilot study provoke further promising and focused research direction and generate other researchable questions towards e-waste recycling.

6.1 Preliminary Design Implications

Because e-waste recycling can be viewed as a decision-making process in which users' internal factors and external variables with respect to social environment and the conditions of electronics are involved. Thus, as designers, we cannot determine what users should do with their e-waste and which recycling method is better than other ones. But we can support and facilitate users' different recycling behaviors through two main design directions: (1) the design of information systems and interactions enabling e-waste recycling behaviors to be easily performed; (2) The design of electronic products that are easily recycled.

Eco-friendly e-waste recycling container system design. Due to most participants prefer convenient recycling ways, ideal recycling services could be provided both at home and in office where e-waste would be recycled without wasting extra time as well as efforts. Because people will adopt different recycling actions in terms of the situation of the e-waste, the recycling container system should segregate the target objects into different categories, like selling, donation and re-manufacture. And the system can be programmed to communicate relevant information with users, the recycling companies and charity organizations. Thanks to the revolution of Internet connectivity of smartphones and other portable wireless devices, users can be able to share their own e-waste information that is sent from the container system with others, thus facilitating the recycling.

Local e-waste recycling information network design. A city-based e-waste information network such as website and local recycling navigation system would be needed to provide relevant news and information regarding donations, recycling locations and professional recycling instructions, so people know how and where to dispose or donate their e-waste. In addition, social media platforms can be used to facilitate social engagement in e-waste and bring up conversations between manufacturers and users, so manufacturers and designers can gain more knowledge from user behaviors to develop better products and users can learn from others to effectively reduce personal e-waste.

Universal electronic components design and informative communication design. As for engineers and electronic manufacturers, developing and producing a wide range of electronic products with universal and interchangeable replacement parts would be ideal for users to self-repair and cannibalize old electronics, hence to reduce unnecessary e-waste.

Product packaging and information designers should carefully consider and provide a clear, strong and compelling visual

communication system about how to recycle this specific electronic product after being replaced, and thus educate consumers sustainable information and possible solutions towards e-waste recycling.

6.2 Future Work

Based on the findings of this pilot study, there are several directions for extending this work. It would be worthwhile to design information and recycling container system to improve e-waste recycling situation. For us, we are interested in studying the attributes of e-waste that afford the existing recycling practices, especially the ones affording the specific kind of recycling activity referred to as "second use" in this paper, because we see users as a type of creative everyday designer who appropriates design artifacts and surroundings around them to support their dynamic everyday routines and needs [35] and we believe that appropriation of e-waste extends the value of electronics in sustainable ways and it would be more valuable to use the revealed attributes of e-waste to inform future electronics design and thus enable the electronics easily recycled.

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