'Close the Loop' An iBeacon App to Foster Recycling Through Just-in-Time Feedback.

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Abstract
Contemporary micro-location technologies such as Bluetooth Low Energy (BLE) show promise in enabling new experiences when interacting with physical spaces. An emerging BLE technology is iBeacons, with the retail sector pioneering their use to enhance shopping experiences. There is scope for the HCI sustainability community to explore the use of iBeacons to raise awareness around sustainability issues, particularly in public and communal spaces. This work presents embryonic research exploring the design of a prototype iBeacon-based sustainability application called 'Close-the-Loop'. The application builds on previous sustainability and just-in-time feedback research to encourage end-users to engage in recycling behaviours in a large university canteen space. Findings from a focus group and short ethnographic study provide design insights to further develop the prototype to increase engagement with appropriate recycling practices.

Author Keywords
Micro-location; iBeacons; Sustainability; Recycling; Behaviour change; Nudging; Just-in-time feedback.

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: User Interfaces.

Introduction

Environmentally friendly management of residual waste such as recyclable food packaging is pivotal in working towards a more sustainable society. The actions of reduce, reuse and recycle within waste management processes are particularly important, especially in relation to individuals' public and communal engagement with appropriate waste disposal practices. Recycling in UK public or communal spaces such as shopping malls or universities is not as prevalent as household waste management. In this regard, a large body of research is present in environmental psychology literature on defining the prominent factors that predict recycling behaviours in such spaces. Work by Prestin and Pearce [10] reviewed these factors and found that enhancing recycling infrastructure and increasing adolescents' recycling knowledge were the most successful factors to foster recycling habits. Interestingly, their findings revealed participants' attitudes and intentions for recycling were high, but poor infrastructure and lack of knowledge were determined as major barriers to achieve the desired behaviour.
Amutenya et al. [1] also emphasise the infrastructure issue and claimed that increasing the number of recycling bins will improve use by removing the distance barrier. However, a simplistic approach that only increments the infrastructure is unlikely to achieve sufficient engagement levels for sustainable recycling. They concluded that a more effective approach would be accompanied by awareness-raising campaigns, as people tend to react more positively when equipped with relevant knowledge.

Mobile devices are a promising and ubiquitous channel for delivering feedback guidance and engagement with daily recycling behaviours. Smart phones are personal objects, they are normally kept close at hand for a user to readily interact with the surrounding environmental context. Some of these interactions are contextualized outdoors using the built-in GPS sensor. However, GPS is unreliable when used indoors, offering a poor user experience for location purposes. One emerging technology that offers accurate indoor micro-localisation is BLE beaconing [3].

Presented in this paper are the early findings of deploying a prototype recycling application called 'Close the Loop' (CtL) in a large university canteen space. The app was designed to nudge users with contextualized feedback throughout the process of buying food items and their subsequent disposal. Qualitative data, derived from a short ethnographic study and focus group, was analysed using a grounded theory approach [11] with findings providing design insights to guide future work.

Background

Previous sustainability research in HCI has used mobile phones as mediators to promote sustainability practices. Coskun and Erbug [5] conclude that most of these studies are related to energy awareness and transportation. Recycling interventions that adopt technology appear to be a relatively unexplored area in HCI, thereby identifying an opportunity to investigate the potential use of micro-location technologies coupled with just-in-time feedback. Gaea [4] is a location-based multiplayer mobile game designed to encourage behaviour change towards recycling by using public displays in outdoor spaces. It relies on GPS and 3G technologies for the placement of virtual objects and the location of recycling bins. Glouche and Couderc [7] propose an enhanced system for automatic waste identification at the bin level through mobile phone notifications. The aim of the augmented bins was to assist users in the waste sorting process by using RFID or QR codes for correct bin identification. BinCam [12] is a social system to playfully motivate

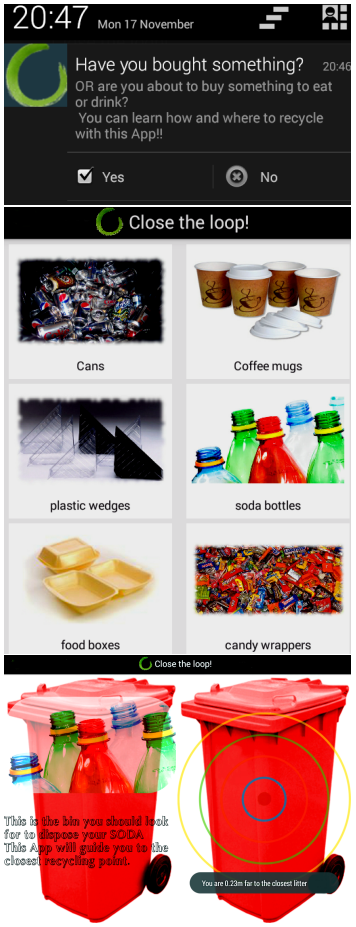

Figure 1: Four screen-shots of 'Close the Loop' app belonging to different steps to guide the end-user to the appropriate recycling bin (in this case the red bin for plastic packages).

reflection about recycling habits of young adults. The system automatically logs waste items through images captured by a smart phone installed on the underside of the bin lid. Captured images are uploaded to Facebook. These systems take advantage of context to convey just-in-time feedback in order to support users' decision-making at important junctures when disposing their waste. The Just-in-Time (JiT) concept has been covered by sustainable HCI researchers not only for recycling but also for controlling thermostats [8] and the efficient operation of everyday consumer appliances such as coffee makers [2].

The novel approach in this work is embodied in the design of the CtL app which guides the user by nudging feedback throughout the *entire* process of buying a product till disposing of it. JiT feedback coupled with iBeacon technology has the potential to strengthen the contextual element of the physical space, which could result in stronger feedback reinforcement.

'Close the Loop' Prototype Design

CtL was designed and developed for Android phones with BLE functionality (Android 4.3 onward). It featured a design that builds on previous JiT feedback approach [8]. To enable this feedback, easibeacons[1] were deployed in vending machines and within the canteen's recycling points. The application ran in the background triggering the first user-notification (top of Figure 1) whenever a user stands in front of an iBeacon-enabled vending machine for a period of time, see top of Figure 2. The user is then asked to select the correct packaging of the item bought, see middle picture of Figure 1. Once the packaging is selected, the application shows the correct bin colour for the item, see left-bottom of Figure 1. The application then returns to background running for a set period and eventually it reminds the user to recycle by displaying the location and distance to the closest recycling point, see bottom-right of Figure 1. Finally, when the user approaches the iBeacon-augmented recycling point, the app praises their sustainable action, see bottom of Figure 2.

[1] http://www.easibeacon.com/

Research Method

The aims of the study were twofold: *i)* investigate the potential effectiveness of JiT feedback and micro-location technologies for a recycling intervention, and *ii)* analyse qualitative user data from ethnographic and focus group methods to generate robust design insights for future iterations of the prototype. This approach has been used successfully in previous HCI sustainability work [6]. Throughout the whole study images, interaction and audio data were collected.

Ethnography

A short in-the-field study was carried out using the rapid-ethnography method with four participants [9]. Each participant was given a mobile phone with the CtL app installed and given instructions on its use whilst situated in a large university canteen area. Participants were given the task of using the app whilst purchasing a drink from either a vending machine or manned cash till. Two researchers facilitated and observed the tasks, interjecting when help was required or when opportunities arose to ask key questions.

Focus Group

A focus group was carried out directly after the rapid-ethnography session with two main activities: *i)* discussion of the prototype application and the experience of using it, and *ii)* understanding and discussing the

Figure 2: One of the focus group participants interacting with the CtL app in different stages towards closing the recycling loop.

cognitive processes of buying items with subsequent recycling in the canteen space to know when it should be more effective to trigger user notifications. To support the latter activity a card sorting task was completed that allowed participants to construct a personalised account of their actions when purchasing recyclable items.

Figure 3: Participants sorting and annotating the cards during the cognitive activity.

Grounded Theory

GT analysis was applied to produce design insights to enhance the next iteration of the CtL app with the intention of creating a longitudinal recycling intervention. Audio data from the focus group was transcribed and coded by two researchers. Both researchers agreed on the final coding list for inter-rater reliability purposes. A total of 209 conceptual codes at the short sentence level were identified in the open coding stage, with further refinement in the axial coding stage resulting in 6 main category codes containing 51 sub-categories. Each of these 6 categories represents a main design insight theme.

Findings and Discussion

From the GT analysis six main design-insight themes were produced. The themes were *Knowledge, Feedback, Engagement, Barriers, Attitudes, and Infrastructure*. See Figure 4 for an illustration of identified themes. The remainder of this section briefly discusses each of the themes with supporting user quotes from the analysis.

Knowledge This theme identified the knowledge and awareness levels participants had of recycling both in the immediate vicinity and at home. Participants voiced some of their colleagues had no awareness of recycling P3: "*Nothing, nothing says that you don't put paper in here [the bin] or don't put glass in here.*", and on the topic of food packaging awareness: "*If I was queuing, let's say for the coffee machine, and I've never been here before, I might not know what kind of cup is going to give to me. It could be... plastic or paper.*" This highlights the need for basic recycling information to be displayed prominently that addresses both infrastructure (i.e. bin colours) and acceptable packaging materials.

Feedback Displaying timely feedback throughout the entire process of buying a food item and disposing of the packaging was deemed a crucial attribute for engagement. Careful attention must be paid to temporal periods in terms of displaying notifications, for example time spent looking at vending machines or waiting in queues, P1: "*I lean towards the queuing. Because at that point I definitely know I will buy something. I'm queuing up. So the feedback information would be useful.*" Additionally participants stated the frequency of feedback should taper off if a user regularly recycles.

Engagement A number of attributes were evident in the data highlighting the importance of retaining user engagement with the app and recycling in general. Incentives were mentioned as a hook, P2: "*I think what would keep people checking the phone more and using the app more is some kind of point's rewards system, so you get money off your coffee.*" Personal profiling was also

stated as being useful to facilitate tracking your recycling habits over time and to receive bespoke feedback.

Barriers This was an important theme that underpinned the constraints to recycling in public and communal spaces. Participants expressed frustration at a lack of industry-wide bin standards such as colour, shape and pictorial icons to aid the public in recycling, P3: "*The issue in the university as well, particularly with paper recycling is they have a thin slot, so if you tried to recycle a paper card, it won't go in.*" The use of pictorial feedback was suggested, P4: "*I notice there is a good example in the library...there is actual colours, as well as big images that show you what needs to go in there [the bin].*" Visibility and placement of bins was also a crucial factor in carrying out recycling.

Attitudes Lifestyle factors were identified as limiting recycling practices. Cooking habits for example could necessitate extra tasks, i.e. washing out glass jars before recycling, P1: "*...a lot of students I know do not recycle. It is partly because they are lazy and don't want to take the time to wash out a jar of sauce or whatever and put it in the recycling bin.*" and "*They don't want to take time to actually like move things into separate bins like in their own house. But then again they don't actually know much about recycling neither, like any knowledge of recycling.*" From the data it appears some groups prefer convenience over recycling, which may involve extra tasks such as cleaning, sorting, and going to a distant bin location.

Infrastructure Even with the best intentions of carrying out recycling, the environmental infrastructure must be configured to support it. Consistent physical attributes of recycling bins was desirable to allow easy identification of the correct bin for a specific type of waste. Micro-location technologies such as iBeacons could play a valuable role in supporting infrastructure around recycling by enhancing feedback and bin location attributes of a physical space.

Figure 4: The six categories around Recycling extracted through GT analysis with data from four participants.

Our results provide useful design implications for designing and deploying indoor, location-enabled, recycling interventions. Each of the six categories derived from the GT analyses represent a thematic design-insight, enabling researchers to build effective recycling-themed sustainability interventions. Some of our findings resonated with the work of Prestin and Pearce [10] in that infrastructure plays a critical role in facilitating recycling practices. This highlights the importance that technology alone does not present a one-stop solution to successfully increase recycling practices. Indeed, the absence of consistent standards applied to recycling bins in terms of their physical attributes presents end-user conflation, and potential disengagement with recycling tasks. Participants voiced concerns over the disparity between recycling bins at home, and bins in student accommodation and public spaces. Concerns focused on the disconnection from sustainable practices carried out at home, which are not mirrored outside the household context, like universities.

The results of this work have already had an impact in the university where we carried out the research. We are in

consultation with the university in how to improve their infrastructure as highlighted in our data analysis findings. Our future work is then outlined in the next section.

Conclusions

Our qualitative analysis provides a useful set of design implications for technology-enabled recycling interventions, and highlights barriers and positive attributes to decrease the likelihood of disengagement from waste recycling. Although this was a small scale study with a low number of participants, it presents early work investigating the use of emerging micro-location technologies adopted for sustainability purposes. For future work the design insights presented here will be implemented in a larger pilot study in association with infrastructure improvements, finally leading onto a permanent iBeacon installation throughout the university of focus for sustainability purposes.

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