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Will they recycle? Design and implementation of eco-feedback technology to promote on-the-go recycling in a university environment

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ABSTRACT

Recycling rates have plateaued and recycling in public spaces has been targeted as a component that can help increase overall recycling rates. Eco-feedback technology and environmental psychology were combined to study recycling in a semi-public space in multiple social environments. A low-cost, low-energy electronic recycling bin design (WeRecycle bin) uses human-computer interaction and social principles to provide behavior-changing eco-feedback. Using mixed-methods research, we tested the WeRecycle bin in three different experiments by varying social settings and time of exposure, documenting impacts for public recycling. Results show that simple low-energy, low-cost eco-feedback technology resulted in statistically significant increases in recycling activity and can be an important tool in the promotion of recycling activity outside the home.

1. Introduction

The research presented in this paper focuses on the design, implementation, and analysis of eco-feedback technology with the goal to promote recycling in public spaces (on-the-go recycling). On-the-go recycling is common terminology for recycling that occurs outside the home. In 2013, Americans generated 254 million tons (230 million metric tons) of waste or 4.4 lb (2 kg) of waste per person per day, with an average of 2.44 lb (1.1 kg) of waste generated per individual at public events (U.S. EPA, 2015; Cascadia, 2006). The overall recycling rate for the U.S.A. was 34.3% of this solid waste, or 87 million tons (79 million metric tons) (U.S. EPA, 2015). On-the-go recycling represents an important part of capturing more recyclables and increasing the recycling rates in the U.S.A. and worldwide.

We conducted a mixed methods study (including qualitative methods in addition to quantitative data) on recycling behavior related to several interventions in a university setting. We chose the university setting to be able to manipulate the power of context for both organizational change and waste-related behavior change (Gladwell, 2000; Spehr and Curnow, 2015). The technological focal point of this study is a “smart” recycling bin (WeRecycle bin), a recycling bin augmented with sensors to count recycled items and eco-feedback technology to solicit and promote recycling. From a sensing perspective, this concept is not entirely new. Popular commercial/electronic approaches include the SmartBin products (SmartBin, n.d.) and the Dream Machine (PepsiCo, n.d.), among others (Chen, 2012; Dyscario, n.d.). However, these types of bins are limited by geographical unavailability and lack of user feedback at market price (PepsiCo, n.d.). In an iterative design, our first generation smart bin received valuable input from peers to make it more attractive (e.g., adding numerical LED screen and attention grabbing lights while decreasing the duration of the audio file), leading to the second generation bin, the WeRecycle bin.

While the concept of making a pro-environmental activity “fun” or interesting has been explored previously (Thieme et al., 2012; Lockton, 2009; Holstius et al., 2004; Stern, 1999; Wang and Katzev, 1990), our approach was different in that it was developed considering materials and energy conservation through the Principles of Green Engineering (Anastas and Zimmerman, 2003) (other application-focused designs provided feedback without an explicit concern for energy usage or modularity). This is an important environmental issue since modularity could avoid obsolescence through parts replacement, therefore reducing waste (Anastas and Zimmerman, 2003). For energy usage, we designed the circuit to keep power demand as low as possible, since if energy savings from recycling are not more than the energy used by the bin, there will be

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no energy benefit of recycling (Attari et al., 2010). Additionally, we reduced costs by using the minimum technology for eco-feedback.

In this paper, we explore how technology and factors of social change could play a role in the management of waste in public spaces, in this case, recycling. Based on the three factors of social change: *Context, Innovators,* and *Stickiness factor* (Gladwell, 2000) and some waste behavior related factors: *Environment, People,* and the *Ickiness factor* (Spehr and Curnow, 2015), we believe that a technologically-enhanced feedback-providing bin could be an important agent of change. Specifically, we examined the following questions: (1) Does a technologically enhanced bin capture the attention of people otherwise engaged during the cultural setting of a sports event? (2) Does the WeRecycle bin spark the same interest as an interactive non-technological bin? (3) Does a technologically enhanced recycling bin divert recycling from other non-technological ones?

2. Background

Independent of the morality of working in community to achieve a more sustainable way of life, recycling takes time, effort, and can be a challenging endeavor. Thanks to a widespread out-of-sight-out-of-mind attitude, there is little motivation to pursue solutions for a problem that, traditionally, has been managed by other people (e.g., large companies and governments) (Thogersen, 1996). So it is not surprising to find lack of participation in activities such as recycling, or even water and energy conservation (Berglund and Matti, 2006). Research in environmental psychology attempts to understand individual commitment to environmentally conscious activities and, as such, is essentially a cognitive approach. On the other hand, human-Computer Interaction (HCI) research typically follows behaviorist methodology, focusing on designs that yield desired outcomes.

Despite differing philosophical underpinnings, both disciplines agree on the importance of analyzing human behavior as a factor in successful pro-environmental interventions, convergence that has been rarely reflected in practice. In a 2010 article, Froehlich et al. compared and contrasted studies in HCI and environmental psychology, specifically in evaluation, experimentation, and analysis techniques. So, from the technological perspective, the study highlighted the need for interactivity, information presentation, and context, but from a holistic perspective it suggested synergy between the two disciplines for more effective approaches.

Numerous environmental activities were explored in Froehlich et al. (2010), however, when it came to municipal solid waste they highlighted a significant trend. From 139 studies in HCI and 82 studies in environmental psychology, 27 were specific HCI systems analyses and 12 were environmental psychology involving eco-feedback technology. Although 24 papers addressed energy consumption, only 3 targeted solid waste management and recycling. The authors suggest that this discrepancy may be due, in part, to the particular challenges posed in modifying solid waste management and recycling behaviors. These challenges also play a role in mismanaged (e.g., littered) waste, along with logistics which include location and availability of bins (Spehr and Curnow, 2015).

Solid waste management, relative to water and energy conservation, is a more complicated undertaking, requiring considerable effort for people (vonBorgstede and Biel, 2002; Schultz and Oskamp, 1996). Schultz and Oskamp (1996) suggest that recycling creates additional cognitive and physical challenges since we each must choose what to recycle. Furthermore, on-the-go recycling, by virtue of its public nature, poses visibility and accessibility challenges (London, 2009). According to London (2009), innovative approaches and interventions are needed to inspire and motivate people to manage solid waste and recycle. In addition, the challenge becomes greater when trying to engage entire communities in different social environments (e.g., micro vs. macro scales).

Analyzing community pro-environmental behavior requires a broader social context than individual behavior. In this regard, social work explores how individual behavior is influenced by interactions among micro, mezzo, and macro systems. Micro and mezzo systems center on individuals and close groups surrounding them, macro systems include cultures, communities, institutions, and organizations. Interactions between social systems depend greatly on the type of structure they are a part of. For instance, organizations (macro structure) are composed of people with a mutual goal (mezzo context), who perform established activities (micro tasks). Communities, less structured, are people with commonalities that connects and distinguishes them from others (Zastrow and Kirst-Ashman, 2010).

The change process in organizations and communities is similar, but in this paper we will work primarily with the principles of organizational change. The first principle, the law of the few, refers to the importance of people (innovators, ambassadors, "salesmen, connectors, and mavens" (Gladwell, 2000)) on changing people. The principle of "stickiness factor" requires something to keep the new phenomenon interesting. And, the "power of context" relates to community exploration to understand and work in the target environment (Burke, 2011). Furthermore, Gladwell (2000) noted that most successful community behavior interventions generally adhere to these principles.

In order to complement and bound the study, we will also address some common waste behavior factors. Mirroring the organizational change principles, we will focus on the *environment, people, and ickiness* factors in waste behavior, which influence how people manage waste in public settings (Spehr and Curnow, 2015). According to Spehr and Curnow (2015), an ideal environment would be one displaying cleanliness and care (i.e., setting a clear context goal). This is a demonstration of how other people treat and feel about the place, thus guiding people's behavior. As a representation of a personal barrier to push through in order to make a behavior permanent, we will focus on the association between trash and germs that pervades developed societies, the *ickiness factor* (Spehr and Curnow, 2015). We will address relevance of the principles and factors in the results section as we discuss the organizational characteristics of our target system, a university setting.

Previous research on recycling in university settings has revealed benefits in analyzing the community during the design of recycling strategies. For instance, one study suggested visibility, convenience, and information are synergetic in encouraging a recycling mentality among university communities (Kelly et al., 2006). On the other hand, another study found that information about amount and type of recycled material filled an information gap that people find discouraging when recycling (Katzev and Mishima, 1992). For recyclers, the latter is a "peek behind the [recycling] curtain," which increased their desire to participate in recycling (Katzev and Mishima, 1992). Both cases agree that providing information or feedback appeared to motivate recycling behaviors.

Information and feedback are key elements in promoting behavioral change as long as they are explored within the proper context. Within a micro social environment, behavioral changes occur based on individual perceptions and reactions to timely interventions. However, it is undeniable that mental processes influence the action-axiom of present and future experiences even when a behavior is specifically related to certain stimulus (Boettke and Leeson, 2006). In other words, our actions are directly or indirectly related with the notion of our previous knowledge or a set of preconceived notions coming from past experiences (a priori) and learning outcomes.

However, we believe that by utilizing interactive interfaces, we can focus the recycler on the immediacy of the action. For instance, by providing immediate information and feedback, HCI based eco-feedback interfaces address the disconnection between individual recycling and the positive impact of the action (Froehlich et al., 2010). This can lead to more effective interventions in the long run since positive interactions would allow users to enjoy the fleeting moment of recycling. As a part of a user-centered design in HCI, the creation of quality user experiences shares importance with the principles of human capabilities analysis, involvement of users in the design, and iterative testing (Sharp et al., 2007). Moreover, one of the most powerful paths towards recycling focus and an important element in user-centered design is the affective component (i.e., the feelings that it evokes in users), which is the basis for eco-feedback and many other persuasive technologies (Sharp et al., 2007).

Although several studies have targeted the role that behavior change plays in recycling, three in particular informed the design of this research. Wang and Katzev (1990) explored a pledge system that established commitment as a powerful force for continuity of behavior at the individual level; however, it did not have long-term effects at the group level. Stern (1999) explored the effects of interactive information versus incentives, concluding that deployed together they can have "synergistic effects" on recycling. Lastly, Holstius et al. (2004) conducted a study that concentrated on evaluating a robotic interface, using sensors and lights to provide feedback depicting solid waste effects on real and robotic plant life. However, they did not demonstrate any human behavior change from a previously observed baseline. Our WeRecycle bin and experimentation design was primarily based on the premise of multidisciplinary synergy and previous work in the area. In this research, we draw on the knowledge, skills, and innovations of many disciplines in exploring the ability of opportune, interactive stimulus to encourage human engagement in recycling activities. Additionally, we evaluate our eco-feedback interface through active observation that not only allows us to test the functionality of the interface, but that also allow us to analyze recycling behaviors.

3. Methodology

In order to evaluate a technologically-enhanced feedback-providing bin as a change agent, we designed three experiments. The first was a two day experiment to determine if a technologically enhanced bin would grab people's attention at a community event and increase the number of items recycled. We also explored the possibility of our WeRecycle bin diverting items from other bins, through a one week experiment in a highly controlled environment. And lastly, we evaluated the WeRecycle bin against a baseline and a non-technological interactive option for a month each.

3.1. Framework

We were guided by previous frameworks in designing and evaluating a recycling intervention (Schultz et al., 2007; Steg and Vlek, 2009). Our framework is outlined as follows: (1) the behavior to be changed was the low rate of public on-the-go recycling (2) add information and salience to recycling, which makes a significant difference when trying to change behaviors in recycling (Montazeri et al., 2012), (3) to address the delayed benefit to the public from recycling, we provided feedback as close to the recycling event as possible (and in environments where social reinforcement was possible), and, (4) we conducted three experiments, collecting recycling and behavioral data to evaluate our intervention.

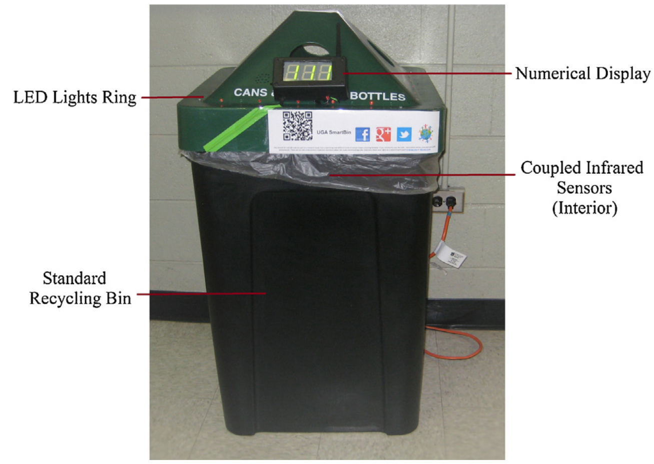

Fig. 1. The WeRecycle Bin 2.0 Prototype.

3.2. Design of prototype

We modified a factory-made standard "Cans & Bottles Only" recycling bin. The bin consisted of a green 4-sided pyramidal lid with round openings for cans and bottles on each side. In order to not disrupt normal functionality of the bin, a funnel following the dimensions and shape of the lid was attached to the underside of the lid to direct items through one opening (4 inches in diameter). The sensors/transmitters were then located at this single point, concealed from possible disturbances (external light changes, hands, camera flashes). Extensive lab testing of the system showed that the funnel opening met the requirements (cans and bottles were passing through), and that the bin was spending minimum energy.

A first generation design of the WeRecycle bin was subjected to peer feedback and consequently further modified. That version used as a display, a low-power LED screen with a scrolling message of thanks ending in the count of items recycled. The bin provided prolonged audio feedback (e.g., birds chirping, a baby laughing) that sounded when an item was deposited in the bin. However, comments received indicated that people would not want to linger by the bin to read a scrolling message and that the count was the most important part and that feedback should be immediate.

Based on the recommendations, we improved the bin and created the WeRecycle bin used in this study (Fig. 1). First, we shortened the audio feedback (with the option to remove it). Then, we replaced the scrolling message with a large counter and complementary low-power LED lights around the top as accents. Specifically, the WeRecycle bin design featured a large numerical display (three one-digit 7-segment LED displays of 1.5 in. size characters) presenting the cumulative number of items recycled in the bin. This display increased by one every time an item was deposited in the bin. Low-power red LED lights surround the top of the bin and are on when the bin is in use. When an item is recycled, the red LEDs turn off, and a corresponding set of green LEDs momentarily turn on, providing color change feedback from red to green (and back to red once the item is in the bin).

In this regard, research supported design decisions related to the color of the lights and even the type of sounds. For instance, research reveals that lights that change from red to green have a calming or soothing effect (Kaya and Epps, 2004), allowing users to experience comfort and enjoyment, thus promoting the use of the interface (Sharp et al., 2007). Now, the bin's capability of audio feedback with programmable sounds can be used for multimodal reinforcement. An advantage of this design is that personalization yields effective pro-recycling responses (Medland, 2010). In this case, the pre-programmable speaker had 40 s of audio memory, so we recorded a short clip from the university fight song. Based on the social characteristics of the experimentation environment, we selected the audio message targeting the university community.

In an integrated design, the technical aspect of the bin greatly depends on human interaction to demonstrate the potential of the strategy. Concealed within the bin interior, a coupled infrared sensor/transmitter system (TSOP1236/TSAL7400 pair modulated by a TLC555) detects changes in reflected infrared light above an empirically defined threshold, and sends a signal to a PIC microcontroller (PIC18F45K20). This microcontroller then directs a series of timed steps that ultimately leads to incrementing the three-digit count, activating the customized sound, and changing the color of the LED lights. A break-beam type system was chosen for its low cost and reliability. This design showed excellent reliability (19 out of every 20 trials) during testing for a variety of types of cans and bottles. Reliability of count also depends on the users, since placing one's hand far inside the bin and through the funnel (not easy) would cause a sensing event; however, this is not concerning to the goal of increasing recycling since this interaction increases activity around the bin.

3.3. Experimental design and social environments

The goal of the experiments was to evaluate people's immediate reactions to the WeRecycle bin and also determine if there was an increase in the quantity of items recycled. The experiments were divided by length, and initial baseline data was collected over the same time window with an unmodified recycling bin. The unmodified bin was then replaced by the WeRecycle bin and data collection was repeated for the same time window under similar circumstances. The experiments allowed for a non-intrusive evaluation of human response towards the WeRecycle bin in a real-world environment.

3.3.1. Two day experiment

The two day experiment was conducted in a controlled macro social system at highly popular college football games. We purposely designed the study to couple recycling activity with a sense of belonging to a community. This type of event typically attracts more than 100,000 enthusiastic fans and university supporters. The experiment site in this case was a large, indoor, heavily trafficked student center food court. Door sensors to the facility counted the total number of visitors for each day, controlling for differences in number of attendees. In addition, to account for the differences in the total quantity of recycling during both events, the university's Office of Sustainability provided recycling quantities for both game days. The baseline and experimental recycling bins were placed beside a trashcan in the same location for each of their respective game days.

3.3.2. One week experiment

The one week experiment was also conducted in a controlled community environment in a familiar university campus building, allowing us to focus beyond the environment/power of context (Gladwell, 2000; Burke, 2011; Spehr and Curnow, 2015). We wanted to examine if people acted as *innovators* and *motivators* for other recyclers (Burke, 2011). Hottle et al. (2015) experimented with the concept through people guiding others to reduce waste through something they call *recycling guards,* though in their case the motivators were part of the research setup. The *st-ickiness factor* was also examined with salience and sound intermittence (Burke, 2011; Spehr and Curnow, 2015). Besides the attractive visual stimuli (to bypass the ickiness of trash), we ensured manual intermittence on the WeRecycle sound (intermittence helps make a behavior more permanent) in an attempt to keep people interested on the recycling process (Burke, 2011; Spehr and Curnow, 2015).

3.3.3. One month experiment

The one month comparison study was also conducted on campus in a setting that allowed for observation of individual behavior in a microsocial setting (student center food court). The stages and prototypes for this experiment were designed based on the most popular and recommended social models in order to measure a reasonable behavioral change (Osbaldiston and Schott, 2012). The first phase was the collection of baseline data using a standard recycle bin (baseline bin). The second phase consisted of non-technological interaction surrounding the standard recycle bin. The third phase consisted of the WeRecycle bin.

The second phase had a non-technological stimuli that prompted interaction from users. First, a large poster of children recycling, with the tittle "We know that recycling means a better planet for us. . .,ẅas placed near the bin. This poster was complemented by a blank white board with the headline "What do you know about recycling?(̈See Supplemental Information). In this setup, the whiteboard served to collect people's comments promoting engagement and information exchange. Acknowledging the risk of an open exchange of ideas, we carefully monitored the board to remove, if necessary, possible identifiers and/or inappropriate language (thankfully, there were none).

3.4. Data collection and evaluation

Exploring effectiveness of the interface, as well as differences in behavioral systems, we employed mixed methods. In all three experiments, we manually counted and weighed the entire quantity of recycled items per deployment period testing the WeRecycle bin's influence and reliability. Also, since the recycle bin was for cans and bottles only, any additional items that were placed in the bin were considered contaminants. In order to further evaluate the bins, we complemented quantitative recycling results with qualitative notes on immediate reactions from users.

To evaluate quantitative data, we used statistics, tables and graphs for comparison, and controlled for external variables. For example, to control for differences in recycling activity and sample size between two different sporting events, two different weeks, and/or three months with different stimuli, we used total university recycling mass and attendance information (provided by the university). Then we used Wilcoxon's Signed Rank test, two-means, and two proportions hypothesis tests, and visual comparisons of tables and graphs to analyze relationships between the numbers of items recycled, visits to the bin, and the quantity of items collected from the bins.

3.4.1. Two day experiment

In the two day experiment, both bins remained in the same place for 48 h each at their respective events. In both events, data collection centered on the number/weight of items recycled, number of unique recyclers, number of visits to the recycling bin (measured at 30 min intervals), and observations of user behavior. For the latter, the lead author covertly (but with Institutional Review Board approval) gathered data for three hours before the start of each game, and two hour during the game, using the observation protocol depicted in Fig. 2.

3.4.2. One week experiment

The one week experiment focused on numerical evaluation of behavior. In this experiment, the WeRecycle bin was introduced in the building as an additional recycling bin avoiding subjectivity of replacing one of the most used recycling bins. This also meant we could analyze if the WeRecycle bin was diverting recycling from

Date: _11/19/2011_ Time: _10:10 AM_

1. Participants:
   Number of people by the bin: __1__
   Number of people using the bin: __1__
2. Interaction with the bin:
   Complete Stop — Quick Stop
   Passed &Went Back — No Stop
3. Distance to the bin:
   <18” — 18”-4’ — 4’-12’
4. Body Position:
   Head position & movement: >
   Arms position & movement: =
   Legs position & movement: /|
   Feet direction: >>
   Hands comments: <>
   Facial expressions: :)
5. Participant brings external attention to the bin:
   Yes — No
6. Approximate time of interaction: __3 sec__
7. Comments:
   There were 7 people looking at the boy who threw a bottle and they all celebrated when the number changed.

Fig. 2. Example of Completed Observation Protocol.

other bins. As a baseline, the recycling (mass and count) at every recycle bin in the building was tracked for one week before deployment. The same quantitative measurements were taken once the WeRecycle bin was deployed, along with counting the items recycled in the WeRecycle bin each day. To compare the baseline with the experimental week data, we used the statistics two proportion hypothesis test.

3.4.3. One month experiment

During this 12-week time period (separate months of baseline and interventions), we compared the three different recycling strategies outlined previously. Every four weeks, we conducted each experimental phase collecting data from immediate reactions (using the observation protocol in Fig. 2) during three consecutive random hours Monday through Friday between 9am-7pm for a total of 20 observations (60 h) per phase. Through graphical comparison and statistics, we analyzed the number of visits to the bin, number of items recycled per observation, and total number and mass of items recycled in each bin per 4-week phase. Like in first experiment, daily attendance to the building was obtained from the university.

4. Results

4.1. Recycled items

4.1.1. Two day experiment

Table 1 presents the total attendance in the facility, total weight recycled, weight recycled at the experiment location, and the total number of items recycled for each sporting event. Total attendance was higher at the baseline game, which led to a higher overall recycling tonnage; however the weight and the number of items recycled at the WeRecycle bin were greater during the second game. The difference is also illustrated in Fig. 3, which presents the four-hour observational window for both the baseline and the WeRecycle bin.

Fig. 5 also illustrates a pattern that is consistent for each game. Shortly before the game, recycling participation peaks, with a dramatic decrease after the game begins. In addition to the visual

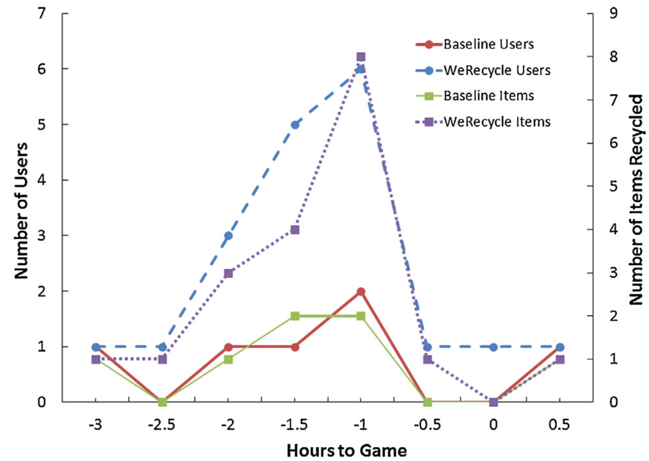

Fig. 3. Comparison between the WeRecycle Bin Observed Visits And Baseline Observed Visits.

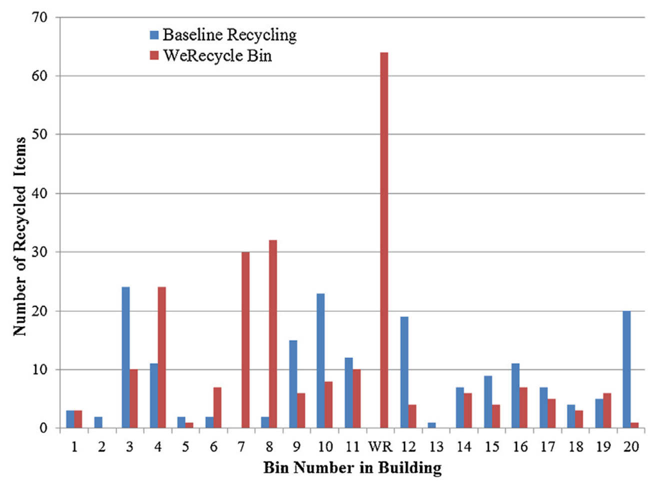

Fig. 4. Number of Recycled Items in Baseline vs. WeRecycle Intervention Week.

difference between the use of the baseline bin and the WeRecycle bin, a Wilcoxon Signed Rank Test determined with a 95% probability that the number of visits (persons who used the bin to recycle) and recycled items were significantly higher at the WeRecycle Bin than the baseline bin (Visits: T+ = 21, $P_0 = 0.013$; Items: T+ = 15, $P_0 = 0.021$).

4.1.2. One week experiment

The total amount of recycling increased for the entire building during the WeRecycle week. Table 2 illustrates that recycling from the bins surrounding the WeRecycle Bin was diverted to the WeRecycle bin, with the largest diversion of recycling occurring at Location 10, which was directly across the hall from the WeRecycle bin, inside a computer lab. Other surrounding bins illustrated decreased quantities as well during the experimental week (Fig. 4). Fig. 4 also shows increased recycled items at other locations during the experimental week, mostly around the entrances of the building and offices. In addition, the highest recycling rate in one bin during the baseline week was significantly lower (99% of a two proportion hypothesis test: $z = 3.67$; $p = 0.0001$) than the recycling on the WeRecycle bin. The recyclable items on the WeRecycle bin, however, were not the only indicator of interest from the participants. The interest and curiosity towards the bin were also demonstrated by the electronic counter and visits to our website, to a lesser extent. While we counted 64 recyclable items plus three contaminants in

Table 1
Recycling Activity in Baseline vs. WeRecycle Event (2-day).

Events	Building Attendance (# of people)	Total Event Recycling (Kg)	Total Event Recycling	Bin Recycling (Kg) (items)	
Baseline bin	21,411	7210	13.88%	0.30	13
WeRecycle bin	10,719	3780	10.95%	0.45	21

Table 2
Recycling Quantities of Baseline vs. WeRecycle Intervention.

	Bldg. Total Recycling		Bin Number in Building									
	(Kg)	(Items)	(Kg)					(Items)				
			10	11	WR	13	14	10	11	WR	13	14
Baseline	3.62	179	0.67	0.24	N/A	0.40	0.01	23	12	N/A	19	1
WeRecycle	5.56	231	0.06	0.28	2.34	0.23	0	8	10	64	4	0

N/A = Not applicable–WeRecycle bin not placed for baseline.

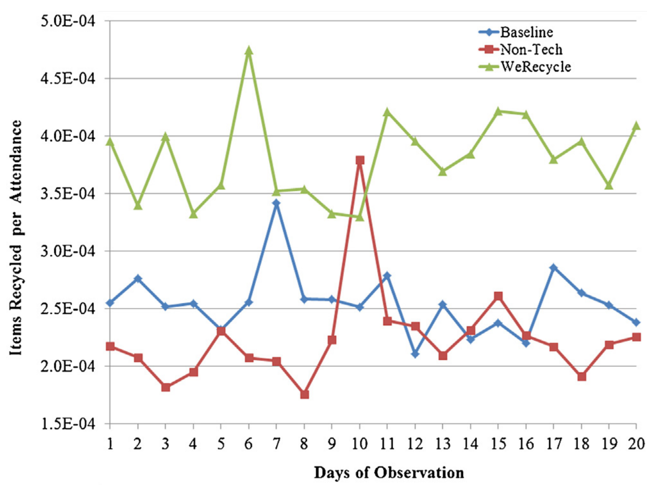

Fig. 5. Normalized Items Recycled during the Baseline and Interventions.

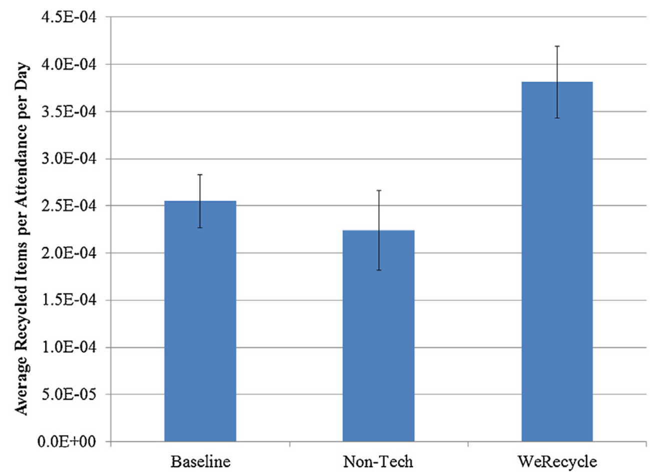

Fig. 6. Average Recycled Items per day per visitor during the Baseline and Interventions.

the WeRecycle bin, the electronic counter registered 111 counts. These extra counts generally occurred when the users pass their hand through the sensors (deep inside the bin) to observe a reaction from the bin. While rendering the count displayed to users as inaccurate, this interaction with the bin did promote fun for the users, which contributed to the goals of the intervention.

4.1.3. One month experiment

In the month-long experiment, we found differences between the recycled items in the baseline vs. WeRecycle intervention. Table 3 presents the total attendance at the location, the total number of observed visits, the total mass of recycling and the total number of items recycled for each time period. Attendance was lowest during the non-technological intervention, followed by the WeRecycle bin deployment and then the baseline. The number of recycled items was highest for the WeRecycle intervention followed by the baseline and the non-technical intervention. Additionally, the WeRecycle intervention had the least amount of contamination in the recycling bin (23 items), followed by the baseline (42 items) and the non-technical intervention (60 items).

In order to take into account how the number of visitors impacted the number of items recycled in a public setting, we divided the number of recycled items by the number of visitors per day of the baseline vs. the interventions (Fig. 5). Although there is no overall trend to the data, the WeRecycle intervention data appears higher than the others. Fig. 6 illustrates the daily average of the same data showing the WeRecycle bin significantly higher by one standard deviation than either the baseline or the non-technical intervention. This difference was also calculated statistically through the two-means hypothesis tests that established a 99% probability of increased recycled items during the WeRecycle intervention ($t_{32} = 12.45$, $P_{32} = 2.75E-15$; $t_{31} = 11.48$, $P_{31} = 8.99E-15$).

4.2. Immediate reactions

From sticking hands into an otherwise ignored and/or “icky” bin to smiles and celebrations when people recycled, the WeRecycle bin catalyzed a positive attitude about recycling. In general, behavioral changes were observed, not only at a community level, but also by individuals who evidenced a positive response in body language and attitudes towards eco-feedback driven recycling activity (Meeren et al., 2005; Mozo-Reyes, 2012). In Table 4, we provide a summary to further explicate the behaviors observed during the WeRecycle bin intervention highlighting interest determinants from observation data (Mozo-Reyes, 2012).

In general, people became more interested in recycling when they got immediate feedback from simple lights giving a color change and a counter increasing, turning it into a fun or exciting activity worth investing time as shown in both the WeRecycle two day and one month data. In a macro social environment or community event, it is also easier to transmit the excitement for the activity, as shown in the number of people promoting the bin, perhaps because these types of environments follow organizational change principles and waste behavior factors (Burke, 2011; Spehr and Curnow, 2015).

Table 3
Recycling Activity during the Baseline, Non-Tech and WeRecycle Interventions.

Intervention	Dates of Intervention Start-End	Attendance Bldg. Total (people)	Total Observed Visits	Total Recycling (items)	Total Recycling (Kg)
Baseline	09/29/11–10/27/11	169,781	17	60	1.18
Non-Tech	01/30/12–02/27/12	143,753	9	44	0.90
WeRecycle	03/22/12–04/19/12	156,912	20	83	2.18

Table 4
Immediate Reactions and Body Language of WeRecycle Bin Users.

No.	Observations	Two Day Experiment		One Month Experiment		
		Baseline	WeRecycle	Baseline	Non-Tech	WeRecycle
1	Participants					
	# people by bin	8	25	18	12	24
	people using it	6	19	17	9	20
2	Interaction with the bin					
	Complete Stop	2	11	5	5	18
	Quick Stop	3	7	9	4	2
	Passed &Went Back	0	1	0	0	0
	No Stop	1	0	3	0	0
3	Distance to the bin					
	<18”	3	11	6	9	19
	18”–4′	3	8	11	0	1
	4′–12′	0	0	0	0	0
4	Body Position towards the bin					
	Head @	2	18	9	5	18
	Arms Both @	1	16	7	3	17
	Legs Both @	1	16	7	3	17
	Feet Both @	1	16	7	3	17
	Hands: Both @	1	16	7	3	17
	FE: Smiles	0	15	0	0	15
5	Participant promotes bin	0	5	0	0	3
6	Avg. Time Interaction/sec	3.5	5	2	4	10

This was demonstrated as well in the one-week experiment when some of the most experienced recyclers took the task to guide and enhance the experience for their closest friends. The innovators acted as leaders prompting smoother reactions and offering guided experience to other participants thus becoming the few that lead the community to increase recycling (Mozo-Reyes, 2012). Continuing the trend, people guiding others, as well as inspiration and behavior change could promote increased rates of recycling and a positive attitude toward recycling into the future (e.g., *the st-ickiness factor*).

5. Discussion and summary

This mixed methods study, incorporating principles from HCI and environmental psychology, can provide a holistic evaluation of a pro-environmental behavioral change, like recycling. By combining technology with social context for the design and implementation of the interface, we have a better understanding of eco-feedback technology intended for pro-environmental behavior. We also learned that when using technology as a recycling enhancing tool, it is important to have community feedback informing early design, as well as an understanding of the target community through social science theories and techniques.

The non-technological engagement intervention did not yield the same results as when technology was used, perhaps because technology makes recycling a more attractive environment for this community (Spehr and Curnow, 2015). While recycling activity was normalized per person/attendance we could not control for increased use of single-use items between baselines and interventions; however, the experiments were all conducted under “normal” conditions, so there were no other influencing factors (e.g., other special events, catastrophic events, water shortages, etc.) that may significantly increase use. Interactivity was demonstrated to be one of the key elements that make the WeRecycle bin a more effective approach towards recycling, but HCI characteristics such as immediate feedback and subtlety of color and pictorial realism (performing a “green” activity) were also factors that may have made it a successful strategy. The WeRecycle bin demonstrated that people are individually receptive to interactive interventions through the one month experiment, although more organizational change was observed when the intervention was applied at a community event. The WeRecycle bin has the capability to attract users and engage them with statistically significant more recycling activity than a baseline bin in various timeframes and social settings. We also established that in some cases recycled items were diverted to the WeRecycle bin, which may be influenced by people tending to use the bin that looks more cared for or that has been shown to matter more according to the behavior of others (Burke, 2011; Spehr and Curnow, 2015). We also found less contamination in the WeRecycle bin (contamination of recycle stream is a common issue in community recycling systems), which could be a significant co-benefit along with the increase in recycling. The WeRecycle bin is also capable of raising the number of items recycled at a specific location during a sporting event, even when the overall attendance and activity decreases compared to the baseline.

Introducing electronically delivered stimuli can increase recycling by appealing to the psychology behind group behavior and change. Specifically, by employing classic reinforcement principles in the design of the WeRecycle bin, people became more interested in recycling at this bin. Users of the WeRecycle bin showed a positive attitude towards recycling (smiles, laughs, celebrations, etc.) when they received immediate feedback from a change in light color, a numerical increase in the displayed count, and/or hearing an encouraging sound when they deposited an item in the bin.

We believe this feedback fostered a positive attitude toward recycling, allowing it to be perceived as an enjoyable activity worthy of the time invested. In the same regard, the different social environments facilitated interest and excitement in recycling, thereby adding weight to organizational change principles. We observed how people pushed through the "ickiness" factor to put their forearm inside the bin to activate sensors, and we saw people following after others out of curiosity for the bin, and still others actively guided people to it. Since one WeRecycle bin in a specific location can improve attitudes towards recycling in a short period of time, we would recommend moving the bin around a facility (randomly replacing one bin in use, over time) to keep the intervention intermittent, new and exciting. Further research on the bin could address habits of formation and a deeper understanding of social structures that influence pro-environmental behaviors.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resconrec.2016.06.024.

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