Wireless Waste: Cell Phone Recycling Behavior of San Francisco Bay Area Residents and Students

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ABSTRACT

Cell phone consumption has increased drastically in the past decade; however, recycling rates in the United States are only around 10-12%. This alarmingly low recycling rate demands attention because mobile phones contain toxic and non-degradable materials that pollute landfills if they are disposed of through the traditional waste stream. To better understand the factors influencing cell phone recycling behavior, this study uses three analytical frameworks: economic, environmental attitudes and behaviors, and perceived consumer effectiveness. I administered a paper survey to Bay Area Rapid Transit (BART) passengers and an analogous online survey to students at UC Berkeley and found that the cell phone recycling rate for students was 20% and 28% for BART commuters. Information, pro-environmental behavior and attitudes, and perceived consumer effectiveness were positively correlated with cell phone recycling. Theories about recycling behavior suggest that inconvenience is a major barrier for consumer; however, only 6% of non-recyclers said that cell phone recycling was inconvenient. I found that 67% of the student sample and 61% of the BART sample who did not recycle their cell phone stored their devices for future disposal or as a back up phone. Only 2-3% of the sample threw away their phone. This study suggests that recycling rates could be increased by encouraging consumers through information campaigns that seek to increase their knowledge of cell phone recycling, and perceived consumer effectiveness.

KEYWORDS

Perceived Consumer Effectiveness, Pro-environmental behavior, e-waste, logistic regression, environmental attitudes & behaviors

INTRODUCTION

In the past 30 years, the electronics industry has boomed, producing newer, cheaper and smaller products that have become more abundant in homes and landfills (Geyer & Blass, 2010). Environmentalists and public health advocates have pushed to keep these products and their hazardous components (e.g. lead, copper, mercury, and arsenic) out of the traditional waste stream (Fishbein, 2002). However, the same qualities that make electronics attractive to consumers, especially their small size, also make it difficult to enforce policies that keep them out of landfills. The case of cell phones is considerably more difficult because of their relatively short lifespan, on average only two years, and their relative ubiquity compared to other electronics. The rapid rate of product development in the mobile phone industry ensures that new models are continually introduced and the service providers' contract structures ensure that new devices are continually purchased (Geyer & Blass, 2010). Mobile phone providers typically offer a highly discounted phone upgrade when it is time to renew one's contract so most consumers stop using their device, on average, 8 years before the phone is said to reach the end of its life by manufacturers (Fishbein, 2002). Though cell phone consumption has ballooned, the US EPA estimates that less than 9% of electronic waste (e-waste) is recycled, while the rest is stored or improperly wasted in landfills (Nixon, Saphores, Ogunseitan, & Shapiro, 2009); however, estimates from the EPA for cell phone recycling rates are higher— around 25% in California and 10% in the entire United States (Silveira & Chang, 2010).

It is unclear why there is such a low incidence of e-waste recycling, but evidence points to the general lack of knowledge about proper disposal and the perceived inconvenience of special disposal of e-waste (Iyer & Kashyap, 2007). Carlson (2001) argues that environmental awareness is not enough to encourage pro-environmental behavior, but that convenience is most important to consumers (Chen & Tung, 2010; Steg & Vlek, 2009). Studies have shown that consumers stockpile their e-waste until they find a convenient time to dispose of it (Saphores, Nixon et al., 2009). One study found that California households were willing to pay a 1% Advanced Recycling Fee, a recycling tax paid at the time of purchase to support local recycling (Nixon, Ogunseitan, Saphores, & Shapiro, 2007). Their findings suggest that the biggest barrier to e-waste recycling is inconvenience, not the cost of recycling or the opportunity cost of storage, and that inconvenience may take precedent over pro-environmental attitudes (Nixon et al., 2007).

It has also been observed that pro-environmental behaviors are not practiced in isolation, but that individuals engage in multiple pro-environmental activities. Their actions reflect the social and personal norms about the environment, which motivate these particular actions (Carlson, 2001; Babcock, 2009). Dietz, Fitzgerald, & Shwom (2005) note that a person's values are often related to self-reported behaviors, behavioral intentions, and measures that express an individual's concern for the environment. This suggests that an individual's values about the environment are reflected in their attitudes about environmental issues, which in tern are subsequently reflected in their behavior (Dietz et al., 2005). Additionally, one pro-environmental can indicate a person's engagement with other pro-environmental behaviors if they are reflective of similar environmental norms and values.

There is also a relationship between e-waste recycling rates and consumers' perception of how effectual their behavior is in influencing environmental change, a theory called Perceived Consumer Effectiveness (PCE). PCE is a framework for understanding how consumers perceive the impact of their consumption behavior, which can be influenced by their background (such as race, socio-economic status, education, etc.), general environmental knowledge, as well as cultural and personal norms (Chen & Tung, 2010; Ellen, Wiener, & Cobb-Walgren, 1991). If a person's PCE is high, they perceive that their actions have a direct effect on social and environmental issues, and thus value those actions more (Ellen et al., 1991). If PCE is sufficiently high, other factors such as perception of inconvenience carry less weight in decision-making, and a person will be more likely to engage in pro-environmental behaviors such as recycling (Chen & Tung, 2010). For example, people from lower socio-economic groups tend to be more willing to recycle their e-waste, even at a greater cost and inconvenience (Nixon et al., 2007). It has been suggested that low-income families perceive the environmental quality of their surrounding is "poor," lending urgency to environmental issues and implying that they perceive individual recycling efforts as effective (Nixon et al., 2007). Similarly, young people tend to recycle at higher rates because they perceive that environmental issues directly affect their lives and may reflect the shift in values in recent decades that emphasize environmental consciousness (Nixon et al., 2009). Differences between age groups, gender, rural and urban communities, and income greatly affect e-waste recycling incidence, and environmental awareness alone does not explain patterns of recycling behavior (Nixon et al., 2007). While PCE is very useful in explaining pro-environmental behaviors, it is inherently an indirect measure of many factors affecting recycling behavior and has not yet been applied to cellular phone recycling behavior.

Studies about electronic waste recycling and cell phone recycling behavior in particular often utilize only one analytical framework, setting limitations on the depth of understanding of motivations behind consumer behavior. My study seeks to determine what factors are most explanatory of cell phone recycling behavior from three different analytical frameworks: economic, environmental attitudes and behavior, and perceived consumer effectiveness. I use each of these three frameworks separately and then synthesize the frameworks to complement and strengthen my analysis, so that I can obtain a more comprehensive study of cell phone recycling behavior than past studies.

METHODS

Data Collection and Study Site

I administered paper surveys to 50 SF Bay Area residents, approaching them on Bay Area Rapid Transit (BART) along the Pitssburg Bay Point line. To obtain a feasible level of randomization, I asked every 4th person who I passed on the train to while walking from car to car if they would be willing to participate in my survey. If they were willing, I administered a paper survey, otherwise I asked them to complete an online version of the survey at their convenience.

I collected 109 online surveys from UC Berkeley undergraduate by sending the survey through email lists that I am subscribed to through campus employment. The email lists were not demographic or major specific so that the groups represented a good cross section of undergraduate students at UC Berkeley. The survey was analogous to the survey for the general population but asked for the students' major, type of residence (residence hall, apartment, coop) and year in school in addition to most of the demographic asked of the general population.

I used STATA statistical software program to run all statistical analyses. In order to increase my statistical power, I combined my student and BART samples for a total sample size of 159. I ran analyses separately if I believed that I would see a difference between the student and BART samples.

Survey Instrument

I collected a unique data set by developing and administering a paper survey to my study population. The survey consisted of four main sections to evaluate the factors effecting e-waste recycling behavior: perceived consumer effectiveness; social and personal perception of the environment and pro-environmental behavior; and demographics. I coded categorical and text responses and transcribed the survey answers into a spreadsheet format using MS Excel to aid in analysis.

Economic Incentives

Guiding hypotheses:

1. Perceived inconvenience of e-waste recycling will decrease a person's likelihood of recycling.

2. Increased exposure to e-waste and e-waste recycling information increases rates of cell phone recycling among individuals.

I tested the importance of an economic framework in explaining e-waste recycling by asking participants a number of questions about the convenience of recycling and about their exposure to information about e-waste. To document perceptions of inconvenience of pro-environmental behaviors, I asked respondents to give their reason for not regularly recycling bottles and cans. I ran a Fisher's Exact Test to test for a significant difference in cell phone recycling rates between those who said that bottle and can recycling was inconvenient compared to those who didn't. I also asked participants why they did not recycle their cell phone using an open-ended question. I coded the responses, including responses indicating that cell phone recycling was inconvenient.

Additionally, I assessed consumers' exposure to information about e-waste by asking if they had seen an e-waste advertisement in the past six months. I also assessed respondents' knowledge of e-waste policy by asking if is true that California bans cell phones in landfills. I used a chi-square test to determine whether there was a significant difference between those who answered correctly and those who answered incorrectly or were unsure. Finally, I asked respondents to evaluate their level of general environmental knowledge using a Likert scale.

Perceived Consumer Effectiveness

Guiding Hypotheses

1. PCE is influenced by demographics (race, gender, and age), information about electronic waste received and general environmental knowledge, perceptions of environmental quality, and environmental attitudes and behavior.

2. There is a positive relationship between PCE and recycling likelihood.

To measure PCE, I asked respondents to rank how strongly they agreed with two statements: "There is nothing any one person can do about the environment," and "The conservation efforts of one person are useless if others refuse to conserve." Respondents ranked their level of agreement with these statements on a scale of 1 (lowest) to 5 (highest). These rankings corresponded to an inverted rating of PCE—those who disagreed with the statements showed high PCE and those who agreed showed lower PCE. To reflect this relationship between the response and PCE, I created two variables: "PCE individual" and "PCE conserve" which correspond to the two questions respectively. Their values were the opposite values of the responses to the questions, so that a rating of 5 was a 1, 4 was a 2, 3 was a 3, etc. for the two PCE variables.

I used an ordered logistic regression model to estimate the effects of race, age gender, respondent's summed ratings of environmental quality in the SF Bay Area, California, the United States and globally, and their self-rating of environmental knowledge on PCE. Finally, to estimate the effects of PCE on cell phone recycling rates, I used a non-parametric test of trend analysis on the BART and student samples separately and also combined.

Social and Personal Perception of the Environment and Pro-environmental Behavior

Guiding Hypotheses

1. Those engaged in other pro-environmental behaviors are more likely to recycle their cell phone.

2. Those who perceive environmental quality to be low are more likely to recycle their cell phone.

I used at pro-environmental behaviors and attitudes as an indicator of cell phone recycling likelihood. I asked respondents if they recycle bottles and cans daily, and constructed a contingency table of beverage container recycling and cell phone recycling. Since counts in the cells were low, I used a Fischer's exact test to find an association between the two behaviors. Additionally, as an indicator of how much they value environmental sustainability and act on those values through consumption, respondents rated how much they agreed with the statement "When choosing between purchasing two products, I will buy the cheaper one even if the other is environmentally friendly." I used a non-parametric test of trend to test for a relationship between this environmental attitude and cell phone recycling.

To obtain a general measurement of respondents' general perception of environmental quality, I asked how they viewed the current quality of the environment at the global, national and local levels. Respondents answered these questions with Likert scale ranking, rating environmental quality as 1 if they believed that it was "very poor" and rating it as a 5 if they believed that it was "very good." I summed individuals' scores from each geographic level to get a continuous estimate of their view of general environmental quality, which increased variation between respondents and made it easier to analyze the data. Using a t-test, I tested if those who recycled their cell phone rated environmental quality lower than those who did not.

Logistic Regression Model

In conjunction to the individual analyses of the different frameworks, I also used a logistic regression that combined all of the different frameworks and their associated variables into one model. I constructed a simple multivariate model, which allowed me to see how the suite of variables worked together to explain the cell phone recycling behavior of respondents. Additionally, I used logistic regression to augment and strengthen my analysis of each individual framework, allowing me to determine how much of the variation in cell phone recycling behavior was attributable to the variables working in concert with each other, as opposed to my other analyses that looked at each framework individually. Only variables that were applicable to both study samples were used in this analysis, including demographics, information intake through news, environmental knowledge, perceived consumer effectiveness, environmental attitudes and behavior (see Table A4).

Demographics

Guiding Hypothesis

1. Demographic factors such as race, age, gender and income will significantly influence the likelihood of e-waste recycling.

I collected demographic information to serve as explanatory variables in my analysis, and as a check for the quality of my sampling method. I collected data on race, gender, income, education and occupation, which were kept confidential because of its sensitive nature.

These demographic variables were also included in my ordered logistic regression analysis of PCE and in the final logistic regression model to find their effect on cell phone recycling. They were also included in the analysis to separate the effects of demographic characteristics from the effects of the three analytical frameworks.

Non-recycling Behavior

Guiding Hypothesis

1. Those who did not recycle their last cell phone are likely to have stored it at home for future use or disposal.

While this study focused on e-waste recycling behavior, past studies found that a significant portion of electronics users held on to their electronic waste products after they were done using them. I incorporated an open-ended question about alternative uses and disposal methods into my survey to capture information about the end of use disposal methods that was open ended. I coded the responses into classifications based off the nature of the answer. I coded responses based on the open-ended question about alternative disposal, resulting in the following categories: storage, back up use, given away, lost, sold, and garbage. If a response included the words, or if the comment clearly described the practice without directly stating the behavior, it was coded in the respective category. Comments that included references to multiple behaviors were coded once in each category.

RESULTS

Sample Characteristics

I received a total of 159 survey responses, collecting 50 surveys from people riding BART riders and 109 student surveys. The semi-randomized BART sample was relatively balanced in terms of gender with 53% identifying as male; however, overall both samples were showed clear sampling biases. While about 47% of UC Berkeley's undergraduate population is male and about 30% identified as white, my sample was composed of 31% males and 44% white (UC Berkeley: Office of Planning & Analysis, 2011). These differences between my sample and the population as a whole may be attributed to the non-random sampling method of administering the survey to students.

Table 1. Average characteristics of sample

	Student	BART
College Grad	—	0.62
Male	0.3148	0.529
Age	20.55	36.43
White	0.4444	0.34

Student n=109 BART n=50

Recycling Behavior

I found that the majority of respondents had recycled some form of electronic waste at least once. Figure 1 shows that 54% of students had recycled an electronic device in the past compared to 73% of the BART respondents. The difference between the two rates was significant at the 10% level using a chi-squared test. There was no significant difference, however, between the cell phone recycling rates of the two groups. At 20% and 28% for students and BART riders, respectively, the results closely mirrored the estimated recycling rate in California of 27% (California Department of Toxic Substances Control, 2010). Figure 1 summarizes the e-waste recycling behavior of the two groups.

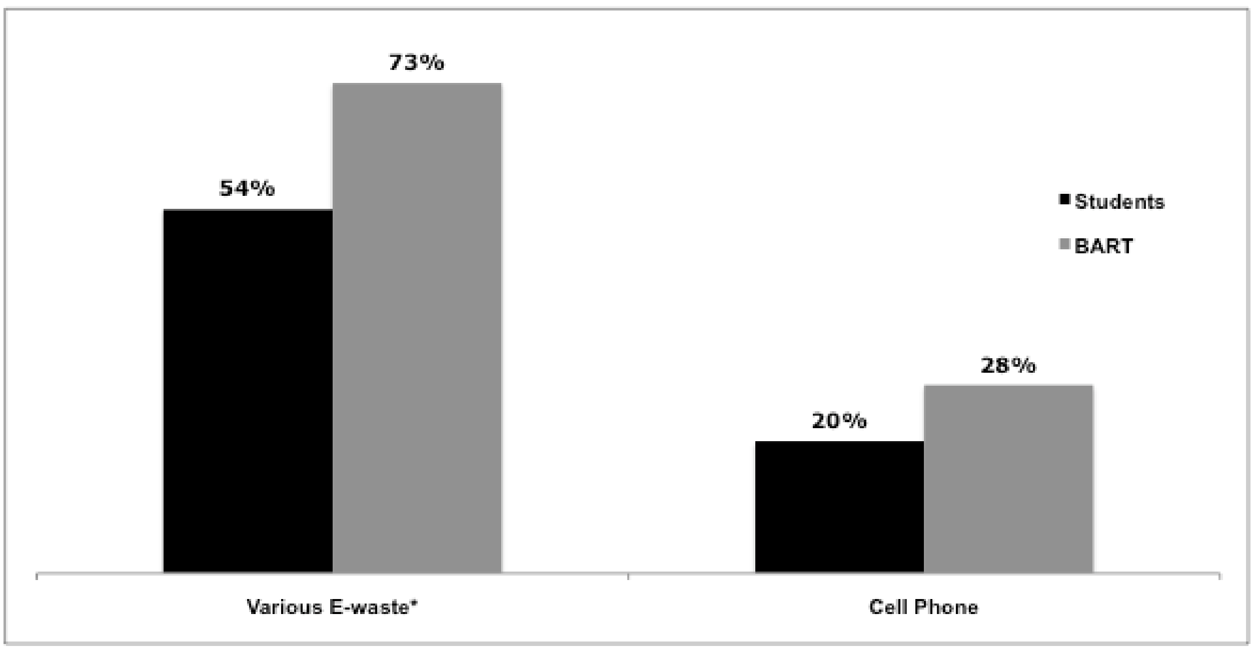

Figure 1. Electronic waste recycling behavior. Students n=109 and BART n=50. *Difference in recycling rates significant at the 10% level.

Economic Incentives

I did not find a significant relationship between inconvenience and cell phone recycling rates. There was no significant difference between cell phone recycling rates of those who said that can and bottle recycling was inconvenient and those who did not (Table 2). Additionally, only 6% of non-recyclers commented that the inconvenience of cell phone recycling was a driving factor in their decision not to recycle their phone.

Table 2. Economic hypothesis results

Hypothesis	Variable	% Who Recycled If 0	% Who Recycled If 1	n	df	Pearson $\chi 2$	p
Lack of Information	Advertisement***	14.29%	37.04%	159	1	10.7524	0.001
	True: Landfill Ban*	17.35%	29.51%	159	1	3.2391	0.072
	Knows recycling site***	13.04%	41.51%	122	1	12.8154	0.000
						Fisher's Exact	1-sided Fisher's Exact
Inconvenience	Container Recycling Inconvenient	20.39%	0.00%	109	1	0.34	0.219

Significance: *p<0.1; **p<0.05; ***p<0.001
Only students indicated that beverage container recycling was inconvenient.

By comparison, 27% of non-recyclers cited a lack of information as a barrier to cell phone recycling (Figure 2). I found significant, positive correlations between cell phone recycling rates and information. Those who had seen an advertisement about e-waste in the month before taking the survey, those who knew that there was a ban on cell phone disposal in landfills, and those who knew of a cell phone recycling site were significantly more likely to recycle their electronic waste. For example, Table 2 shows that 37% of respondents who had seen an advertisement in the past month had recycled a cell phone, compared to a recycling rate of 14% for those who did not— a difference significant at the <1% level.

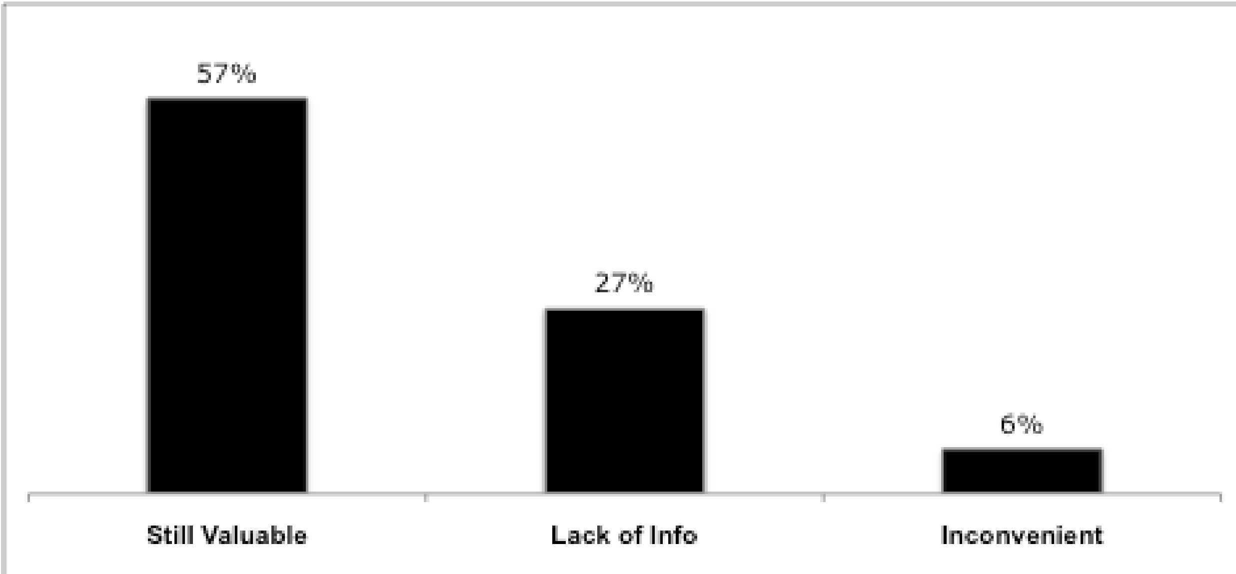

Figure 2. Common reasons for not recycling. Given as a percentage of responses indicating non-recycling behavior. A single user could respond with multiple answers, which were independently coded. Number of non-recyclers =108

Perceived Consumer Effectiveness

Using a non-parametric test of trend, I found that there was a positive relationship between PCE and cell phone recycling rates for students but did not find a significant relationship for the BART sample or for the sample as a whole (Table 3). The results from the student sample were significant at the 5% level and showed that as perceived consumer effectiveness increased, the individual was more like to recycle their phone.

Table 3. Relationship of Perceived Consumer Effectiveness with cell phone recycling. Non-parametric test of trend was used to analyze the relationship.

	All		Students		BART	
	z	p>|z|	z	p>|z|	z	p>|z|
PCE Individual	1.310	0.190	2.19**	0.029	-1.250	0.211
PCE Conserve	1.180	0.236	2.14**	0.032	-1.070	0.284

Significance: *p<0.1; **p<0.05; ***p<0.001

The ordered logistic regression analysis, which modeled the two PCE variables as dependent variables, found that respondents who identified as White or Asian were less likely to have a high PCE. Additionally, Tables A1 and A2 show that as age correspond to slight increases in PCE. Finally, there was a significant negative correlation between ratings of environmental knowledge and perceived consumer effectiveness. I also found that the likelihood of having a high PCE rating increased with the number of news stories about the environment that an individual is exposed to.

Environmental Attitudes and Pro-environmental Behavior

People who had a more negative view of environmental quality were marginally more likely to recycle their electronic waste but by a marginal amount, and they were more likely to recycle bottles and cans regularly, most commonly citing concern for the environment as the key reason for doing so. I found that perceptions of environmental quality were highly correlated with PCE among both students and BART riders, so that those who had a more negative view of environmental quality also responded to questions corresponding to a higher PCE. I found this relationship to be significant for both students and those surveyed on BART.

I also found that those who prioritized pro-environmental behaviors were more likely to recycle their cell phone than others. I found that those who responded that reducing waste important to them were marginally more likely to recycle their cell phone, a relationship that is significant at the <1% level (see Table 5). I also individuals who were likely to buy cheap products of similar “green” products were less likely to recycle their cell phone.

Table 4. Relationship between environmental attitudes and cell phone recycling

	z	p>|z|
Reducing Waste Important***	3.210	0.001
Buy Cheap Products***	-3.830	0.000

Significance: *p<0.1; **p<0.05; ***p<0.001

Logistic Regression

Results from the logistic regression estimate reflected the results from the independent analyses. Environmental quality, having seen an e-waste advertisement, number of cell phones owned in the past year, number of electronics owned, and whether the individual was white were found to be significant explanatory variables. While advertising and cell phones owned were both positively correlated with cell phone recycling, supporting my hypothesis about the direction of the relationship, environmental quality (+), number of electronics owned (-), and white (+) did not go in the direction that I thought they would. Environmental quality and identification as white both were found to negatively contribute to PCE rating, which was found to be positively correlated with cell phone recycling rates.

Non-recycling behavior

Surprisingly, only 2% of students and 3% of BART riders who did not recycle actually threw away their last cell phone, leading to disposal in a landfill. I found that the vast majority of respondents were storing their cell phone (67% of students and 61% of BART commuters), and 10-11% of them indicated that they were saving their phone as a back up, in case their current phone became unusable for some reason. Figure 3 summarizes the comments based on non-recycling disposal method.

Figure 2 shows that many respondents did not want to throw away or recycle their phone because it still retained value—monetary value and sentimental value manifest through stored pictures, files and contact information. 57% of non-recyclers indicated that they were retaining their old cell phone because the device was still valuable to them.

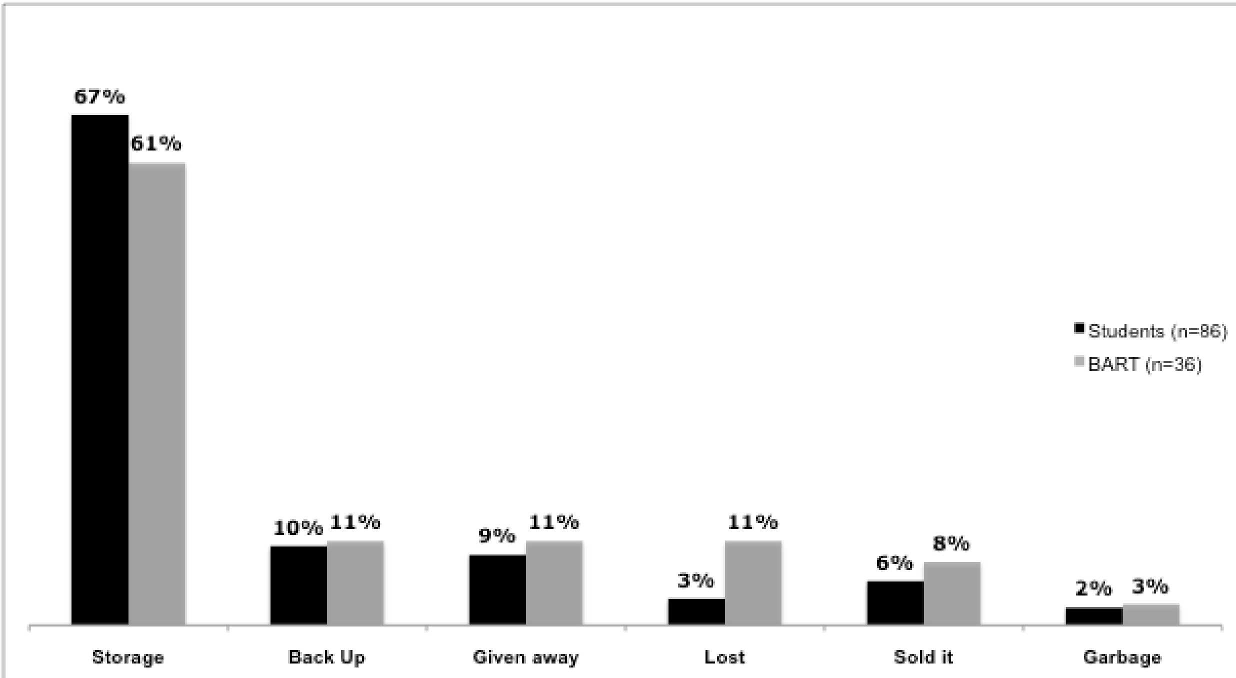

Figure 3. Alternative disposal methods to recycling by those who did not recycle their phone.

DISCUSSION

Key Findings

My multivariate logistic regressions did not suggest any significant relationship between the probability of recycling and variables relating to Perceived Consumer Effectiveness, information, or demographics, and chi-square tests demonstrated no significant difference in the proportion of phone recycling by students and BART riders. However, BART commuters did recycle general e-waste at higher rates than the student population. This difference may be explained by the fact that the general population, which is older with a more settled lifestyle, may consumer electronics at higher rates than students with typically more limited means. Students recycled at a rate of 20% and BART respondents at a rate of 28%, which is at the upper end of recycling rate estimates and is similar to the EPA's estimates of recycling rates in California (US Environmental Protection Agency, 2008).

I found that the guiding hypotheses of my study were largely supported by my findings, and that the multiple analytical frameworks that I employed facilitated deeper understanding of cell phone recycling behavior. My results showed that many consumers store post-use cell phones because the still hold value. While I found that information, PCE, and pro-environmental behaviors and attitudes were all positively correlated with cell phone recycling likelihood, perceived inconvenience was not significantly associated with rates. This may suggest that proliferation of cell phone recycling sites may not have as large an impact on overall recycling rates compared to government sponsored advertising and information campaigns.

Economic Incentives

Contrary to my hypothesis, I did not find a significant relationship between perceived inconvenience of cell phone recycling and recycling rates. While inconvenience was a cited as a reason for not recycling in both populations, only 7 people indicated that this was a deterrent for them. This contradicts other e-waste recycling motivation studies that found that perceived inconvenience of the recycling process was a huge barrier for consumers (Darby & Obara, 2005). My results suggest that inconvenience is not the most important factor driving the cell phone recycling behavior of consumers, but it is likely that it is still an important to factor that was not effectively elicited by my survey instrument. Most importantly, I asked an open-ended question about why the respondent did or did not recycle their last cell phone, which returned many different responses that were coded by me. While this method allows for the respondent to elaborate on their experiences and motivation in detail, categorical responses could have queried the issue of inconvenience more explicitly (Nardi, 2006).

Following my hypothesis that increased dissemination of information and knowledge about electronic waste recycling will increase rates; I found that 25% of students and 31% of BART riders cited lack of information as the key reason for not recycling. Figure 2 shows that this was the second most frequent reason given for not recycling. Additionally, the results of my chi-square analysis demonstrated that those who knew that there was a ban on cell phone disposal in landfills were more likely to have recycled their phone, suggesting that informing the public about the cell phone laws and existing recycling sites could lead to an increase in recycling rates. A simple search for “cell phone recycling in Bay Area” generates dozens of potential means of recycling through drop off locations, mail-in services, and recycling drives. But getting this information requires that a person be aware that cell phone disposal has unique issues from other types of waste, and that cell phones should be recycled. In fact, 31% of students and 46% of BART respondents had seen an advertisement about electronic waste recycling in the past month, suggesting that promotion is already effectively reaching some groups of people. It seems likely that advertisement about e-waste recycling by the EPA or environmental groups could motivate consumers to look into recycling methods when they consider how to dispose of their phone.

My findings using an economic framework, suggest that lack of knowledge about proper disposal is the biggest barrier to cell phone recycling, supporting the findings of past studies that highlight lack of knowledge about the e-waste problem and proper disposal (Macauley et al., 2003; Ongondo & Williams, 2011; Saphores et al., 2009). While many people received information about e-waste recycling in some form, as evidenced by the number of people who had recently seen an advertisement about e-waste recycling, this often did not translate to action. Carlson (2001) argues that environmental awareness is not enough to encourage pro-environmental behavior; instead, she emphasizes the importance of convenience in shaping consumer decisions. While this is one possible reason why cell phone recycling rates are low, Figure 2 shows that lack of information was cited more times as a main reason why an individual did not recycle, suggesting that inconvenience is less of barrier than the lack of enough information to promote action.

Surprisingly, I found that most non-recyclers did not recycle their cell phone because they believed that their phone was still valuable in some way. About 6% of students and 8% of BART respondents indicated that they had sold their cell phone, and 9% and 11%, respectively, indicated that they had given it away for someone else to use. Additionally, 10 % of students and 11% of BART respondents indicated that they retained their phone after use because it was still functional and they wanted to keep it as a backup. This suggests that the perceived latent value of the phone, which is a real dollar value in addition to sentimental and emotional value for some people, is the main barrier to increased cell-phone recycling rates. This may denote a particularly important difference between cell-phone recycling and beverage container recycling—consumers do not see their phones as trash.

Many respondents indicated that they were keeping their cell phones for future recycling trips or, most commonly, they were holding on to their phones because they believed that the phone was still valuable as a back up or possibly to sell. This reflects the findings from Saphores et al. (2009) that showed that consumers stockpile their e-waste until they find a convenient time to dispose of it. The unique nature of electronic waste compared to most other things that enter the traditional waste stream or are more commonly recycled, like bottles, cans, paper and other refuse, may account for this. Cell phones retain value even after their owner no longer uses them, and this is likely one reason why recycling rates remain low. One respondent commented that they had sold their old phone to someone for $200. While this phone’s resale value is quite high, the comment reflects the fact that used cell phones maintain much of their value even after they are done being used by the owner. Thus rational consumers would be inclined to hold on to their phones even though they are not being used. In general; however, older cell phones (or e-waste in general) are more likely to be recycled or thrown out first because their value has depreciated and newer, more advanced models have replaced it.

The use of incentives has been suggested to increase recycling rates in order to overcome barriers associated with latent value. Importantly, these incentives need not be monetary. For example, one respondent commented that she was motivated to recycle because her cousin received a point for every cell phone they collected in a recycling competition for their school. Similar programs that offer reward points at retail stores or discounts on new phone purchases would likely be very successful.

Perceived Consumer Effectiveness

Perceived consumer effectiveness was influenced by demographic characteristics, information and environmental attitudes; however, analysis in this section was somewhat limited. While income has been shown to be related with PCE–with lower socio-economic groups generally have higher PCE and middle and high-income groups have lower PCE (Ellen el al., 1991)— I omitted income from my analysis because many of the BART riders felt uncomfortable reporting that information, and many gave what appeared to be annual income instead of the requested monthly income. The inconsistency in responses meant that the variable was not obtainable from my sample. I found that people who identified as white or Asian were more likely to have lower PCE than other groups, and this was a significant relationship. Ellen et al. (1991) suggest that minority groups are often disproportionately impacted by environmental degradation, and as a result may more active stakeholders on environmental issues than majority racial groups. She found that minority groups had higher levels of PCE, contrary to conventional theories of pro-environmental behavior that usually posit that white individuals are more likely to engage in environmental activities (Ellen et al., 1991).

I found that those who ranked environmental quality high were less likely to have a higher PCE. While this seems counter-intuitive, it's been suggested that individuals might not believe that their actions will have a significant impact on the environment because environmental quality is already relatively high (Ellen et al., 1991). Additionally, people may perceive that "easy" changes have already been made, so individual consumer decisions may be ineffective in comparison to collective actions (e.g. government intervention, community organizing, corporate stewardship) that are perceived to have a larger impact (Ellen et al., 1991; Carlson, 2001).

I did not find a significant association between cell recycling rates and PCE for the entire sample and for the BART sample, but there was a positive and significant relationship for the student population. While my results from this analysis were not uniformly significant, the positive relationship within the student sample suggests that my hypothesis is valid. It is likely that the small BART sample size may be why I did not find a significant relationship for that sample and the general sample, and I believe that the trend seen for students is generalizable for the general population as well since it both supports and is supported by theory. Thus, it seems likely that those who perceive that their actions have a significant impact on the environment—at the individual level— are more likely to recycle their phone. Ellen et al. (1991) support this finding in addition to several other PCE studies. This suggests that advertisements and information campaigns should be constructed to empower the consumer as well as inform them of the benefits of cell phone recycling. This would increase Perceived Consumer Effectiveness and in turn increase the recycling rate of cell phones.

Social and Personal Perception of the Environment and Pro-environmental Behavior

I found that respondents who showed more engagement with pro-environmental behaviors and attitudes were more likely to recycle their cell phone. A Fisher's exact test demonstrated that there was a significant relationship between cell phone recycling and beverage container recycling, indicating that those who regularly recycle are more likely to recycle their cell phone. Though not surprising, this result is interesting because beverage recycling has been in place in California for about four decades and has become habit for most people (about 92% of my sample said that they regularly recycle beverage containers), while cell phone recycling has only been a pressing environmental issue for about a decade (Carlson, 2001). My results suggest that daily one's disposition toward daily pro-environmental behaviors can be used as an indicator of actions that happen far less frequently— like cell phone recycling.

My results also showed that pro-environmental consumer behavior can be used to explain cell phone recycling. I used one's willingness to buy a cheap product over a similar, more costly environmentally friendly product, as an indicator of pro-environmental consumer behavior. I found that those who were less likely to buy the cheap product over the green product were more likely to recycle their cell phone. This supports my hypothesis, and suggests that environmentally conscious consumption could also be used as an indicator of end-of-use behaviors. Individuals who are willing to incur the added cost of the environmentally friendly product are probably more likely to act similarly for other pro-environmental behaviors. This may be what I am observing in my sample — individuals who are willing to incur the added costs from environmental behavior are also more willing to forego benefits from the latent value of their phone, are more likely to take time to research and to travel to recycling sites.

Non-recycling Behavior

I found that only 2% of students and 3% of the BART sample threw their cell phone in a trashcan, while the majority (67% of students and 61% of BART respondents) put their phones in storage. Once respondent's comment about storage provides insight into this finding, "I don't know of any place to recycle my cell phone. My previous cell phones are in a drawer somewhere." Many comments echoed this person's experience with disposal: not being sure about when or where to recycle their cell phones many users set their devices in a drawer that serves as the household e-waste depository. This suggests that the majority of end-of-use devices is diverted from the landfills and is being put into storage. This means that the potential hazard from toxics and metals polluting landfills from traditional disposal of cell phones is already low and is likely decreasing over time as well, as recycling rates continue to rise in the state (site toxics substances).

A number of people (10% students and 11% BART) said that they were holding on to their phone so that they could use it for future use, suggesting that there is already a culture of reuse, which has been promoted by the phones' latent value. One respondent commented, "I didn't recycle it because I wanted to keep it. It is more beneficial for me to have it as a back up, to use in the event that my current phone should break. Using an old phone is a lot cheaper than buying a new phone." This comment indicates that the mobile phones don't just have resale value, but are also valued by the consumer for the convenience of being able to reuse them in case another phone is lost or broken. Studies have primarily focused on cell phone recycling; however, a significant amount of cell phone divergence from landfills does not occur through recycling mechanisms but through reuse and resale (Saphores et al., 2009). This leaves room for future studies to expand on current recycling research, potentially focusing on reuse and resale of phones as a pro-environmental behavior.

The difference in the number of people that have phones in storage compared to other disposal methods is striking (See Figure 3). As millions of phones continue to be produced annually, it is important to account for the growing stockpile of phones that vastly outnumbers the amount of cell phones recycled annually (Saphores et al., 2009). This suggests that serious analysis of e-waste recycling must not solely focus on increasing recycling rates, but on processing the tons of stored cell phone waste growing in the US. So while the immediate indicators of cell phone recycling are encouraging in California, there is potential for substantial improvement in order to capture and process current and future e-waste.

Limitations

Sample size, sample method, the uniqueness of my study system, and the scope of my statistical analysis limited my study. Due to time limitations stemming from the high amount of effort exerted to conduct my in person survey, I was unable to obtain a sample size sufficient to obtain a good level of statistical power. Additionally, my student survey collection was non-randomized which limited the balance in my sample demographics. I attempted to mitigate the effects of these limitations by combining the student and BART samples for more statistical power. Though concerns about the external validity of my sample are valid, my results largely supported my hypotheses, which were formulated based off of theory. This suggests that my sample and analytical methods are not invalidated, and that inferences made could be applicable to the wider Bay Area.

Since I sampled on BART I only captured a tiny subset of a specific type of Bay Area commuter. While BART passengers are diverse demographically, they might differ from people who commute by other means in terms of environmental attitudes and behaviors and other unobservable factors that would bias the results. Furthermore, since two thirds of my sample was comprised of students, my results may reflect the biases associated with higher education attainment than the general population and exposure to pro-environmental discourses. Additionally, the Bay Area is known for its environmental consciousness compared to other American regions, and is politically left leaning. Because of this, my study is most suited to make inferences for Bay Area residents, but it is less applicable to other areas of the state and the country.

Future Directions

Despite the limitations of this study, my findings are compelling. Using a sampling method that is more randomized, such as a mail-in surveys, could produce more significant findings, and would provide more clarity on cell phone recycling behavior. Additionally, this study serves as a first look into the current state of cell phone recycling. Since Nixon et al. (2007) conducted their study using a mail-in survey of Californians there has been virtually no published research on consumer behavior regarding cell phone recycling. Since then, millions of phones have entered the market and mobile technology has become more integrated into the collective consciences of American consumers. We need further behavioral studies that combine multiple theoretical frameworks to better understand how well we are handling the e-waste problem. Studies such as this one that combine multiple theoretical frameworks are able to look at cell phone recycling holistically.

While my results did not show that inconvenience was a major contributor to low e-waste recycling rates, perceived inconvenience of taking phones to recycling centers or kiosks in stores may be implicitly bound in the motivations of those who are storing their cell phones for future disposal. Research using Geographic Information Systems would certainly help to precisely estimate the effect that proximity to recycling locations has on recycling rates. This approach could be used to create a map of possible cell phone recycling sites, which people could use to find their closest recycling option. My research also suggests that targeted information campaigns would effectively increase recycling rates. This would shift from current regulatory policies and enforcement (which is essentially unfeasible at the individual consumer level) to educational policies, which is able to reach millions of people simultaneously through television, radio, print, and social media advertising. Potentially, this could drastically increase recycling rates, especially for those individuals who are currently hoarding multiple devices, and is more cost effective than other interventions.

Broader Implications

As our technology continues to advance, more and more people are using cell phones as their primary means of communication, and there are millions of people entering adulthood who cannot remember a time *without* cell phones. With the changing consumer base, and the number and the diversity of cell phones, it is important to clearly understand how consumers are disposing them after use. Studies such as this one can help us to strategically use our limited resources on educating our public about the importance of cell phone recycling, on making it more convenient to recycle, and to target specific groups of people to use our resources most efficiently.

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APPENDIX

Table A1. PCE individual ordered logistic regression results

Variable	Odds Ratio	SE	z	p
"Government is doing enough to protect the environment.'	0.760	0.205	-1.020	0.309
"Electronics companies are doing enough…"	0.929	0.221	-0.310	0.757
Environmental Knowledge	0.915	0.206	-0.400	0.692
Number of news stories about the environment	1.091	0.058	1.630	0.102
White**	0.371	0.160	-2.290	0.022
Asian**	0.387	0.186	-1.970	0.048
Age**	1.038	0.019	2.010	0.044
Male	0.706	0.261	-0.940	0.346
Environmental Quality***	0.790	0.066	-2.820	0.005

Significance: **p<0.05; ***p<0.001

n=134 df=9 LR c2= 28.81 p>c2=0.0007

Table A2. PCE conserve ordered logistic regression results

Variable	Odds Ratio	SE	z	p
"Government is doing enough to protect the environment."	0.862	0.231	-0.550	0.580
"Electronics companies are doing enough…"	1.038	0.247	0.160	0.875
Environmental Knowledge	0.800	0.180	-0.990	0.320
Number of news stories about the environment**	1.121	0.057	2.250	0.024
White	0.581	0.248	-1.270	0.203
Asian	0.463	0.219	-1.630	0.104
Age*	1.035	0.018	1.940	0.052
Male**	0.451	0.163	-2.200	0.028
Environmental Quality	0.940	0.074	-0.780	0.436

Significance: **p<0.05; ***p<0.001

n=134 df=9 LR c2= 19.72 p>c2=0.0197

Table A3. Logistic regression estimates

Measure	Mean	SD	b	SE	z	*p*	e (Odds Ratio)
Student	0.686	0.466	-1.926	1.430	-1.350	0.178	0.146
Reducing waste is important	4.132	0.858	-0.094	0.512	-0.180	0.854	0.910
PCE	3.761	1.076	0.611	0.450	1.360	0.175	1.843
PCE (others do not conserve)	3.421	1.171	-0.321	0.402	-0.800	0.424	0.725
Environmental quality**	11.077	2.166	0.548	0.215	2.550	0.011	1.730
Number of news stories about the environment	2.779	4.252	-0.012	0.082	-0.140	0.886	0.988
Newspaper main newsource	0.654	0.477	-0.095	0.800	-0.120	0.905	0.909
Has seen an e-waste advertisement**	0.340	0.475	1.363	0.724	1.880	0.060	3.908
Environmental knowledge	3.359	0.850	0.807	0.632	1.280	0.202	2.242
Knows of landfill ban	0.384	0.488	1.420	0.839	1.690	0.091	4.135
Knows an e-waste recycling site	0.434	0.498	1.206	0.812	1.480	0.138	3.339
New phone in the past year	0.548	0.499	0.576	0.901	0.640	0.523	1.779
Number of years with current phone	1.978	1.694	0.079	0.286	0.280	0.782	1.082
Number of cell phones in the past year***	1.088	0.791	2.067	0.754	2.740	0.006	7.902
Number of electronics owned**	6.395	4.993	-0.320	0.154	-2.080	0.037	0.726
Age	25.474	10.428	0.038	0.041	0.910	0.363	1.038
White**	0.429	0.496	2.321	0.986	2.350	0.019	10.190
Asian	0.318	0.467	1.108	1.167	0.950	0.342	3.029
Male	0.392	0.490	-0.043	0.839	-0.050	0.959	0.958
Constant***			-15.449	5.350	-2.890	0.004	-

Significance: *p<0.1; **p<0.05; ***p<0.01

$\chi^2 = 48.08$ p= 0.0003 *df*=19 n=99