Promoting Proper Waste Behavior with Packaging Design

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ABSTRACT

Single-use, nonbiodegradable plastic and “use and throw” packaging are pervasive in everyday packaging applications, and the boom in e-commerce sites such as Amazon further increased the demand for single-use, durable packaging. According to the UN, it is estimated that we produce 400 million tons of plastic waste a year. The recovery of plastic waste through recycling programs is low, with the United States recycling only 14.8% of recyclable waste. To address these issues, there is a potential to inform the consumer about how to properly sort waste through the design of the packaging with both explicit and implicit cues. Everything from the words on the packaging to the tactile feeling of the package influences customer purchase behavior. In this study, I found that the plastic resin code system was insufficient for identifying recyclables, it was difficult for respondents to determine how to separate their waste, and cleaning the containers was the most difficult part of separating recyclables. I found that the major points that could be addressed with packaging are establishing a standard for recycling and waste sorting labels, using these labels on all goods sold in the United States, improving the design of existing recycling labels, and making packaging that is easy to empty, clean, separate, and fold.

KEYWORDS

packaging design, waste-sorting behavior, labeling standards, UX/UI Design, habitual behaviors, sorting package waste, sustainable behavior, plastic waste

INTRODUCTION

Single-use, nonbiodegradable plastic and "use and throw" packaging are pervasive in everyday packaging applications, and the boom in e-commerce sites such as Amazon further increased the demand for single-use, durable packaging (Arora et al. 2022). According to the UN, it is estimated that we produce 400 million tons of plastic waste a year (UNEP 2023). The recovery of plastic waste through recycling programs is low, with the United States recycling only 14.8% of recyclable waste according to Yale's Environmental Performance Index for Recycling (Wolf et al. 2022). To meet the demand, new plastic material is constantly being made from petroleum, referred to as "virgin plastic" (Arora et al. 2022). Additionally, much of the packaging market is still composed of non-biodegradable, petroleum-based plastics. The issue of petroleum based plastics and the associated microplastics lie in their permanence and they are classified as a "planetary boundary threat" with the ability to disrupt ecosystems and physiochemical properties of the environment (Prata et al. 2019). Although some efforts are being made to reduce the amount of plastic used in packaging, it is not universal and it does not solve the main problem of a large volume of virgin plastic waste being produced, with most of it persisting in the environment. Implementing existing greener packaging solutions such as compostable and biodegradable plastics and materials would decrease the burden of plastic waste and microplastics on the environment, but only if paired with properly collecting the packaging at the end of its life cycle.

In many developed countries, the means and infrastructure to implement a circular economy, or at least better end-of-life options for plastic waste such as recycling plants and industrial composting plants are already in place. Despite increasing consumer awareness about sustainability topics and the desire to lead more sustainable lives are rising and studies suggesting that global consumers are willing to pay more for environmentally friendly products (de Freitas Netto et al. 2020), recycling and composting rates remain low. This may suggest a gap between the desire to perform environmentally green acts and the means to do so physically or mentally. Physical factors would be access to infrastructure that regularly collects separated, recyclable waste. Mental factors would be the psychology behind the actions of the individual and the knowledge of the correct way to sort waste. According their study in barriers to developing a compostable packaging market in Poland, some of the issues were related to a low awareness and a low tendency to buy foods in compostable packaging, which was attributed, among a few

reasons, to a lack of social commitment to circular waste management strategies such as recycling and composting and lack of consumer knowledge (Kędzia and Turek 2022). It has been observed that some countries such as the United States (ranked 105 out of 130 nations on Yale's Environmental Performance Index for Recycling) place less emphasis on learning how to properly sort waste than countries like South Korea, whose government even issues fines on improper sorting of waste (ranked 1 out of 130) (Wolf et al. 2022).

To address these issues, there is a potential to inform the consumer about how to properly sort waste through the design of the packaging with both explicit and implicit cues. Everything from the words on the packaging to the tactile feeling of the package influences customer purchase behavior (Granato et al. 2022). And according to a review on the role of packaging design on consumer behavior, packaging can be an effective medium for encouraging consumers to properly sort waste (Nemat et al. 2019). It was found that waste such as food packaging is more likely to be properly sorted if it was easy to empty, clean, separate, and fold because waste sorting is a habitual action rather than a conscious one (Nemat et al. 2023). Considering all these factors, it should be feasible to create a packaging design that increases the rate of correct waste sorting. Additionally, the design must be deliberate and not superfluous with specific language to avoid association with vague greenwashing language (Chang 2023). Another avenue of my research will include the role of compostable packaging in the market. An increase in oil prices has seen the price of petroleum-based plastic closer matching the price of bio-based plastics (Markevičiūtė and Varžinskas 2022). This along with increasing social pressures on companies has increased consumer experiences with compostable packaging and therefore there is an opportunity to study consumer confidence in the novel packaging to sufficiently protect the product from shipping damage, pests, and normal storage conditions. From this, we can see how to improve the packaging to increase consumer confidence in compostable packaging to increase its implementation in the market.

In this study, I will conduct surveys on a study population of predominantly young adults to assess experiences with compostable packaging, knowledge about waste sorting and environmental terms, and waste sorting habits. With the information collected, I will design packaging that suits my goals. My central research question is: how can the information on packaging and the appearance of packaging affect the proper sorting of waste? Specifically I ask:

1. What gaps exist in the public's knowledge of what biodegradable or compostable waste is and how it should be disposed of?

2. What information, keywords, or attributes are most effective to include on the packaging that increases the rate of correct disposal of the packaging and if it should be recycled, reused, or disposed of? How can packaging design make waste sorting intuitive?
3. What are the barriers to buying compostable packaging or goods with compostable packaging and how confident are consumers that compostable packaging will properly protect their goods?

RESEARCH FRAMEWORK

UX/UI Design and Package Design

I will be using standard User Experience Design (UX Design) methods to guide the framework of my research. UX Design has been used successfully to solve user-centered problems such as packaging since "the essence of UX research is to try to provide a simplified representation of the interaction between humans and objects in order to understand how this interaction can be optimized" (Luther et al. 2020). Studies suggest that packaging design consider a combination of product centered design (PCD) and user centered design (USD/UX) (Bix et al. 2009). As such, it would be appropriate to use some UX Research methods such as user interviews, surveys, and A/B product testing to find consumer preferences.

An important aspect of UX Design is that it is flexible to the problem that needs to be solved. There are times where the problem cannot even be identified exactly and more research on the users must be done to deliver the desired product or outcome. Consequently, it is common to go though the phases of the UX Design process multiple times as the project progresses. A UX design skillset can be described as a toolbox where some tools are used multiple times or not at all during a project.

There is also the other field of design closely tied with UX, which is UI Design, or user interface design. User interface design is "described as being responsible for a product's appearance, interactivity, usability, behavior, and overall feel" ("What Is UI Design?" 2023). It is often applied in the context of websites and digital applications, but it can also apply to physical factors. Designing a package means also designing the fonts, positioning, graphics, and other visual attributes that belong on the packaging.

Specific UX Research Methods

For specific methods of user research, according to career UX Designers, they found that most used the same methods of user research, which were using personas/scenarios and interviews/focus groups. They were referred to as basic methods integral to any UX Designer (Gray 2016). When formatting my surveys, I will be using a modified version of the UEQ, the most commonly used standardized user experience questionnaire used in published literature (Díaz-Oreiro et al. 2019). There is not a lot of literature on UX methods, which may be because there is no one correct method to use, and it is highly dependent on the preferences of the UX Designer.

Theory Reviews in Packaging Design

There are various theories in psychology and graphic/packaging design that dictate the effectiveness and purpose of certain areas on the package. One such theory is the Gutenberg diagram (effect). For languages that read top to bottom, left to right, the reader follows the page from the top left to the bottom right in a Z shape. There are four main quadrants: primary optical area (top left), strong follow area (top right), weak visual area (bottom left), and terminal area (bottom right); The primary optical area is the most valuable area on packaging and the terminal area is the best place to put a call-to-action such as a recycling symbol or other label (Nemat et al. 2023).

Along with the location of information and symbols on the packaging, the wording and material of the packaging is just as important. In a study on the effectiveness of explicit and implicit cues in green packaging, it was found that combining explicit cues with meaningful implicit cues were counterproductive, where too much green information can overload the reader and create green skepticism about the product (Granato et al. 2022). Information that is too vague may also promote thoughts of greenwashing, which is counterproductive to the desired message of the packaging. Combining explicit cues with meaningless implicit cues, on the other hand, enhanced the sustainability salience of the product (Granato et al. 2022). It was theorized that good communication within the explicit cues (the language) could create an association between the meaningless implicit cue (a texture or color that is novel) and sustainability, which may also improve proper waste sorting behavior.

Because packaging is an intersection of function and user interaction, packaging designers must include aspects of both when creating a new type of packaging. The Lockhart packaging matrix visualizes the intersections of the three categories of functions the packaging must fulfill with the three categories of environments in which the functions must be performed (Bix et al. 2009). The three categories of functions are: communication, utility, and protection while the three types of environments are: physical, human, and ecospheric (Figure 1). I will be using the matrix to organize relevant elements to designing the prototypes.

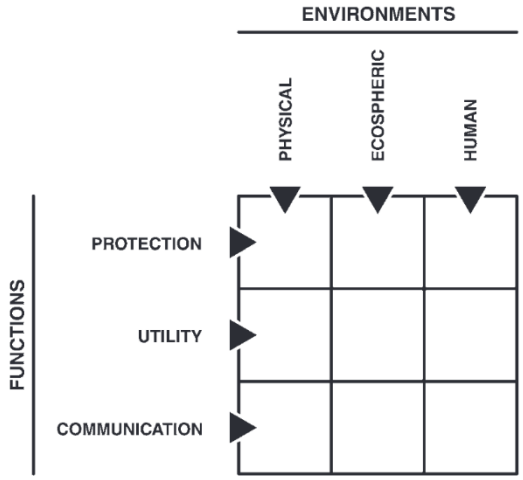

Figure 4. The Lockhart packaging matrix.

Figure 1: Lockhart packaging matrix (Bix et al. 2009)

Lastly, there is the fact that consumers – humans, are more likely to interact with novel and/or engaging stimuli. This behavior is explained by the optimal-arousal theory, which states that "specific environmental stimuli can persuade an individual to process the stimuli related information and in turn, lead to exploratory behaviors" (Shukla et al. 2022). Delivering information in a creative way can also hold the attention of the reader long enough for the reader to process this information. However, like the case with the combination of explicit and implicit cues, too much can deter the consumer. Especially in a retail setting where there is little time to process, packaging that is too divergent and original may dissuade the consumer from processing the information due to the higher cognitive effort needed as suggested by the Yerkes-Dodson law (Shukla et al. 2022).

Considering all these theories, the goal of the study is to create packaging that combines clear explicit cues with meaningless implicit cues while following the principles of the Gutenberg diagram and use the Lockheart packaging matrix to organize and prioritize functions and user interaction aspects of the packaging, and then consider using creative elements to engage the user with the packaging.

Theory Reviews in Waste Sorting Behavior

On the individual level, research has shown that waste sorting behavior is a habitual behavior, and it should be made as intuitive as possible to promote habit forming. The WSFs (waste sorting functions) are a group of functions that are steps in the ideal waste disposal process: easy to empty, easy to reseal, easy to clean, easy to fold, and easy to separate (Nemat et al. 2023). The package should also clearly inform the user of the proper way to dispose of the packaging in the form of labels and symbols. Common standards of labeling used are the recycling symbol along with the number category of plastic, as well as the OK compost standards that define the grade of composability as certified for home compost or industrial compost. A criticism of the current labeling for recycling plastic is that it can be confusing for the consumer on what types of plastic belong in the landfill or the recycling bin. There are mostly 7 types of plastic in use, but not all are recyclable. In India, recycling plastic bottles is straightforward because there is only one standard of plastic used for bottles, which also tends to be more durable and reusable (Begley and Sadhguru 2018).

In terms of other ways of promoting correct waste sorting behaviors, it was found in a study of waste sorting behavior in Shanghai that level of incentives, incentives for altruistic behavior, and perceived ease of use are the most effective to promoting waste sorting behavior (Xia et al. 2021). These incentives can be either societal or governmental, but both may be used as it is in South Korea. According to South Korean law, waste must be sorted properly to avoid sanctions, fines, and consequences such as stopping of garbage pickup. Rewards will be given with successful recycling of drink bottles will award credits to the community. Because the consequences and rewards are both communal, neighbors hold each other accountable and there is social pressure (Rijayanti et al. 2020). It must be noted that some cultures hold social pressure in different regards. East Asian cultures such as Korea and China are communal societies, where ‘face’, or reputation

is a very important aspect in making decisions. Western countries such as the United States are individualistic, and social pressure may not be as effective to promote or change behavior.

Government policy is shown to be an effective motivator for proper waste sorting, not just because of the financial incentives, but because education programs can inform people of the long-term benefits of proper waste sorting. The study by Govindan et al. recommends that there should be publicity and education on the long-term benefits of waste sorting programs and establish environmental values, along with providing infrastructure for waste sorting, providing incentives with reward and punishments, and recruiting volunteers to assist in and promote proper waste sorting (Govindan et al. 2022). In the previous section about packaging design theory, the relevance of a combination of explicit cues with meaningless implicit cues to sustainable disposal behavior was mentioned. In the same study, it was found that the sustainable disposal behavior could be enhanced with statements connecting the cues by an authoritative external source such as the government (Granato et al. 2022). In a study by Kędzia and Turek, they conducted interviews with stakeholders in the market regarding the barriers to implementing sustainable packaging. When considering the four dimensions of sustainable development: environmental, economic, social, and governance, it was found that most of the barriers were related to issues in governance and a few economic and social issues.

BACKGROUND

US Waste Sorting Policies and Infrastructure

First, there are at least 7 types of plastic in use and only some can be recycled. Including lower grade plastics in the recycling bin will contaminate the higher-grade plastic and downgrade it (Begley and Sadhguru 2018). There is also not much awareness on the proper way to dispose of new materials such as compostable plastics, most of which can only be composted in an industrial compost facility. There are labels backed by standards in use in the EU to differentiate industrial grade compost materials with home grade compost materials, but such labels have not been widely introduced in the United States. Hence, it is not widely known what such labels mean, and there is confusion of the difference between compostable, recyclable, and biodegradable (Allison et al. 2021). Compostable materials cannot be included in recycling bins and must be disposed of in the

landfill if not compost option is available. Some biodegradable material is compostable but not all should be composted.

The confusion and lack of standards may be attributed to the system of government in the United States. In order to implement environmental regulations made by Congress, the states must cooperate, but the degree of cooperation varies drastically from state to state (Farber 2016). Additionally, political polarization regarding environmental grew since the 1980s when Reagan took office, and environmental regulation has been 'sharply adversarial' since then (Farber 2016, p.5). The dominant form of government starting with Reagan's term was coined as "neoliberal ideology", which says that the government should stay out of regulating markets and businesses. This meant that there was little political reason to implement standards for labelling and materials because it could be seen as 'government overreach'. Perhaps because of this, the United States also lags behind on regulations (compared to EU) regarding labeling, consumer protection and transparency, and environmental topics.

Another issue is that government policy in the US is highly fragmented due to the emphasis on state's rights. The education curriculum is highly varied depending on the state and county, which may or may not include environmental topics and public waste sorting education. It is up to the states to pass and enforce laws regarding the environment, which would include standards for materials use. For example, California has strict environmental protections in its laws and prioritizes environmentally friendly legislation compared to some other states in the United States. One such law is SB 54, which states that producers must "ensure all packaging material sold, distributed, and imported in California is recyclable or compostable by 2032" (Zhu 2023). Usually, producers will modify their products around the policies of states with high market share such as California, so we can expect to see a higher volume of compostable or recyclable packing in the US market in the coming decade. The availability of waste sorting tools and infrastructure is also highly varied depending on state, county, city due to different priorities in policies and access to government income from taxes.

Lastly, the population density of the US makes it difficult to establish infrastructure networks for proper waste management. There are few areas where the population density is high enough to establish separate facilities for recycling for plastic, recycling for paper, composting, and landfill without substantial losses. For perspective, the population density of EU member states

(as of 2007) is 300 persons per square mile while the population density of the US is 81 persons per square mile (Stockingblue 2018).

Site Discussion

There were two main sites where the study will be conducted: UC Berkeley campus and online questionnaires and interviews. The advantage of conducting the study on the Berkeley campus is that there are students from many backgrounds from different countries, who may have had a different education regarding waste management. Even if many students are from California, the emphasis on proper waste sorting is highly varied depending on the city or county. The awareness of proper waste sorting would be higher than average due to the presence of the Berkeley Zero Waste Program on campus with all waste bins in campus having 4 categories with pictures of acceptable types of waste. The Berkeley Zero Waste Coalition "aims to bring together waste-related organizations at UC Berkeley to improve communication between them, collaborate on initiatives, be a resource for zero waste on campus, and foster a zero waste community" (Zero Waste Coalition 2024). For the recruitment method for this site, I will contact student organizations to distribute surveys with incentives to participate.

METHODS

General Study Methodology

I used standard User Experience Design (UX Design) methods to guide the framework of my research. The four main stages of UX Design are Research, Definition and Ideation, Prototyping, and Testing (Gray 2016). In the Research stage, researchers will conduct market research on competing and existing services as well as conduct interviews and surveys with users to uncover issues with the current service or product. For the scope of this study, the service is defined as the labels, information, resources, and logistics associated with waste sorting in the US market. I used these methods to (1) Identify what information and areas or subjects would be useful to include on the packaging to increase consumer awareness and trust in the product's sustainability; (2) Find which types of packaging were sorted correctly most often then understand

what factors on the packaging were involved; and (3) Find positive and negative experiences with compostable packaging and consumer confidence.

Research Stage

Information about the topic was gathered by reviewing existing literature on waste sorting systems, packaging design, and circular economy and by observing potential issues, or 'pain points' for possible exploration. Survey questions were then written based on the gaps in literature and on the potential issues theorized. There were 22 questions, excluding demographic questions, and they were focused on obtaining quantitative data. Most questions were either binary, ordinal, or categorical multiple choice to keep the answering process quick. There were a few questions that were text inputs, but they were optional to promote responsiveness. One of the questions was made to simulate a waste sorting activity with 10 different pieces of trash. A picture was provided of what these objects looked like to aid in the activity. Participants were asked to sort the waste as they normally would. Finally, a list of interview questions was prepared to elaborate on research gaps that remained after the survey results. As opposed to the survey questions, the interview questions focused on obtaining qualitative data. During the semi structured interview, the pool of questions was consulted to gain as much information as possible from the interviewee based on their lived experiences. As such, not all questions in the pool were used and some questions were improvised. The sorting activity was repeated but with the question of what the participants thought were correct, and participants were asked to elaborate on their reasoning. The interviews were conducted on Zoom and Google Meet, which are web conferencing programs. The interviews were recorded but names remained anonymous.

Definition and Ideation Stage

During this phase, all the information from the previous phase was organized using data analysis techniques from Qualtrics and various UX methods to outline the most prominent issues with current packaging design in relation to waste sorting, to create designs for new labels, and to draw up possible solutions that would solve the issues.

Data analysis with tools from Qualtrics was used to organize the quantitative data from the surveys.

I used experience mapping to organize the qualitative data into groups and considered which responses were the most common in number. Larger groupings were given more weight in

the final analysis. Another experience map was made for the survey data to group responses according to demographic data to analyze issues or experiences that may be specific to certain demographics. Next, a user persona was created based on these experience maps and the data to imagine the average user trying to navigate the current waste sorting system and a journey map of the process was made to clearly outline when issues would arise when trying to sort their household waste. Finally, all of this was used to propose possible solutions and design new labels.

Prototyping and Testing Stage

This stage was not fully completed in this study due to the short timeframe available. Ideally, there would be multiple rounds of interviews and user testing, but this was not feasible for the scope of this study. This portion would also include the A/B testing discussed earlier. The prototyping and testing stage would cover topics for future research, such as designing and testing packaging for more types of products, proposing policy changes, and gathering more data to repeat the UX process.

Site Selection

The survey was distributed to UC Berkeley student groups by email and word of mouth and further distributed to the social groups of students. An opportunity to enter a raffle for a 25-dollar gift card was offered to encourage completion of the survey.

Survey Group Selection

The makeup of the survey population was defined by voluntary participation. Questions about demographics and knowledge on environmental topics were included to gauge potential bias within the survey population. To supplement the diversity of respondents and provide convenience to the respondents, I will also be conducting an online version of the activity and survey online and distributing it though online channels such as questionnaire websites, emails, class forums, and other forums. Making online versions of the surveys will create the opportunity for high volumes of responses since participants can respond at their own pace. Part way throughout the survey, I was informed of the possibility that participants could be located outside of the United States due to the online format, but these responses were still considered in the final analysis.

Interview Group Selection

Participants were chosen from the group of survey participants who had indicated interest in further participation in the study. Since the interviewees were to be chosen from the pool of survey participants, care was taken not to have too much repetition between the survey question and interview questions.

RESULTS

Survey Results

A total of 52 responses were recorded. The survey was distributed among circles were environmental knowledge and thus care for the environment was higher than average. This was considered in the final analysis, that this pool of respondents recycle much more often, 49% answered recycle all the time, 30% answered most of the time, 15% answered about half the time; than the national average of 32% and the state average of 40% and declining (source needed). Since this study is focused on improving the experience of all users and the same issues affect both groups, the survey data still can be used to create solutions that apply to a wider population.

To measure the environmental consciousness of the survey group questions such as ' How knowledgeable are you about carbon emissions (including non CO2 greenhouse gases)?' and 'How knowledgeable are you on the pros and cons of recycling?' were asked. The data indicates that the study group was on average moderately knowledgeable on the pros and cons or recycling and microplastics, while very knowledgeable on carbons emissions, and the difference between biodegradable, compostable, and recyclable (Figure 2).

Question	Mean	Median	Score Range	"Middle Value"
How knowledgeable are you about carbon emissions (including non CO2 greenhouse gases)?	3.6	4	1-5	3
How knowledgable are you on the pros and cons of recycling?	3.4	3	1-5	3
How knowledgeable are you about microplastics and its effects?	3.1	3	1-5	3
Do you know the difference between biodegradable, compostable, and recyclable?	3.6	4	1-5	3

Figure 2: Statistics for the questions measuring environmental awareness.

Despite the high rate of recycling, there was confusion over which items belonged to which waste bin. Items like takeout boxes and used pizza boxes, which must be landfilled or composted after being soiled by food waste, were incorrectly sorted (takeout box (13.6% bottles and cans recycling, 6.8% mixed paper recycling), used pizza boxes 29.5% mixed paper recycling). There was a higher rate of correct recycling for bottles and glass (milk jug 82.2% bottles and cans recycling, glass soda bottle 91.1% bottles and cans recycling). Since some people answered that they do not recycle or they may not have access to certain types of recycling, the landfill option was not considered an incorrect option.

When participants were asked about their knowledge on the seven plastic recycling codes, a majority of respondents answered that they were unsure of the meaning of the symbols. 30% answered definitely not, 18% answered probably not, 21% answered may or may not, 18% answered probably yes, and 12% answered definitely yes. With 1 being definitely not and 5 being definitely yes, the mean was 2.8. This suggests that the plastic recycling codes are not very helpful in communicating what plastic waste can be recycled.

When comparing the participants' confidence in two forms of transit packaging (bubble mailers and cardboard boxes) and two forms of secondary packaging (traditional bubble wrap and compostable paper bubble wrap) to protect their goods, cardboard boxes and traditional plastic bubble wrap ranked higher respectively. Cardboard boxes had a confidence score of an average 7.64 out of 10, bubble mailers a 6.02 out of 10, plastic bubble wrap a 7.08 out of 10, and honeycomb paper bubble wrap a 6.12 out of 10.

Half of respondents answered that they had received broken merchandise when ordering online. Of the 26 who indicated that they had received broken goods, 8 said the container was a cardboard box only, 7 said a bubble mailer, 4 said plastic with bubble wrap, 3 said cardboard box with bubble wrap, and 2 said some sort of other packaging. Of the 7 who received broken goods in bubble mailers, 1 gave a confidence score of 3, 1 for score 4, 3 for score 5, 1 for score 6, and 1 for score 7. The average confidence score for these respondents was a 5. Of the 8 who received broken goods in cardboard boxes only, 1 gave a confidence score of 4, 2 for score 5, 1 for score 6, 1 for score 7, 2 for score 8, and 1 for score 9. The average confidence score for these respondents was a 6.5. Experiencing a negative shipping experience with a certain type of packaging dropped the confidence score by an average of 1 point compared to the group average.

The data for participants' recycling rates in childhood and recycling rates current was compared and there is a strong correlation between the rate of recycling during childhood and the rate of recycling now. 100% of respondents who said they recycled sometimes growing up said that they recycled sometimes currently (Figure 3).

		How often did you recycle in your household growing up?					
		Total	Never	Sometimes	About half the time	Most of the time	Always
How often do	Never	2.20%	0.00%	0.00%	0.00%	4.30%	0.00%
you recycle in your	Sometimes	4.40%	33.33%	100%	0.00%	0.00%	0.00%
household now?	About half the time	11.10%	33.33%	0.00%	100.00%	8.70%	5.90%
	Most of the time	33.30%	0.00%	0.00%	0.00%	56.60%	11.80%
	Always	48.90%	0.00%	0.00%	0.00%	30.40%	82.40%

Figure 3: Recycling rates from childhood is a good predictor if they will recycle in the future, recycling rates remained at a similar rate or better for most participants.

When asked about obstacles to recycling and separation of waste in their household or community, respondents pointed out lack of a compost bin, lack of knowledge on correct sorting, lack of motivation to clean containers, difficulty of maintaining a compost bin, and incorrect sorting from other households or household members.

Participants were asked how often they make an effort to buy items with compostable packaging, 2.0% answered always, 33.3% answered sometimes, 19.6% answered a few times, and 45.1% answered that they haven't considered it a factor.

Interview Results

5 people were interviewed. Interviewees were asked to look at recycling labeling standards for the US and Canada, UK, and Australia and New Zealand, then point out helpful features of each labeling standard as well as rate which one was the most helpful overall. 4 of 5 interviewees rated the Australia and New Zealand labeling standard, also known as the Australasian Recycling Label (ARL), as the most helpful out of the three labeling standards (Figure 4). Participants highlighted the images, the difference in shape of the image area from the instructions (the circle with icon compared to the rectangle region for the instructions), and legibility of the instructions due to the spacing of the margins as factors that made the standard helpful. The US and Canada standard, also known as the How2Recycle label, was confusing to participants due to crowded

text, monotonous use of graphics, and lack of differences visually between recyclable, not recyclable, and checking locally labels (Figure 5). The UK standard was not rated as helpful, and there was not as much feedback compared to the other two (Figure 6).

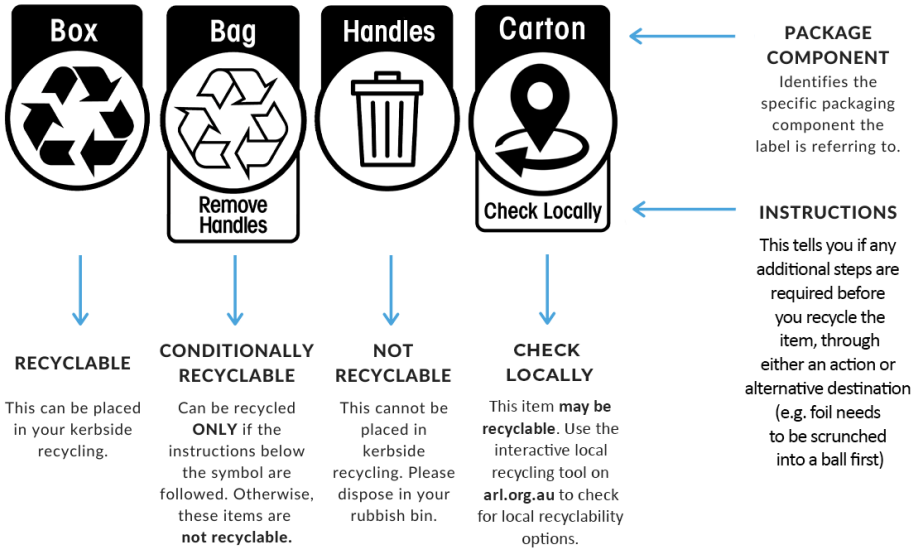

Figure 4: The Australasian Recycling Label (ARL). Shown to interviewees. (PlanetArk 2024)

Figure 5: How2Recycle labels (US and Canada), use of Mobius Loop. (StopWaste 2024)

Figure 6: UK recycling labels. (Wilshee's 2020)

When asked about which part of the recycling process was most difficult, all interviewees said cleaning the containers was the most tedious. Some also expressed troubles in sorting paper waste and determining if it goes in compost, mixed paper recycling, or landfill. Some paper goods contain inks that cannot be composted, plastic linings that cannot be recycled, and other components. One person, interviewee 1, explained that when they were learning to sort paper waste, they were told of the 'tear test' where if they were able to tear a piece of paper or paper-based product, it would go into compost, and if not, it would go in landfill.

Respondents were asked about any trends or policies about waste sorting and recycling they had noticed in the past 3 years, interviewee 1 discussed their experience with Zero Waste initiatives in UC Berkeley's Chou Hall. The program outlines that a large part of minimizing confusion in waste sorting is eliminating excess sorting options and removing production of landfilled waste, hence eliminating the need for landfill waste bins. Chou Hall does not produce any landfilled waste and does not provide landfill waste bins to the public, other than in restrooms for feminine hygiene products.

Figure 7: Chou Hall waste bins. Only Compost and Recycling is available. (Zero Waste 2024)

Another trend that was mentioned was compostable single-use packaging and a move away from reusable containers. The COVID-19 pandemic emphasized a need for hygiene and single use takeout products, and communities moving towards Zero Waste initiatives needed to replace plastic single-use utensils and takeout boxes with compostable options. Interviewee 2 mentioned that in their online shopping packages, they were noticing an increase in the use of paper based and compostable packaging such as cornstarch packing peanuts, paper wrapping, honeycomb matrix paper, and compostable bubble mailers.

Interviewee 4 talked about their experiences with keeping pests out of food in compostable packaging. Pantry moths were able to chew through the paper packaging and infest the food and it led to a loss in a large quantity of food. They then took measures such as keeping the packages in reusable plastic containers with airtight seals, keeping food items in the fridge, and moving food to reusable plastic containers.

When asked about how they learned about plastic bottle and glass recycling growing up, several people mentioned that they learned basic recycling in elementary school and from watching their parents. They remembered that you were, and still able to, exchange empty plastic bottles and glass bottles for some money. Interviewee 5 talked about a trip to Germany where they used the bottle returning stations to get back their deposit they paid when purchasing the drink. This system is known as the Pfand system.

Figure 8: Pfand bottle return stations. (Bouliane 2024)

DISCUSSION

Habit Formation and Access to Information

As stated earlier, waste sorting is a habitual behavior, and like other habits, can be learned with regular repetition. Researchers estimate that it takes 66 days after the first performance of regular behavior to form a habit (Gardner et al. 2012). Removing obstacles to performing the activity, also known as addressing pain points in the UX field, will also improve the likelihood of successful habit formation. The specifics of removing the obstacles through design will be discussed in a later section.

Education on Waste Sorting

Researchers at Brown found that most habits take root by the age of 9, and are unlikely to change after (Pressman et al. 2014). This is supported by the data collected in this study on the correlation between waste sorting in childhood and waste sorting currently. Consequently, it can be inferred that it is important to start education on the details of waste sorting early in childhood development. Children are at school for most of their day, and incorporating recycling and waste sorting programs in schools can help familiarize students with waste sorting and normalize it as a

normal part of their daily routine. Establishing school or other community buildings as a place of access to recycling and composting can decrease landfill waste streams in communities where there is a lack of household access to waste sorting options.

There is also a lack of education on *why* or *how* certain parts of the recycling process are done. For example, a major pain point of sorting waste brought up in data collection was the cleaning, washing, and drying of containers before recycling. Requirements for the level of cleanliness required are also vague and differs depending on region. Vocalizing the main culprits of recycling contamination as oils, sticky foods, and non-water liquids can help people know what to look out for when cleaning their containers (NLWA 2023). Also explicitly labelling cleaning instructions on containers would have the same effect. One interviewee mentioned that rinsing out the containers seemed like a waste of water. Advertising that recycling saves water despite the water you use to clean the containers and a quick rinse and a wipe down with a paper towel is enough for avoiding contamination may improve people's propensity to clean their recyclables (EcoMyths 2022). In other words, the steps of separating waste needs to be simplified, explicitly stated, and explained.

Reducing Steps and Difficulties in Sorting

Labeling Standards

It is clear from the research, survey data, and interviews that the current methodology for labeling recyclable and compostable products in the US is inadequate, and so an in-depth analysis for a possible replacement was studied, namely the three labeling systems reviewed in the interview portion: the How2Recycle labeling system, the UK labeling system, and the Australasian Recycling Label (ARL) system.

How2Recycle (US and Canada)

How2Recycle is a project under GreenBlue, an environmental nonprofit dedicated to the "sustainable use of materials in society". How2Recycle's model relies on partnerships with consumer packaged goods companies, retailers or quick service restaurants who pay an annual fee to GreenBlue to be able to use the How2Recycle labeling system. GreenBlue then conducts a recyclability assessment on the submitted packaging to categorize and certify the packaging. The recyclability standards set forth by How2Recycle comply with the Federal Trade Commission's

standards for Guides for the Use of Environmental Marketing Claims, aka 'the Green Guides' (Code of Federal Regulations, Title 16 Part 260) and Section 5 of the FTC Act, 15 U.S.C. 45 (GreenBlue 2024).

The effectiveness of the labels was measured when in late 2021, GreenBlue contracted with a market research firm to assess consumer sentiments on the How2Recycle labels. According to a sorting activity of containers with the How2Recycle labels, Participants were most accurate when disposing of a package with the "Widely Recyclable" label, and they were the least accurate when disposing of a package with the "Store Drop-off" label (GreenBlue 2022).

There is room for improvement in the designs of the labels themselves, but also for the legislation related to recycling labels. It is important to note that How2Recycle is not a government issued standard, nor is it affiliated with any government body, and its use relies on companies being proactive. Dishonest companies who use recycling labels as a form of greenwashing would not want their products to be scrutinized, and consequently would not use clear labeling.

The FTC's Green Guides are also not required to be adopted as a standard by states. Even for states who have adopted the Green Guides in some way in their state legislation, the language used is vague and often does not result in successful lawsuits against dishonest companies. For example, the Green Guides say that to qualify the company to label a product as recyclable, 60 percent of the community that the product is sold to must have access to recycling facilities, but the FTC fails to define what a 'community' is, which led to a case being dismissed (Fraiser 2023). There are also cases where vague language allowed dishonest labelling to label a product as recyclable when it was extremely unlikely that it would be recycled. The federal judge ruled that technically the company was not engaging in deceptive marketing because there were facilities in the US that could theoretically recycle the material (Fraiser 2023). Vague laws enable dishonest companies to lie about the recyclability of the materials used in an attempt at greenwashing. Falsely labelled waste is then sorted with recyclable content, and will contaminate the batch.

There was an in-depth discussion about laws related to recycling labels in this section, but only because of its relevance to the study site, the United States. The latter two sections will focus purely on the design aspects of the labels and the research behind them.

UK labeling system (OPRL)

Interview participants rated the labels as not as helpful, which I speculate is because the Mobius loop was not used, which has been used as the symbol for recycling in the US for decades. More research needs to be done on this labelling system, as I did not receive as much feedback compared to the How2Recycle and the ARL. Based on the reports, it does seem like OPRL has achieved major success in the UK, as they have been approved by the UK government to be one of the two labeling standards to be used on packaging. OPRL also continues to engage in consumer research to improve the clarity and usefulness of their labels (OPRL 2021).

The Australasian Recycling Label (ARL)

The consumer report released by the Australian Packaging Covenant about the ARL The research indicates that the design of the ARL is effective; "when the ARL was present, consumers' correct disposal behaviour increased" compared to that of packaging without the ARL label (Figure 9). Providing disposal instructions for each part of the packaging by graphically separating each part may communicate that each component must be separated and disposed of in different methods. The graphics for indicating different disposal methods are also distinctive from each other: the two Mobius loops for recycling, and the trash can for landfill. The encompassing visual elements, the circle containing an icon and the rectangular black label on top, have enough similarities where they would be grouped together as serving a similar purpose, in line with the theory of visual grouping (Malik 2001).

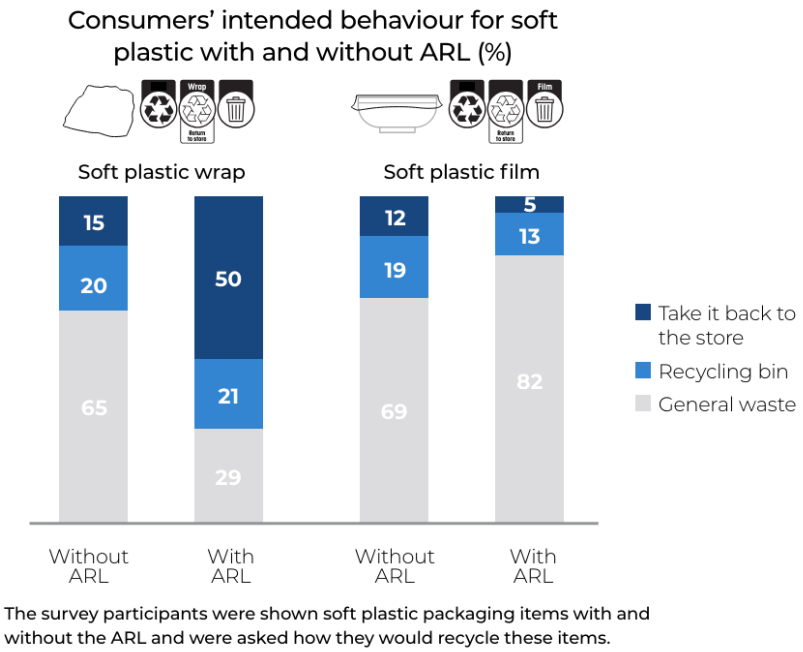

Figure 9: The survey results from the APCO report. The correct disposal of the soft plastic wrap increased dramatically with the presence of the ARL. (APCO 2023)

Another relevant part of the report presents data that concludes on-packaging labels are the best channel for businesses to help their customers recycle packaging correctly (APCO 2023). This indicates that improving labeling may be one of the biggest factors in improving recycling rates in the US.

Further research should be conducted but based on the research and the results from this study, the Australasian Recycling Label (ARL) is the most promising in terms of design. Steps should be taken to establish a standardized recycling labeling scheme nationally like in the Australia and New Zealand, as well as the United Kingdom, where mandatory recycling labels are to be required on all packaging by 2026 (Barsony 2024). OPRL started in a similar position to GreenBlue and How2Recycle, and GreenBlue should similarly work towards standardization by law in the United States.

Novel Packaging Designs and Materials

As stated earlier, the research found that packaging should be easy to empty, clean, separate, and fold to enable proper waste sorting (Nemat et al. 2019). Packaging with different

components with different disposal methods should visually distinguish themselves from each part so that they are not mistakenly disposed of together. The tactile and visual elements of the packaging could also evoke similarities to other materials traditionally recycled, such as using cardboard colors or paper colors for packaging that should go into paper recycling, would be a helpful indicator for the disposal method via the principle of visual grouping (Malik 2001). The container should also include explicit cues such as ‘tear here’ or ‘detach here’, or a physical tear line paired with implicit cues such as color to indicate how the different elements should be separated. One such design is Bruk by Pushan Panda (Figure 10).

Figure 10: Plastic drink pouch housed in a tearable paper container for easy separation. (Panda 2022)

Based on the requirements of a container that would be easy to empty, clean, separate and fold from Nemat et al.’s study, I drew up a preliminary design (Figure 11). The top would be made of plastic, the same material as the recyclable plastic cap, and most of the box will be made of mixed recyclable paper materials. There will be pre-folded lines along the side to indicate how the box should be folded when flattened for disposal. The steps of disposing of this container would be to fill the container with some water and a bit of dish soap, remove the water, use the pull tab to separate the paper carton from the plastic drink spout. The paper carton is disposed with mixed paper, and the plastic is disposed with plastics recycling.

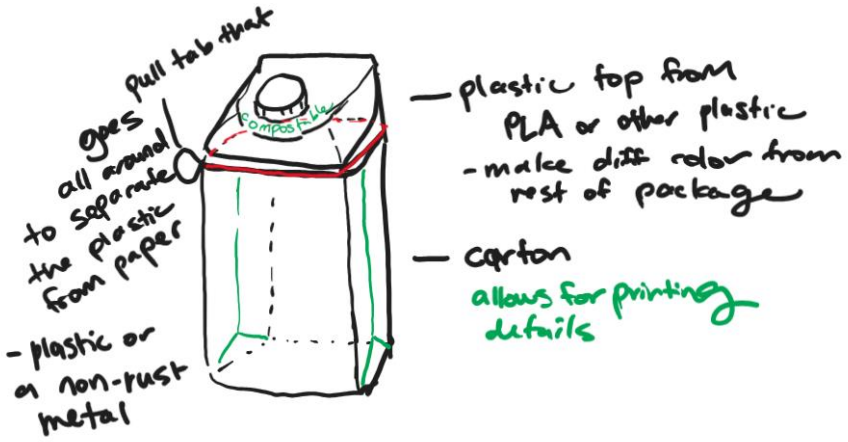

Figure 11: A sketch of a possible design based on the requirements of empty, clean, separate, and fold. (Drawn by self)

It is unlikely that single-use materials will be eliminated because of the convenience of use-and-throw, so the single-use packaging must be able to be recycled or composted to minimize microplastics and landfilled waste. This includes single-use packaging materials such as bubble wrap, bubble mailers, plastic tape, and plastic wrap. Proposed replacements currently viable for the market include honeycomb matrix wrapping paper instead of bubble wrap, biodegradable plastics, paper wraps and other equivalents made from cardboard or paper.

Closing the loop on plastic – Pyrolysis

There is research being done on possibly converting polyolefins such as polyethylene (PE, plastic code 2 and 4) and polypropylene (PP, plastic code 5) back into fuels for energy or to be made into new products via a process called pyrolysis (Tullo 2022). An issue is that the input for pyrolysis has to be relatively pure when compared to conventional waste streams. However, if there is a pyrolysis plant that focuses on breaking down streams of packaging from big retailers like Amazon, grocery delivery, and others, who have already standardized their packaging, it would save a lot of plastic waste from landfills and oceans. Another concern is that it would require massive amounts of energy to do on an industrial scale, and it would not be environmentally feasible to run on dirtier sources of petrochemical energy like oil. This is still a newer technology

and far from seeing widespread adoption, but it is a possibility to make recycling viable for more types of plastic.

Government Action

Access to Waste Sorting and Zero Waste Options

Several respondents from the survey and interviews, as well as from the research, stated that they do not have access to composting bins. Composting is rather new compared to recycling, so the availability of composting centers is not as widespread. The burden of providing waste sorting facilities usually falls on municipalities, which are often underfunded outside of major cities and suburban areas. Providing grants and funding from the state or federal level to municipalities could help increase access to waste sorting options such as recycling and compost by either improving existing waste processing plants to recycle more types of waste or by erecting new recycling or composting plants.

From the survey data, it doesn't seem like compostable packaging is a major factor for consumers, and it is secondary to the actual product. More research needs to be done on the reasoning behind this, whether it is because compostable packaging is not widely used and thus would severely limit purchasing options, there are no compost bins in their area, or some other factor. This does suggest that the onus of implementing compostable packaging falls on companies to use compostable packaging and government action to require zero waste alternative packaging and provide composting centers.

Government Policies and Incentives

Enacting legislation such as the measure Plastic Pollution Prevention and Packaging Producer Responsibility Act (SB 54) to reduce single-use plastic production in California will help the move towards zero waste and reduce the need for landfill use (Zhu 2023). More needs to be done to crack down on greenwashing and deceitful marketing, and the FTC's guidelines need to be reviewed and revised. As mentioned before in the labeling standards section, adopting a labeling standard for recyclables could help fight vague greenwashing labels. In South Korea, there are fines up to 300,000 won (about $220 USD) associated with incorrectly sorting food waste, but the feasibility of such a measure in the United States is questionable (Ulsan Bukgu 2024).

Limitations and Future Directions

This study was conducted over a period of 6 months and was not able to cover the prototype testing phase. The next steps to initiate the prototype testing would be designing packages based on the research and data, and then recruiting a focus group to test the packages. Results from the testing will prompt revisions and more prototype testing. The outreach of the survey was also limited to environmental student organizations at UC Berkeley and thus skewed the data towards more environmental awareness and higher rates of recycling. Despite this, the data acquired from this survey population is still useful to apply to the US population, as addressing the issues even people familiar with recycling still have can also help increase correct waste sorting for a broader population. Nevertheless, a larger and a more diverse sample size is required to get a more accurate data set.

Conclusion

In this study, I found that the plastic resin code system was insufficient for identifying recyclables, it was difficult for respondents to determine how to separate their waste, and cleaning the containers was the most difficult part of separating recyclables. Recycling information is most effective when it is present on the packaging as opposed to the internet, advertisements, and other sources of information. I found that the major points that could be addressed with packaging are establishing a standard for recycling and waste sorting labels, using these labels on all goods sold in the United States, improving the design of existing recycling labels, and making packaging that is easy to empty, clean, separate, and fold. The vague language in the FTC's Green Guide could be revised to be more specific to make greenwashing easier to prosecute and more funding could be provided to communities without access to recycling and composting centers.

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