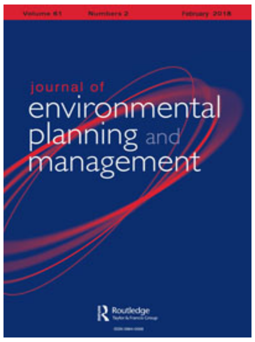

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Convenience improves composting and recycling rates in high-density residential buildings

Alessandra DiGiacomo[a]*, David W.-L. Wu[a], Peter Lenkic[a], Bud Fraser[b], Jiaying Zhao[a,c] and Alan Kingstone[a]

[a]*Department of Psychology, University of British Columbia, Vancouver, Canada;* [b]*Sustainability & Engineering, University of British Columbia, Vancouver, Canada;* [c]*Institute for Resources, Environment and Sustainability, University of British Columbia, Vancouver, Canada*

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Increasing volumes of solid waste, implicated in environmental pollution and health problems, are central to the current environmental crisis. In two randomized field experiments, we demonstrate that convenience dramatically boosts recycling and composting rates in multi-family dwellings and university residences. When compost bins were placed on each floor in a multi-family residence, instead of on the ground floor, composting rates increased by 70%, diverting 27 kilograms of compost from the landfill per unit per year. When recycling stations were placed just meters from suites in student residences, instead of in the basement, recycling increased by 147% (container), and 137% (paper), and composting increased by 139%, diverting 23, 22, and 14 kilograms of containers, paper, and compost, respectively, from the landfill per person per year. Simply making recycling and composting convenient can significantly increase waste diversion, and as such this single intervention has important implications for waste management and environmental policy.

Keywords: waste management; recycling; composting

1. Introduction

Over the past few decades, issues related to composting and recycling have become increasingly prominent. Composting involves the decomposition of organic waste into a material called humus, which can be added to soil to improve quality. Recycling involves reusing materials such as plastics, paper and glass, thereby reducing the amount of waste entering landfills. In Canada, residential waste production is on the rise: Canadians each produced 418 kilograms of waste in 2004 compared to 366 kilograms in 2000. Recycling is also on the rise – Canadians recycled 112 kilograms per person in 2004 compared to 71 kilograms in 2000. Composting also increased from 32 kilograms per person in 2000 to 51 kilograms in 2004 (Stats Canada 2013).

However, despite the increasing recycling and composting rates, the majority of waste produced by Canadians is still sent to landfills, which directly contribute to water, air, and soil pollution. Previous studies have suggested that landfills are contributing to both environmental and health problems in Canada (Davies and Mazumder 2003). Handling waste in landfills exposes humans to hazardous emissions from the landfill itself and increases the risk of contracting diseases via inhalation or physical contact with waste (Hossain *et al*. 2011; Giusti 2009). These landfills affect the environment in numerous

*Corresponding author. Email: adigiacomo@psych.ubc.ca

ways, including introducing contamination to water (leached heavy metals and synthetic organic compounds), to air (carbon dioxide, methane emissions, greenhouse gases, volatile organic compounds released into the atmosphere), and to the soil (heavy metals and synthetic organic compounds leaked into the earth).

More generally, organic waste in landfills is one of the main contributors to greenhouse gas emissions as it converts to methane after undergoing anaerobic decomposition (Li, Park, and Zhu 2011; Khalid *et al.* 2011). Methane emitted from decomposition in landfills is particularly problematic for global warming, since it can effectively absorb the sun's heat, warming the atmosphere. In fact, methane is a greenhouse gas that is 21 times more potent than carbon dioxide in terms of its global warming potential. The Environmental Protection Agency has developed the Waste Reduction Model (WARM) to help solid waste planners and organizations track reductions in greenhouse gas emissions from different material management practices (EPA 2015). According to WARM, landfills have accounted for approximately 16.2% of the total US anthropogenic methane emissions (EPA 2010), and for 20% of Canadian national methane emissions (ECCC 2014). In Canada alone, 27 megatonnes of carbon dioxide equivalent are generated annually from landfills, of which 20 megatonnes are being emitted into the atmosphere annually (ECCC 2014). This accounts for 3% of Canada's total greenhouse gas emissions (ECCC 2016).

While developed countries now have stringent regulations around the management of landfills (Chartier *et al.* 2014; Townsend *et al.* 2015), the increasing financial and environmental cost of landfilling has motivated many municipalities to create recycling and composting programs aimed at reducing the amount of solid waste destined for landfills and to optimize resource recovery (Domina and Koch 2002; Reschovsky and Stone 1994). For instance, "zero waste" policies are becoming increasingly popular (Cole *et al.* 2014; Hottle *et al.* 2015; Song, Li, and Zeng 2015; Zaman 2015), and several jurisdictions are even imposing mandatory landfill bans of certain materials (Karak, Bhagat, and Bhattacharyya 2012; Liu *et al.* 2015).

Given the urgency of waste problems, it is imperative to identify best practices for increasing recycling and composting adherence, with an eye toward minimizing the adverse environmental consequences of landfilling. Specifically, noting the trend for urban intensification and high-density living (Melia, Parkhurst, and Barton 2011), it seems reasonable and productive for these efforts to be focused on identifying best practices for pro-environmental behavior in high-density buildings such as multi-family dwellings (MFDs). Notably, residential waste contributes approximately 40% of landfill contents (Stats Canada 2013).

There is a general consensus in the literature that residents of MFDs recycle less than residents of single-family dwellings (SFDs: Ando and Gosselin 2005; De Young *et al.* 1995; Fallde 2015). While many studies have examined the variables that influence recycling behavior (e.g. the design of waste bins – Duffy and Verges 2009; information signage – Austin *et al.* 1993; personal attitudes, knowledge, and prior experiences – Tonglet, Phillips, and Bates 2004; atmospherics – Wu *et al.* 2016; see also Schultz, Oskamp, and Mainieri 1995 and Osbaldiston and Schott 2012 for meta-reviews), with respect to the question about residents in MFDs recycling less than those in SFDs, one of the unifying themes is that recycling is less convenient in MFDs (e.g. Ando and Gosselin 2005; Derksen and Gartrell, 1993; De Young *et al.* 1995; Fallde 2015; Margai 1997). Convenience has been defined as the distance to a recycling station (Ando and Gosselin 2005), the amount of space available to store recyclables (Westergård 1996), the ratio of collection bins to households (Stevens 1999), or certain housing characteristics, such as floor level or the presence of an elevator (McQuaid and Murdoch 1996). In all cases, SFDs are considered to be more convenient than MFDs. This difference is critical for the disparity in recycling behaviors between the two dwelling environments.

The specific emphasis on convenience in recycling behavior is consistent with the perception that inconvenience is a barrier to recycling. For example, non-recyclers identified personal and household inconveniences (e.g. no curbside pickup, distant drop-off site) as important reasons for not recycling (Vining and Ebreo 1990). Relatedly, attendees of an ecology conference were offered a discount if they took a sustainability pledge to reduce their resource use at the conference (i.e. bring in a reusable water bottle). Sixty-two percent of respondents stated that inconvenience was their biggest obstacle when it came to fulfilling the sustainability pledge they signed, although a definition for inconvenience was not provided (Jarchow *et al.* 2011). Similarly, Wagner (2011) found that 28% of respondents think that increased convenience would prompt them to recycle. Moreover, curbside pickup increased the probability of recycling newspaper and glass by 22% and 37%, respectively, compared to only having drop-off centers available (Reschovsky and Stone 1994).

Although these findings converge on the conclusion that convenience increases recycling, the data are based largely on questionnaires, surveys, or reported behavior. There is surprisingly little direct evidence that convenience actually increases rates of recycling and composting. There are a few notable exceptions, however, and these studies guided us in the present investigation. For instance, improved convenience – reduced travel distance and time – increased recycling of paper and pop cans in classrooms by 20% (Ludwig, Gray, and Rowell 1998), and in offices by 50% (Brothers, Krantz, and McClannahan 1994). This finding leads us to question whether these convenience interventions are similarly effective in housing environments such as MFDs. There are two studies from which to draw and the conclusions they suggest are contradictory.

According to Yau (2012), the answer is that convenience matters little in MFDs. He obtained data from various property management companies and used an analytical model to compare the total amount of paper, plastic, and metal materials disposed of over the course of one year in 122 Hong Kong high-rise buildings. Thirty-five percent of the buildings had recycling stations on every floor, and the rest did not. Although exact figures were not reported, Yau (2012) concluded that having recycling bins on every floor did not increase the amount of recyclables collected. There are a number of factors to keep in mind when considering the results of this study. First, details about the 122 buildings were unavailable, meaning that although we know that 35% of the buildings had recycling stations on each floor, it is difficult to make inferences about the relative convenience of each building. For example, it could be that some buildings without recycling stations on each floor could have been perceived as more convenient than those with recycling stations on each floor, due to various factors such as physical size, presence of an elevator, etc. Second, it is unclear how the 122 buildings fared on education about recycling and composting, and whether residents knew about the bins or understood what should go in them. Third, the situational context of this study may explain the null results. As Yau (2012) pointed out, his study coincided with the aftermath of the SARS outbreak, and as the common areas that housed the convenient recycling stations were poorly ventilated, it is possible that residents were deterred from using these bins for the fear of poor environmental hygiene and mismanagement.

In contrast, according to Bernstad (2014) and Larkhan (2016), convenience does play a role when it comes to increasing sustainable behaviors such as composting and recycling, respectively. Bernstad (2014) found that composting rates increased by 30% after residents were provided with disposable food waste sorting equipment. In this study, 1,632 rental units in Sweden were outfitted with special food waste sorting equipment which consisted of a metal hanger and a holder for paper bags. These holders were attached to the inside of cupboard doors underneath the kitchen sink, enabling residents to simply remove and dispose of the paper bag filled with food waste. Prior to the installation of this equipment, each household composted an average of 0.66 kilograms of food waste per week. This increased to 0.99 kilograms of food waste per week just four weeks after the disposable sorting equipment was installed, and results show that the gain was maintained long-term (i.e. up to 26 months later). Larkhan (2016) used waste audit data on 12 multi-residential buildings in the Greater Toronto Area to determine that although retrofitting recycling chutes in the buildings had no impact on recycling rates, placing a recycling bin in building lobbies increased recycling by 3.8%. It was, however, unclear whether this figure reflected a significant change in recycling behavior and the study did not examine composting behavior.

In summary, the literature on convenience suggests the following: (1) there is a widespread belief (most notably among Western scholars) that inconvenience is a barrier to recycling; (2) this belief has only been directly supported by two experimental studies which were conducted in classroom and office settings; and (3) experimental studies from MFDs yield conflicting results: one contradicts the idea that convenience matters, in that having recycling stations located on each floor of a high-rise building did not improve recycling (Yau 2012), and the other suggests that convenience in the form of special sorting equipment increased proper food waste disposal (Bernstad 2014).

The primary question emerging from the literature is whether composting and recycling rates can be increased by shortening the distance to composting and recycling bins (i.e. by improving convenience). Since convenience has been shown to change other types of behaviors, such as choosing healthier food options (Hanks *et al*. 2012; Wansink and Hanks 2013), we hypothesize that placing recycling and composting bins closer to residents' suites will lead to an increase in recycling and composting rates.

Given the limited experimental evidence and divergent findings, the current study directly manipulated convenience in two randomized field experiments where buildings were randomly assigned to conditions and their composting and recycling behaviors were monitored over time. Our first study manipulated the distance from the compost bins to the suites in a residential building, and measured the amount of compost produced in conditions where the bins were on the same floor of the suites (highly convenient), at the base of the elevator by the building entrance (moderately convenient), or outside of the building (inconvenient). We then replicated and extended this experiment by measuring compost, paper, and container (e.g. glass bottles, jars, plastic bottles) recycling in student residences, introducing other forms of inconvenience, such as having different types of bins in different locations, or presenting the residents with the temptation of using one general-purpose garbage chute instead of having to travel to the basement to recycle and compost.

2. Experiment 1

In this study, we examined composting rates in three multi-family residential buildings by varying convenience. Convenience was manipulated by altering the distance from the entrance (i.e. the door) of each suite to the closest available compost bin. We predicted that increased convenience (i.e. decreasing distance) would increase composting rates.

3. Methods

3.1. Buildings and conditions

There were three buildings in this study, and the buildings were randomly assigned to three conditions. Prior to the study, none of the buildings had a composting program. During the study, each building was fitted with either one or multiple compost bins (described below) and weekly compost pick-up was arranged. This service was provided free of charge to residents by the research assistants. The three buildings were selected for study because they are owned and operated by the same real estate company, are reported to have comparable demographics and physical layouts, and did not have an existing composting program. The buildings were reported to be at full occupancy at the time of data collection during the study (from October to December, 2014). The buildings' operations manager reported that although precise demographics for the buildings could not be obtained due to privacy restrictions, the residents in all three buildings were equivalent in terms of demographics. These are relatively new buildings (built in 1992 and 1994), and according to the Statistics Canada 2006 census, the surrounding area is considered to be an affluent upper class neighborhood, with the highest income bracket listed in the census – between \$50,572 and \$180,615. The metropolitan area average individual income is \$36,123.

In the least convenient condition (Building A), one large (27.5 (width) × 27.5 (depth) × 46 (height) inches) compost bin was placed outside the building in the main garbage disposal area on the ground floor. In the more convenient condition (Building B), one small (11 × 15 × 26 inches) compost bin was placed by the elevator on the ground floor, in addition to the large compost bin in the main garbage disposal area. In the most convenient condition (Building C), the same small (11 × 15 × 26 inches) compost bin was placed by the elevator on each floor, in addition to the large compost bin in the main garbage disposal area. Each building had four floors, consisted of both 1- and 2-bedroom units, and contained a centrally located elevator. See Table 1 below for a detailed description of the conditions.

Since the current study only assessed convenience as a function of distance, we did not manipulate composting practice or equipment within each residential unit. The units themselves were comparable across buildings, with an interior space of between 639 and 671 sq. ft.[1] for 1-bedroom apartments and 791 sq. ft. for 2-bedroom apartments. The

Table 1. Conditions and buildings in Experiment 1. Convenience is defined as a function of distance (i.e. shorter distance is more convenient).

Condition	Building	Description	Floors	Number of 1-bedroom units	Number of 2-bedroom units
Least convenient	A	One large compost bin located in the main garbage disposal area	4	30	19
More convenient	B	One large compost bin located in the main garbage disposal area + one small compost bin by the elevator on the ground floor	4	22	10
Most convenient	C	One large compost bin located in the main garbage disposal area + one small compost bin by the elevator on each floor	4	22	10

Figure 1. Floor plan of Building A (the least convenient condition). Each number is a suite. The red line represents the Euclidian distance traveled and the red numbers represent the distance in feet. 3.28 ft = 1 meter.

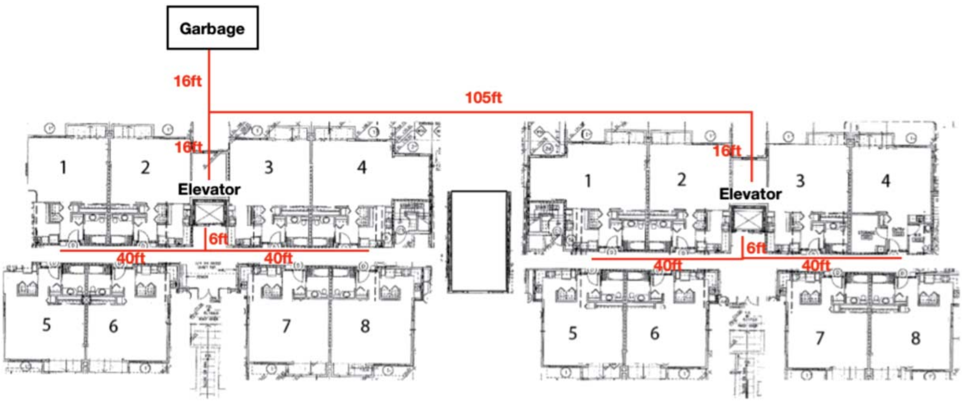


Figure 2. Floor plan of Building B (on the left, the more convenient condition), and Building C (on the right, the most convenient condition). Each number is a suite. The red line represents the Euclidian distance traveled and the red numbers represent the distance in feet. 3.28 ft = 1 meter.

kitchen spaces were either 85 or 92 sq. ft. for 1-bedroom apartments or 108 sq. ft. for 2-bedroom apartments.

All three buildings were located along the same street: Buildings B and C were side by side and Building A was on the same road less than a mile away. Figures 1 and 2 present the floor plan in each building. As shown in Figure 1, Building A contained a main garbage disposal area which was a room with garbage, composting, and recycling bins outside the building on the ground floor. The average Euclidian distance (i.e. not including the vertical distance travelled in the elevator) from a suite door to the nearest compost bin was 130 ft in Building A. This was calculated by adding the average distance from each suite to the elevator on each floor (52 ft), and the distance from the elevator to the main garbage disposal room on the ground floor (78 ft).

Buildings B and C shared access to the same garbage disposal room, similar to the room in Building A, with one composting bin, and garbage and recycling bins. The room was also located outside the buildings on the ground floor. Figure 2 presents the floor plans in Buildings B and C, which were identical. In Building B, the average Euclidian distance from the suite door to the compost bin located by the elevator on the ground floor was 36 ft. The Euclidian distance from the elevator to the garbage disposal room on the ground floor was 32 ft. In Building C, the average Euclidian distance from the suite door to the compost bin by the elevator on each floor was also 36 ft. The Euclidian distance from the elevator to the garbage disposal room on the ground floor was 137 ft. Despite the long distance from the elevator to the garbage disposal room on the ground floor, the closest compost bins were still 36 ft away from the suite door, on average, in both Buildings B and C. Thus, they were still more convenient than Building A.

3.2. Materials

The residents in each building all had access to the main garbage disposal room located on the ground floor of each building (see Figure 3 for a photo of each room). The relative location of the garbage room is shown in Figures 1 and 2. Both rooms contained the same four types of disposal bins, namely, garbage, container recycling, paper recycling, and composting. The dimension of the compost bin in the garbage room was 27.5 × 27.5 × 46 inches.

In addition to the compost bins located in the main garbage room, we added a smaller compost bin (11 × 15 × 26 inches) by the elevator on the ground floor in Building B and four small bins on the four floors in Building C by the elevator. These are shown in Figure 4.

3.3. Procedure

Garbage collection occurred once a week on Thursdays, between late morning and early afternoon. Two research assistants used a DYMO® S250 Digital USB Shipping Scale to weigh all the compost bins in all three buildings in the morning prior to garbage collection. In addition to the Thursday morning weighing, the small compost bins were emptied and weighed on Monday mornings. Each week, therefore, produced twelve data points: the first (Monday) and second (Thursday) weighing of the four small compost bins in Building C and the one small compost bin in Building B, and the weight of the two large compost bins from the garbage disposal rooms. This process continued for a period of four months, with the first four weeks in September serving as a pilot period to train the research assistants in weighing the bins and the building staff on how to provide secure access to the assistants every week.

Figure 3. The main garbage disposal room in Building A (left) and Buildings B and C (right).

Figure 4. Small compost bins located by the elevator at the base of Building B (left) and by the elevator on each floor of Building C (right).

4. Results and discussion

4.1. Data handling

The total amount of composting, in kilograms was calculated per condition per recording period (seven days). An average per bedroom calculation was then made, as there were different numbers of one and two bedroom units in each tower/building. Fifty percent of the contents of the large bin located behind Buildings B and C (see Methods, Experiment 1) were attributed to B and the other 50% to C. This large bin was shared between the two buildings. It was not possible to determine exactly what proportion of waste originated from each building. The following data reflects 10 week-long recording periods.

4.2. Weight of food waste disposed in kilograms per unit per week

A univariate ANOVA was conducted, and revealed that the amount of compost produced in each condition differed significantly, $F(2,27) = 8.23$, $p < 0.01$, $\eta_p{}^2 = .38$. Tukey's multiple comparisons revealed that the most convenient condition produced significantly more compost than both the more convenient elevator ($p < 0.05$)[2] and inconvenient conditions ($p < 0.05$). The results are displayed in Figure 5.

As predicted, the most convenient condition resulted in the highest compost diversion rates, suggesting that a relatively short trip to the compost bin increased composting. Interestingly, the more convenient and inconvenient conditions were not significantly different, suggesting that differences in distance only matter up to a certain point. It could be that the overall inconvenience experienced in negotiating this distance, which included waiting for and travelling on the elevator, was perceived to be equal to the overall inconvenience experienced in travelling to the bin located outside the building, and thus composting rates did not taper off further for longer trips. Even though the only difference between the most and the more convenient conditions was a short elevator ride, residents seem to perceive the latter as quite inconvenient. It is possible that when assessing the convenience of a short elevator ride, residents consider factors that may add effort or time to the trip, such as getting dressed, putting on shoes, putting out candles,

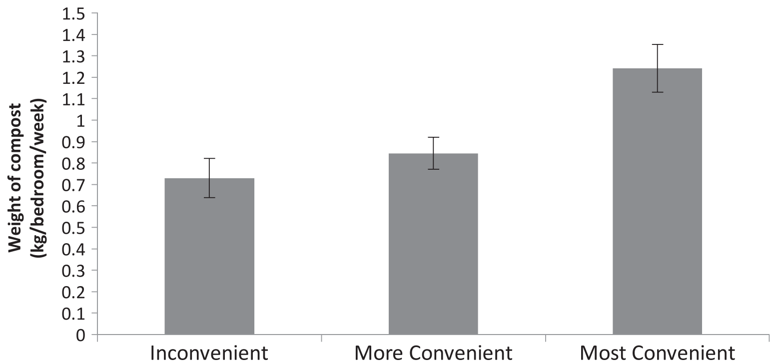


Figure 5. Weight of compost in kilograms, per bedroom, per week. Most convenient condition produces significantly more compost than both the more convenient and inconvenient conditions (error bars reflect ±1 SEM).

and locking the door. These are all actions which may not be required if instead of riding the elevator, the trip consists of walking a few meters down the hall.

4.3. Experiment 2

This experiment extended Experiment 1 in three important ways. First, we broadened our participant sample to university students who live in high-density student residences at the University of British Columbia (UBC), Vancouver, Canada. Second, instead of focusing only on composting, we examined the weight of materials entering three streams of waste: container recycling, paper recycling, and composting. In doing so, we aimed to test whether convenience boosts both recycling and composting rates. Third, we introduced other forms of inconvenience, such as placing bins in different locations, or presenting the residents with the temptation of disposing of waste in a conveniently located garbage chute instead of traveling down to the basement to recycle and compost.

As such, we made one condition highly convenient as in Experiment 1 by minimizing the physical distance to the bins from each suite, and placing the bins right outside the suites (5 ft away). All the other conditions were made inconvenient by increasing distance (41, 97, and 163 ft), locating the bins in separate locations (i.e. compost bins were located outside the building while the recycling and garbage bins were in the basement), or introducing a temptation condition (i.e. having a garbage chute available on each floor). We predicted that recycling and composting rates would be the highest in the convenient condition, compared to the other inconvenient conditions.

5. Methods

5.1. Buildings and conditions

Two student residences located on the UBC campus were used in this experiment. They were composed of multiple separate towers which were randomly assigned to different conditions. Residence A consisted of two high-rise towers and one mid-rise tower. Residence B consisted of three high-rise towers. Thus, there were six towers in the experiment, randomly assigned to four conditions. These particular residences were selected for study primarily due to logistics: they contained enough space to securely store the industrial scale (Brecknell DS100) used for weighing bins; they contained a separate area to store full bins prior to weighing, and the staff were able and willing to

Table 2. Conditions and buildings in Experiment 2.

Condition	Residence tower	Description	Euclidian distance from suite door to bins	Floor #s under observation	Total number of residents
Convenient: hallway drop-off	Residence B, East Tower	Compost (C), container recycling (CR), and paper recycling (PR) bins right outside the suite in the hallway	5 ft	14–17	96
Inconvenient: longer distance	Residence B, North Tower	C, CR & PR in the same basement location	41 ft	1–17	396
Inconvenient: longer distance	Residence A, Tower 1	C, CR & PR in the same basement location	97 ft	1–18	340
Inconvenient: longer distance	Residence A, Tower 6	C, CR & PR in the same basement location	163 ft	7	277
Inconvenient: different bin locations	Residence A, Tower 4	CR & PR in basement, C outside the tower	86 ft	1–18	401
Inconvenient: temptation	Residence B, South Tower	C, CR & PR in basement + garbage chutes open	41 ft (5 ft from suite door to garbage chute)	1–17	396

accommodate a change to their usual waste management procedures for the duration of the study.

The four conditions were: (1) convenient (hallway drop-off), where a disposal station was located just outside each suite in the hallway; (2) inconvenient (longer distance; either 41, 97, or 163 ft), where residents had to travel to the basement of the building to dispose of their waste; (3) inconvenient (different bin locations), where residents had to travel to the basement of the building to dispose of garbage and recycling, and to go outside the building to dispose of compost; and (4) inconvenient (temptation), where residents had to travel to the basement of the building to recycle and compost, but could dispose of garbage using the chute located outside their suite on each floor. Since the current study assessed convenience as a function of distance, we again did not manipulate composting and recycling practice or equipment within each suite. See Table 2 below for a detailed description of the conditions.

Figure 6 presents the floor plan of Residence B, East Tower (convenient condition: hallway drop-off). The Euclidian distance from the suite door to the bins in the hallway was 5 ft.

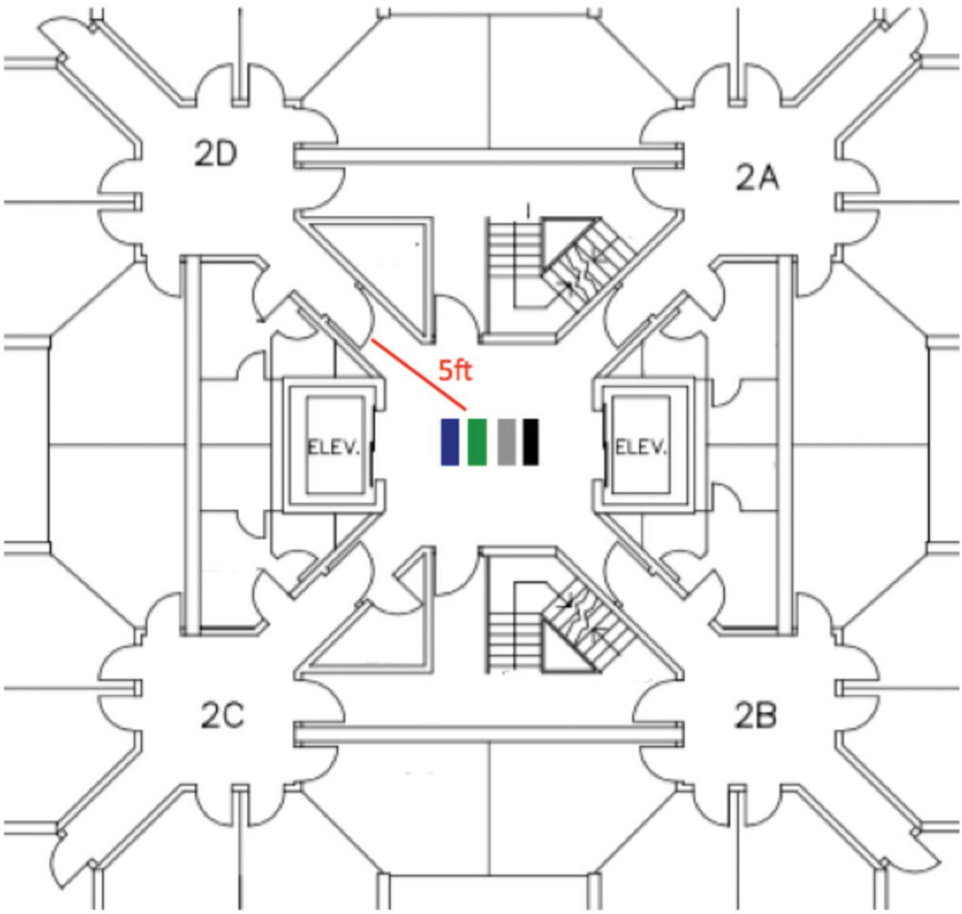


Figure 6. Floor plan of Residence B, East Tower (convenient condition: hallway drop-off). The colored rectangles in the center represent the garbage, compost, paper recycling, and container recycling bins. Each number with a letter is a suite. The red line represents the Euclidian distance between the suite door and the bins, and the red number represents the distance in feet (5 ft). 3.28 ft = 1 meter.

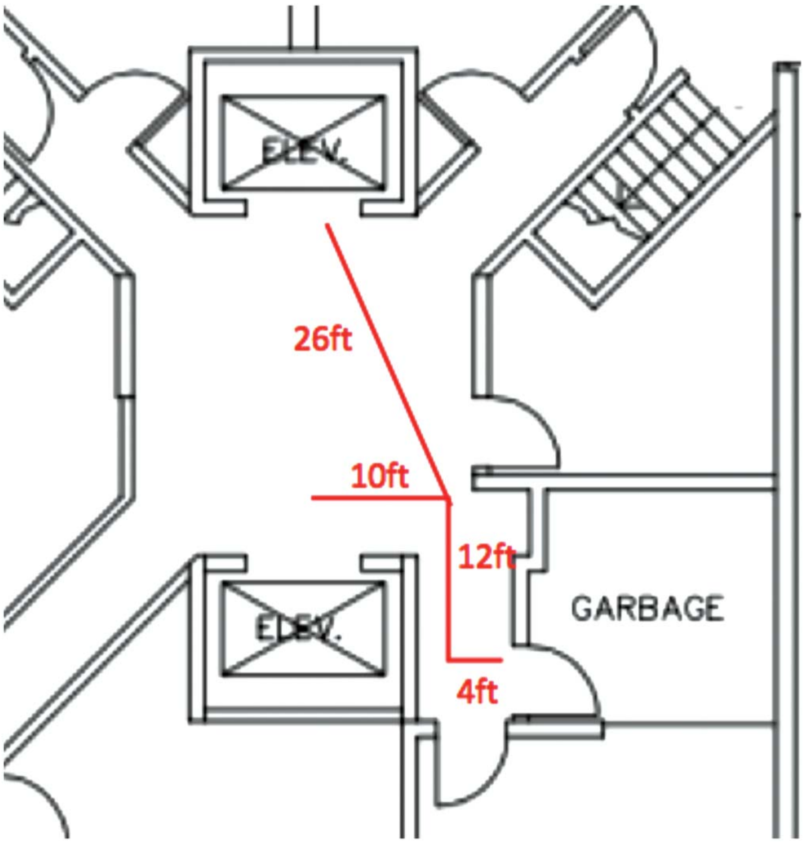
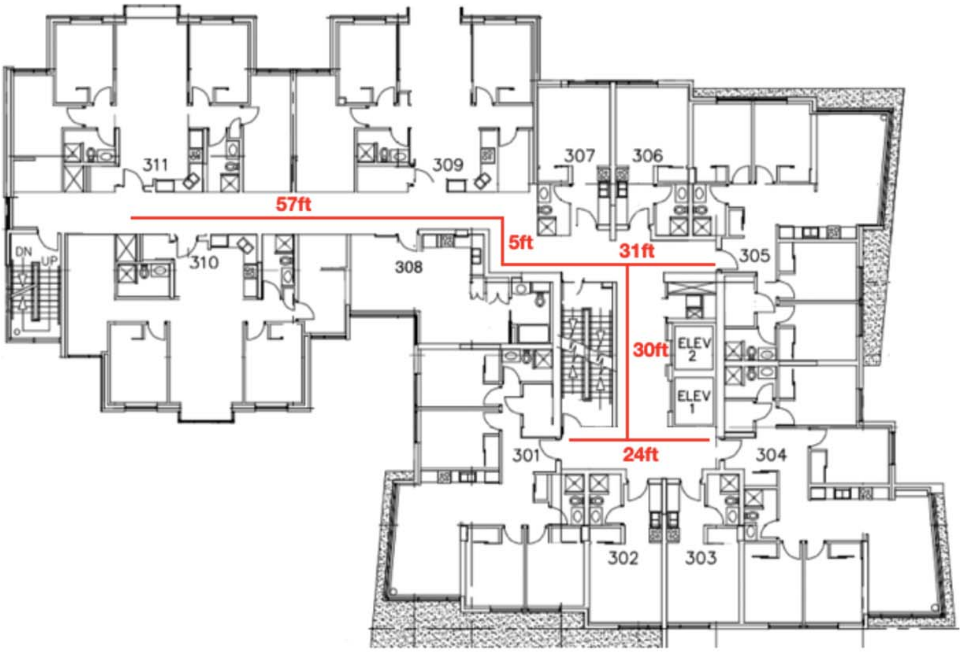


Figure 7. Floor plan of the basement in Residence B, North Tower and South Tower. The red line represents the Euclidian distance between the elevator and the garbage disposal room, and the red number represents the distance in feet. 3.28 ft = 1 meter.

In Residence B, the North Tower (inconvenient condition: longer distance) and the South Tower (inconvenient condition: temptation) had the same floor plan as that in the East Tower, except without the bins in the hallway. In both towers, the bins were placed in a garbage disposal room in the basement of each tower. Figure 7 presents the floor plan of the basement in the North Tower and the South Tower. The floor plan was identical in both towers. The average Euclidian distance from a suite door to the bins in the basement was 41 ft. This was calculated by adding the average distance from each suite door to the elevator on each floor (7 ft), and the distance from the elevator to the garbage disposal room in the basement (34 ft).

Figure 8 presents the suite-level and basement floor plan for Residence A, Tower 1 (inconvenient condition: longer distance). The average Euclidian distance from a suite door to the bins in the basement was 97 ft. This was calculated by adding the average distance from each suite door to the elevator on each floor (76 ft), and the distance from the elevator to the garbage disposal room in the basement (21 ft).

Figure 9 presents the suite-level and basement floor plan for Residence A, Tower 6 (inconvenient: longer distance). The average Euclidian distance from a suite door to the bins in the basement was 163 ft. This was calculated by adding the average distance from



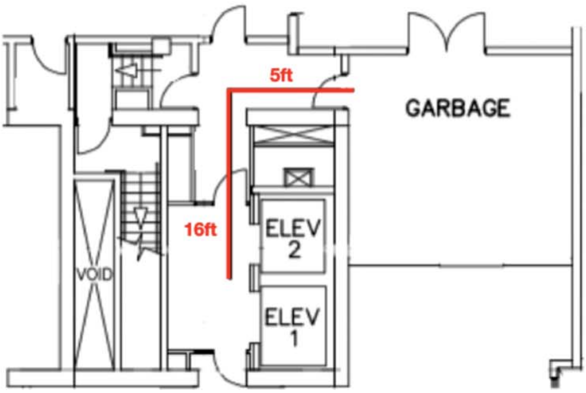


Figure 8. Floor plan of suites (above) and basement (below) in Residence A, Tower 1. A number represents a suite. The red line represents the Euclidian distance between the suite door and the elevator (above) and between the elevator and the garbage disposal room (below). The red number represents the distance in feet. 3.28 ft = 1 meter.

each suite door to the elevator on each floor (138 ft), and the distance from the elevator to the garbage disposal room in the basement (25 ft).

Figure 10 presents the suite-level and basement floor plan for Residence A, Tower 4 (inconvenient: different bin locations). The average Euclidian distance from a suite door to the bins in the basement was 86 ft. This was calculated by adding the average distance from each suite door to the elevator on each floor (78 ft), and the distance from the elevator to the garbage disposal room in the basement (8 ft).

To understand the make-up of the residents in the towers, we administered a questionnaire to the residents which revealed a comparable make-up across all towers in both residences. Of the 250 respondents from Residence A, 95% were between the ages

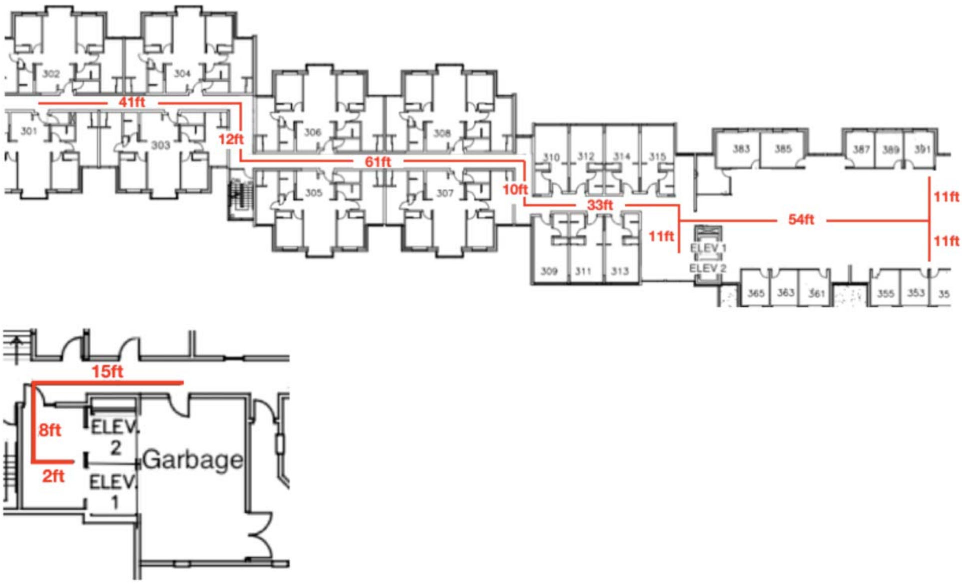


Figure 9. Floor plan of suites (above) and basement (below) in Residence A, Tower 6. A number represents a suite. The red line represents the Euclidian distance between the suite door and the elevator (above) and between the elevator and the garbage disposal room (below). The red number represents the distance in feet. 3.28 ft = 1 meter.

of 18 and 24, and of the 315 respondents from Residence B, 90% were between the ages of 18 and 24. Country of origin was similar across the two residences: in both residences, 48% of residents were from North America; 39% of Residence A vs. 31% of Residence B students were from Asia; in both residences, 7% of residents were from Europe; and 2% of Residence A and 10% of Residence B were from South America. In addition, the populations did not differ in terms of the composition of resident program majors, $c^2(1, N = 379) = 34.86, p = 0.25$.

5.2. Materials

Residents in each tower had access to standard container recycling (gray), paper recycling (blue), and compost (green) bins in the basement of each tower, shown in Figure 11. Each bin was 22 × 24 × 40 inches.

The convenient (hallway drop-off) condition used makeshift recycling stations, shown in Figure 12. Each bin was 11 × 20 × 30 inches.

5.3. Procedure

The custodial staff in each residence tagged each full bin (these bins were not sorted for contamination) every week, identifying the type of trash (containers, paper, or compost) and which tower it came from. They then brought the full bins to a common area in the tower, where research assistants weighed the bins. The research assistants used an industrial scale, the Brecknell DS100 (one was stored in both Residence A and B for the duration of the study) and weighed the bins on Tuesdays and Thursdays between 9 and 10am for a period of three months from September to December. September served as a

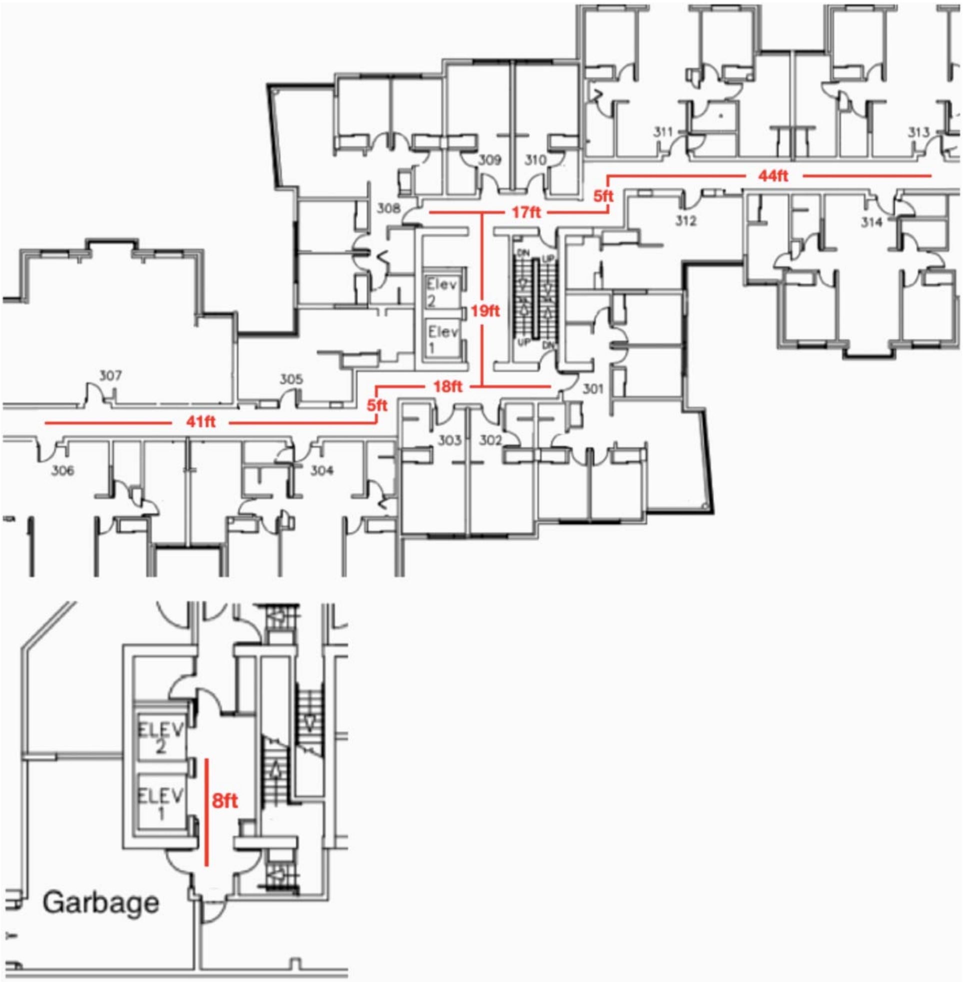


Figure 10. Floor plan of suites (above) and basement (below) in Residence A, Tower 4. A number represents a suite. The red line represents the Euclidian distance between the suite door and the elevator (above), and between the elevator and the garbage disposal room (below). The red number represents the distance in feet. 3.28 ft = 1 meter.

pilot period to train the research assistants in weighing the bins, and communicating with building staff in getting building access every week. The data in the pilot period (September) were not included in the analyses.

6. Results and discussion

6.1. Data handling

The amount of composting, container recycling, and paper recycling in kilograms was calculated per condition in each week. The average weight per person was calculated. This is a slightly different measurement than the one used in Experiment 1, where the dependent variable was the average weight per bedroom. This is due to the fact that, due to privacy laws, we could not determine the exact number of people living in each suite

Figure 11. The container recycling, paper recycling, and compost bins used by residents in Experiment 2.

Figure 12. The makeshift four-stream recycling station used in convenient (hallway drop-off) condition. These were positioned on each floor of the tower, just outside each suite, making access to the bins convenient.

for Experiment 1, but in the current experiment it is possible to calculate a per person measure. Two of the total 12-week observation periods had a missing data point resulting from either a holiday or a change of garbage pickup schedule, so the following data reflects the 10 week-long observation period.

6.2. Weight of waste disposed of in kilograms per person per week

An omnibus multi-variate ANOVA was conducted, and revealed that the amount of waste produced in each condition differed significantly, $F(15{,}144) = 5.21$, $p < 0.001$; Wilk's $\Lambda = 0.302$, ${\eta_p}^2 = 0.70$. The degree of convenience had a statistically significant effect on the amount of material disposed of in each of the three streams: container recycling ($F(5,54) = 8.64$; $p < 0.001$, $\eta_p^2 = 0.44$), paper recycling ($F(5,54) = 7.04$; $p < 0.001$, $\eta_p^2 = 0.40$), and compost ($F(5,54) = 8.04$; $p < 0.001$, $\eta_p^2 = 0.43$). Tukey's multiple comparisons were conducted below to determine the exact conditions that were driving the effect.

6.3. Containers recycled in kilograms per person per week

For container recycling, residents in the convenient condition recycled significantly more containers than those in all other inconvenient conditions, ($p < 0.001$). None of the inconvenient conditions differed significantly from each other ($p > 0.05$).

To test whether having the garbage chute resulted in less container recycling because residents would be seduced into throwing them down the chute, a two-tailed independent samples t-test was conducted to compare the 41 ft condition with the temptation condition which was also 41 ft away. The results showed that residents in the 41 ft condition recycled more containers than those in the temptation condition ($p < 0.01$), despite the fact that the distance to the recycling bin was identical for both conditions. The results are displayed in Figure 13(a).

6.4. Paper recycled in kilograms per person per week

For paper recycling, Tukey HSD post-hoc tests revealed that the residents in the convenient condition recycled significantly more paper than residents in all other inconvenient conditions ($p < 0.001$). There were no significant differences between any of the inconvenient conditions ($p > 0.05$). The results are displayed in Figure 13(b).

6.5. Compost in kilograms per person per week

Similar to container and paper recycling, Tukey HSD post-hoc tests revealed that the residents in the convenient condition composted significantly more than residents in all the other inconvenient conditions ($p < 0.001$). None of the inconvenient conditions were significantly different from each other ($p > 0.05$). The results are displayed in Figure 13(c).

Overall, the results from Experiment 2 showed that the convenient condition consistently resulted in more compost, container, and paper recycling being diverted from the garbage. This supports our hypothesis that improving convenience increases recycling and composting behaviors in high-density residences. Although it is clear that a highly convenient disposal system leads to increased diversion for all streams, the various types of inconvenient disposal systems did not seem to influence diversion in Experiment 2. This implies that there is a threshold for participating in recycling/composting: if residents will recycle and compost only if they perceive the current setup to be convenient enough. The only exception was for container recycling: the temptation condition and the 41 ft longer distance (LD) condition both had the same distance from the suite to the bins, with the difference being that the temptation condition had the availability of a garbage chute on each floor. The 41 ft LD condition resulted in approximately three times as much container recycling than the temptation condition. However, this result did not hold for paper recycling or compost. The availability of a nearby garbage chute was tempting for residents who were disposing of containers, suggesting that the threshold for recycling avoidance was lower for containers than for

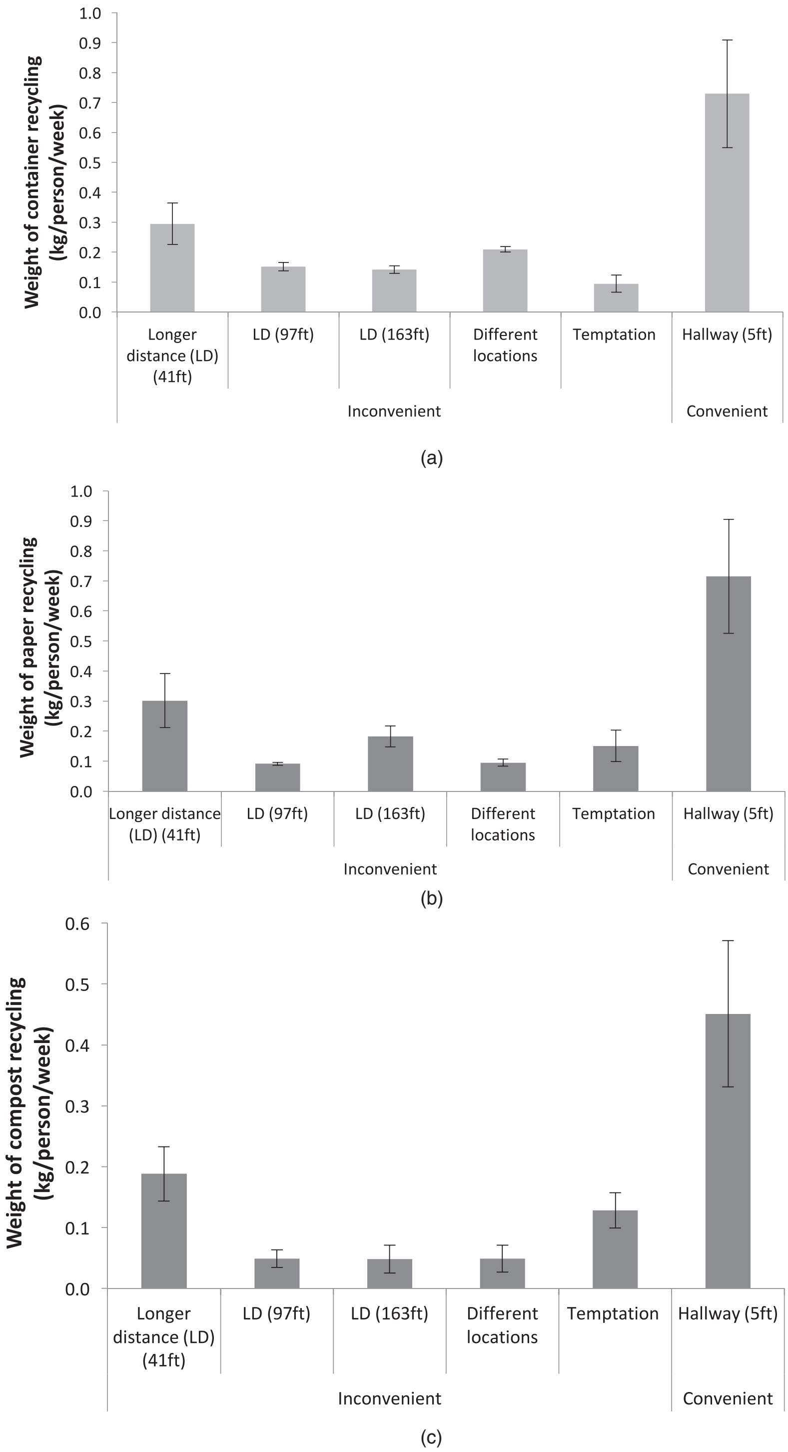


Figure 13. (a) Weight of container recycling in kilograms, per person, per week. Hallway drop-off condition is significantly greater than all other conditions. LD (41 ft) is significantly greater than the temptation condition, where garbage chutes are open (41 ft) (error bars reflect ±1 SEM). (b) Weight of paper recycling in kilograms, per person, per week. Hallway condition is significantly greater than all other conditions (error bars reflect ±1 SEM). (c) Weight of compost in kilograms, per person, per week. Hallway condition is significantly greater than all other conditions (error bars reflect ±1 SEM).

paper or compost. This is consistent with Ando and Gosselin's (2005) discovery that the Euclidian distance to recycling stations had a negative effect on container recycling rates but not on paper recycling rates, suggesting that it is easier to recycle paper than containers, given that containers may be more cumbersome to carry.

7. General discussion

In the current study, we tested how convenience influenced recycling and composting rates by manipulating convenience in residential and student residence buildings, and subsequently measuring container recycling, paper recycling, and composting over 10 weeks. We were specifically interested in examining the functional role of convenience when it comes to diverting waste from the landfill in MFDs, and how different forms of convenience may influence recycling and composting.

In Experiment 1, we manipulated convenience by varying the physical distance between the compost bin and the suites. We found a substantial 70% increase in composting when the location of the bins was highly convenient – with one bin on each floor. This was equivalent to diverting 27 kilograms of compostable materials from the landfill per bedroom unit per year. This finding was replicated and found to be a conservative estimate in Experiment 2, where the composting rate increased by 139% when the bin was 5 ft away from a suite, compared to when the bins were farther away. Bernstad (2014), as discussed earlier, found a 50% increase in composting after implementing disposable in-suite food waste sorting equipment. Taken together, these results show that composting rates are affected more strongly by decreasing distance to composting bins than by providing residents with in suite equipment. It is important to note, however, that data comparing the contamination rates for both of these strategies is not available. Future studies should examine whether implementing more convenient in-suite equipment and shorter distances to compost bins yields an additive benefit. We also found that container recycling increased by 147% and paper recycling increased by 137% when the location of the bins was convenient. This increase was equivalent to diverting 14 kilograms of compost, 23 kilograms of containers, and 22 kilograms of paper, from the landfill per person per year.

Such a dramatic increase in diversion rates is especially impressive given the large scale of the residential complexes. The anonymity that comes from having hundreds of people living in the same building creates an environment that has traditionally been thought to impede recycling behavior (De Young *et al.* 1995). The current study indicates that a mere change in physical convenience (i.e. decreasing the distance from suite to bin), without any change in social-motivational factors through interventions (e.g. De Young *et al.* 1995), leads to a profound increase in composting and recycling in large residential complexes.

Furthermore, the increase in composting and recycling behavior is exceptional given the participant demographic in our study. Both students, relatively younger with little income, and older and wealthier individuals recycled and composted more when the bins were located in convenient locations. Our effect is thus robust across demographic factors such as age, income, and education, which are generally positively correlated with recycling behavior (Gamba and Oskamp 1994; Nixon and Saphores 2009; Owens, Dickerson, and Macintosh 2000). The current results suggest that a simple infrastructure change can have a drastic effect on pro-environmental behavior across demographics.

It must be noted, however, that the current study did not focus on the underlying attitudes or cultural norms of the resident populations. The results of the present study combined with past findings (Bernstad 2014; Yau 2012) suggest that the underlying attitudes and culture of the residents in question may interact with the effectiveness of a convenience intervention. Thus convenience alone may not increase recycling behavior as effectively in populations with different underlying attitudes or cultural backgrounds.

The current study also raises an intriguing question: Is the key ingredient for boosting recycling and composting rates actual convenience (i.e. physical distance to bin) or perceived convenience? Experiment 1 shows that despite the more convenient condition being closer to resident suites than the least convenient condition, recycling and composting rates were comparable. Both conditions required the use of an elevator, which may signal a cost that goes beyond just physical distance (i.e. extra time to turn off the stove, put on shoes, have a conversation with a neighbor, etc.). This could explain that despite the most convenient and more convenient conditions being the same distance away from resident suites, the former produced significantly higher composting rates than the latter. Future studies should examine the impact that perceived convenience has on composting rates. It might be possible to boost composting and recycling rates without changing the physical location of garbage bins, by changing the perception of how convenient the bins are to access.

In conclusion, to our knowledge we report the first direct evidence that increasing the convenience of bins promotes recycling and composting in MFDs. Using the Waste Reduction Model (WARM) calculator developed by the Environmental Protection Agency (EPA 2015), we can precisely calculate that over the course of one year, installing bins in hallways in the three residential buildings under study would result in a total emission reduction of 650 $MTCO_2E$ (metric tonnes of carbon dioxide). Although conveniently located disposal stations may not promote recycling and composting compliance in all contexts, our experiments provide support for their effectiveness in both university student residences and residential buildings. The current evidence has important implications for waste management, environmental policy makers, urban designers, and architects to work toward making recycling and composting more accessible and convenient for the public, with the ultimate goal of reducing waste destined for landfills and the costs associated with it.

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Notes

1. 3.28 ft = 1 meter.
2. The same result is obtained if we omit the compost collected in the shared bin. That is, the most convenient condition produced more compost than the more convenient condition, even when the comparison was based only on the small hallway bins ($p < 0.05$).

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