UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Thinking in 3D: The Effect of 3D Boxes on Waste Sorting Accuracy

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Executive Summary

Waste sorting accuracy has long been a problem for sustainable waste management. One proposed solution is the placement of 3D signage as a guide for people to sort waste. Previous literature found that 3D signage had zero to a minimal increase in sorting accuracy. This study examines the impact of additional 3D boxes on sorting accuracy at the UBC AMS Nest. The study was conducted over the course of two weeks, with one week for each of the conditions. A waste sorting station by Pie R Squared was observed during lunch hours from 12-2pm over the course of two weeks with one week allocated for each condition. In the control condition, the sorting station only had 2D signage while 3D signage was added along with the 2D signage in the experimental condition. Data was collected in the form of photographs of the top of each waste bin. The results from statistical data analysis showed the difference between the two conditions to be insignificant. We concluded that 3D boxes are cost-inefficient based on the results of this study and previous studies, and suggest utilizing a manned, food court style waste sorting station as an alternative solution to sorting accuracy.

Introduction

Previous studies done on waste sorting have highlighted both the benefits and flaws of 3D signage. A 2013 study done in the University of Washington had found that the addition of 3D visuals on the university's waste bins increased the accumulations of compost and recyclables relative to trash (Johnson, 2013). However, replications of Johnson's study at the University of British Columbia found that implementation of 3D boxes had found either no increase or a marginal increase to sorting accuracy. Fu et al. (2016) examined the effect of 3D boxes on waste sorting accuracy at UBC's Stir it Up Cafe in the Buchanan A Building. They found no differences in sorting behaviour with the addition of 3D boxes on waste bins and also found that less than 50% of people they surveyed were paying attention to the 3D boxes' contents. Additionally, a 2017 SEEDS project by Waugh et al. investigated the effect of 3D boxes on garbage sorting accuracy in the UBC AMS Nest by comparing 3D boxes and conventional 2D3D signage with 3D boxes alone. Their results showed only a marginally higher rate of sorting accuracy under the combination of 3D box and conventional sorting signage. The differences in these previous studies' findings serve as the motivation for our current project.

Research Question

What is the impact of additional 3D boxes on sorting accuracy at the UBC AMS Nest?

Hypothesis

We hypothesized that the installation of 3D display boxes alongside conventional recycling signs would improve people's waste sorting accuracy and reduce contamination, but with only minimally significant effects. The rationale behind our hypothesis is due to the fact that previous studies done at the University of British Columbia have found little to no impact on waste sorting with 3D boxes (Fu et al., 2016; Waugh et al., 2017).

Methods

Participants

The participants for this study included students, staff, and visitors using the waste sorting station located at Pi R Squared in the UBC AMS Nest on weekdays. This study was conducted in an uncontrolled environment such that every individual who visited the UBC AMS Nest would have an equal opportunity to use this particular waste sorting station.

Conditions

There were two conditions for this study - the control condition and the experimental condition. The control condition had the waste sorting station located at Pi R Squared with the original signage without additional 3D boxes. The control condition occurred for one week between the period of March 6th, 2019 to March 12th, 2019. The experimental condition used the same waste sorting station, this time with additional 3D boxes alongside with the original signage. The experimental condition occurred for one week between the period of March 13th, 2019 to March 19th, 2019.

Measures

In this study, we used a quantitative measure to determine the effect of the additional 3D boxes at the waste sorting station. We visually inspected the top of each waste bin to determine the percentage of contamination in the two conditions. After consulting with Bud Fraser from UBC Planning and Sustainability, we decided to place items that we would be able to find at Pi R Squared and the UBC AMS Nest inside the 3D boxes. Since the 3D boxes were transparent, we used coloured paper at the back of the 3D box to match the colour of the waste bin. There are four waste bins at the sorting station: compost, recyclable containers, paper, and garbage. In the composite 3D box, we placed napkins, wooden chopsticks, paper plates, paper straws, and compostable containers. In the recyclable containers 3D box, we placed a soda can, a glass bottle, a plastic cup, and a paper cup with a plastic lid. In the paper 3D box, we placed cups sleeves and newspaper. In the garbage 3D box, we placed plastic straws, plastic utensils, plastic bags, and plastic candy wrappers.

Procedures

In our study, we observed the waste sorting station located at Pi R Squared in the UBC AMS Nest during the time range between noon and 2 pm for both conditions. To collect data, we took photographs of the tops of each the four waste bins (composite, recyclable containers, paper, and garbage) at the waste sorting station once for each day for both conditions. During the first week/control condition, the waste bins only had conventional sorting signage to assist people with sorting waste. After a week of observing and collecting data with the control condition, our research team installed four 3D boxes above the existing conventional sorting signage over each of the four waste bins with various objects inside them to demonstrate which items should be placed in the appropriate bin. With the 3D boxes installed, we repeated the process of observing the bins for one week at the time range between noon and 2 pm and collected data by taking photographs of the top of each of the four waste bins once each day.

Results

Data Handling

To transfer images into statistical data, we have counted the number of garbage of each image and labelled the incorrect garbage. The garbage sorting accuracy is reflected inversely by the level of contamination; for example, a contamination level of 60% has less garbage sorting accuracy than a contamination level of 55%. We gave each image a contamination score, which is calculated by the number of wrong waste items divide by the total waste items in each individual bin. After the calculation, we first recorded fraction scores that directly show how many waste items are accounted for as the "wrong throw." We then converted fractions into percentages, which was further used by descriptive data analysis. The primary statistical values that we are investigating are the mean, and the standard deviation of contamination level of each individual bin over the five-days observation, as well as the p-value of the two-sample test, to see the difference of mean between the control group and experimental group.

Data Analysis

All of the statistical data was analyzed by the Excel spreadsheet. A two-sample T-test was conducted, and the result revealed an insignificant difference among the controlled group and 3D box group, t (18) = -0.13, p= .55, with slightly lower sum average contamination percentage (M=37%, SD=35%)) of 3D box condition. Furthermore, we broke down and analyzed garbage sorting accuracy in each waste category. To begin with, we found that in both control and 3D box condition, compost category suffered the least from contamination averaged at 22% (SD= 43.81%) and 4%(SD=6.45%) respectively. Even though it seems like a significant increase in sorting the correct compost, both groups have exactly three days that had a contamination-free compost bin. And in the only two days with contamination, the control group had considerable larger variance from 100% contaminated down to 10% contaminated. While in the experimental group, the contamination level was comparably close in these two days. (14% and 8%). Moving to the Recycling category, both conditions showed a moderate contamination level with 34% (SD=7.92%) for the control group and 29%(SD=18.22%) for experiment group. In the paper category, 3D box demonstrated some effect on reducing contamination, with CL 74% (SD=26.89) for the control group and dropping to 58% (SD=48.92%) after the installation of 3D boxes. In the garbage category, the 3D box has again helped improve the sorting accuracy, in which the CL declines from 63%(SD=26.07%) to 57%(SD=25.08%).

Discussion

The results of our analysis showed that adding 3D boxes to increase sorting accuracy is insignificant based on our P value of .55. Therefore, we reject our hypothesis that the installation of 3D display boxes alongside conventional recycling signs will improve people's waste sorting accuracy and reduce contamination. Although we did find a decrease in the contamination levels of the compost, recycling, paper, and garbage category between the control group and 3D box condition, it was not enough to produce a statistically significant p-value. These results suggest that Fu et al.'s (2016) study on examining the effects of 3D boxes on waste sorting accuracy at UBC's Stir it Up Café is supported as our results also did not produce any significant increase in sorting accuracy.

Limitations

Sorting the number of items through the use of digital images in each waste bin proved to be difficult for both the control and experimental condition since our study relied upon visual inspection. This limitation may have played a factor in giving a more accurate standard deviation concerning the contamination levels and a slightly higher P-value between the control and 3D box condition. Based on the Client's Student Waste Auditing Guideline, we recommend that in future studies, students use the Full Waste Audit since it provides a more accurate and standardized approach when measuring sorting accuracy between different bin categories. This method might yield a more statistically significant result that supports Johnson's (2013) findings on adding 3D visuals on the university's waste bins, increases the accumulations of compost and recyclables.

Another limitation is our uncontrolled environment since we could not control the number of individuals that would visit the Pi R Squared waste sorting station. Therefore, we could not set a standard sample size that would help divide individuals into different treatment groups so that we could gain a more statistically significant result and observe for different variables such as which individuals would be more likely to do a "correct throw" or their decision-making time when visiting the waste sorting station. The time in which our study was conducted in could also explain our insignificant P-value. Since we conducted our study during 12-2pm, individuals were either in a rush to find meals or get to their classes so the rate of their movement may have played an error in their decision making when visiting the waste sorting station.

Recommendations for UBC Client

Based on our findings, 3D boxes may not be the best solution to the improvement of waste sorting accuracy. We believe an alternative solution that could be used in place of 3D boxes is the introduction of a food-court style, manned waste sorting station in the AMS Nest. This will not only create more jobs at UBC, but is also a more cost-effective option than utilizing 3D boxes that cost thousands of dollars. Most importantly, the incorporation of a sorting station will more or less ensure that the waste coming through will be properly sorted with trained employees operating the stations.

References

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Waugh, B., Schmidt, F., Cheung, R., & Quon, S. (2017). Taking an Environmental Step into the 3rd Dimension. Retrieved February 12, 2019, from https://sustain.ubc.ca/sites/sustain.ubc.ca/files/seedslibrary/Visual Prompts for Sorting Waste 3-D Displays and other Waste Signage_0.pdf.

Appendix

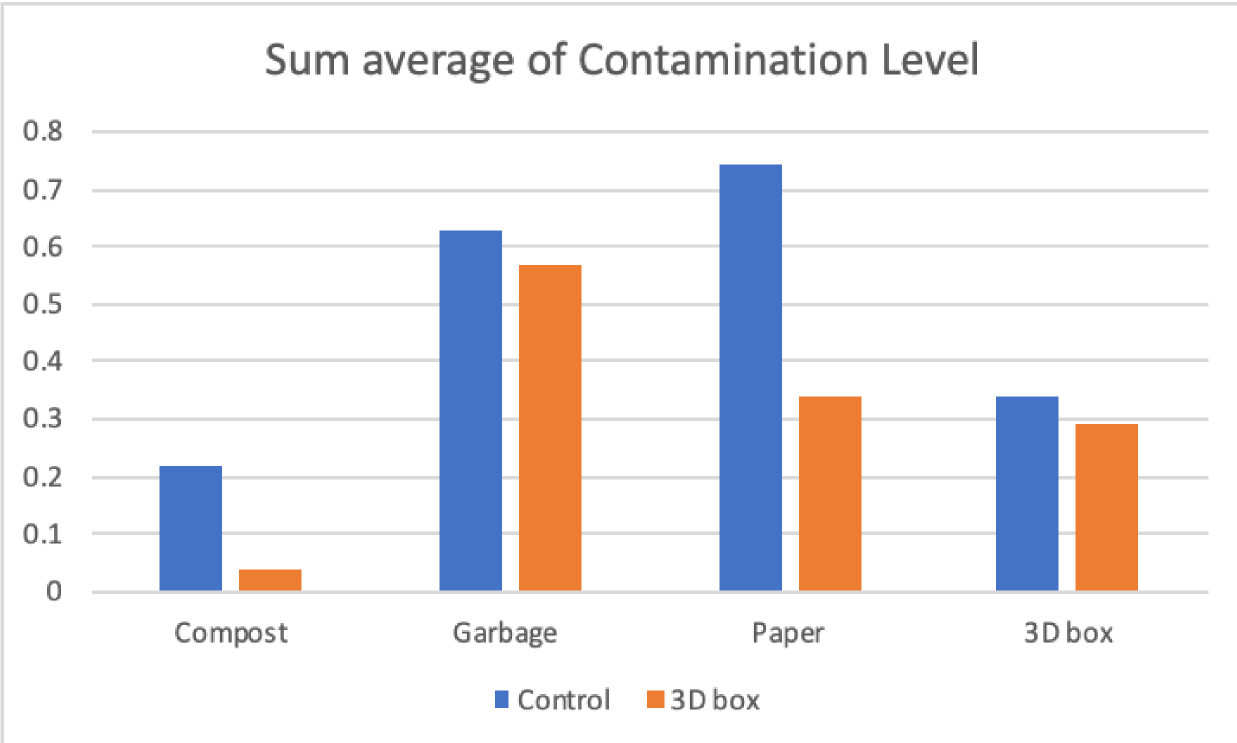

Figure 1. Sum average Contamination proportion of each waste category in each condition

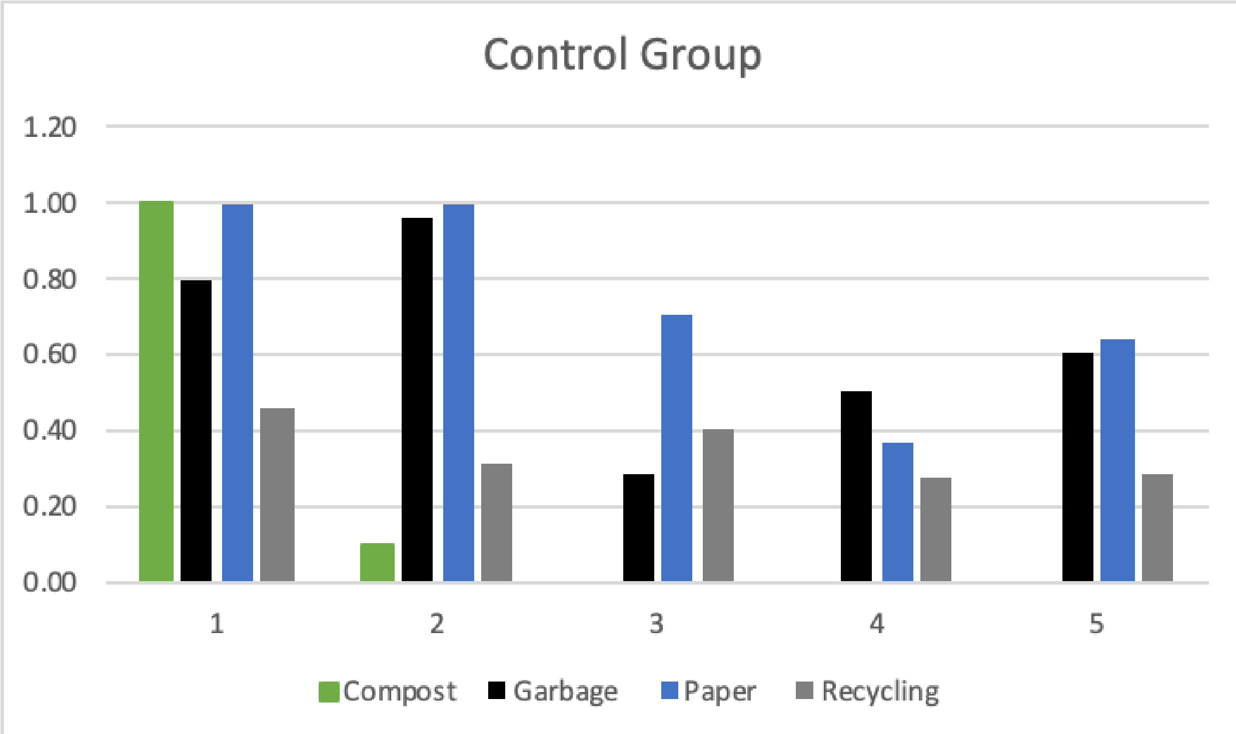

Figure 2. Average Contamination proportion of each waste category in Control Group

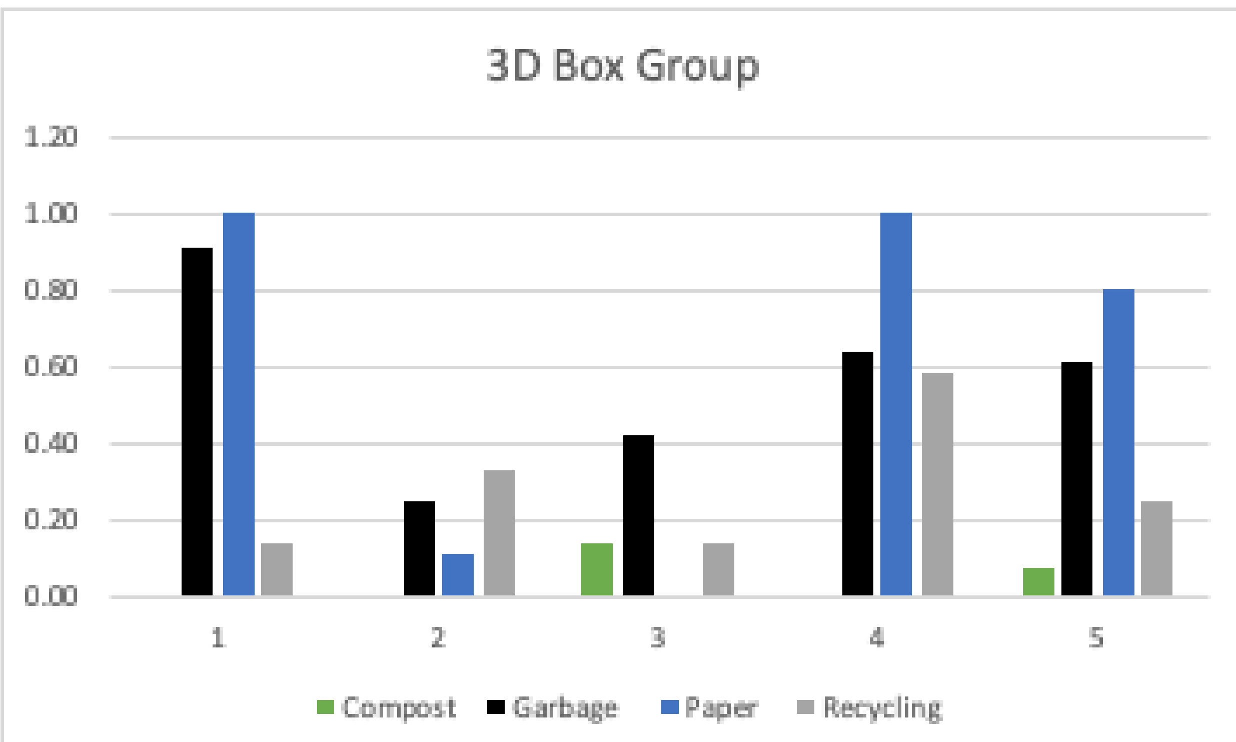

Figure 3. Average Contamination Proportion of each waste category in 3D Box Group

Figure 4. Experimental Condition with 3D boxes

Figure 5. Recyclable Containers 3D Box Design

Figure 6. Paper 3D Box Design

Figure 7. Garbage 3D Box Design


Figure 8. Compost 3D Box Design

Compost	Garbage	Paper	Recycling		3D Box
0.00	0.92	1.00	0.14		Yes
0.00	0.25	0.11	0.33		Yes
0.14	0.42	0.00	0.14		Yes
0.00	0.64	1.00	0.58		Yes
0.08	0.61	0.80	0.25		Yes
Average					Sum Average
0.04	0.57	0.58	0.29		0.37
SD					Sum SD
0.06	0.25	0.49	0.18		0.35

Figure 9. Statistics of 3D Box condition (note: the value represents Contamination proportion)

Compost	Garbage	Paper	Recycling		3D box
1.00	0.80	1.00	0.45		No
0.10	0.96	1.00	0.31		No
0.00	0.29	0.70	0.40		No
0.00	0.50	0.36	0.27		No
0.00	0.60	0.64	0.29		No
Average					Sum Average
0.22	0.63	0.74	0.34		0.48
SD					Sum SD
0.44	0.26	0.27	0.08		0.34

Figure 8. Statistics of Control condition (note: the value represents Contamination proportion)