Categorization and Waste Management: More Complex Recycling Systems Lead to Less Wasting

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Every year over 2.24 billion tons of waste reach landfills globally (United Nations, 2023), posing a significant threat to environmental, social, and personal wellbeing. Efforts to mitigate landfill contributions by facilitating recycling face challenges due to a lack of consensus on what is the most effective recycling system to minimize waste in terms of level of complexity. Three preregistered studies reveal that the complexity of a recycling system—whether it involves a narrow categorization (e.g., *paper*, *plastic*, *metal*, *glass*) versus a broader categorization (e.g., *recyclables*)—influences individual recycling behavior. Surprisingly, broader categorizations lead to increased tendency to waste. In contrast, narrower categorizations promote overzealous recycling, causing contamination in the recycling supply chain. Our findings offer valuable insights for policymakers and a scalable intervention to mitigate both errors, resulting in more effective recycling.

Keywords: Waste, Recycling, Categorization

Track: Consumer Behavior

1. Introduction

Every year, more than 2.24 billion tons of waste are sent to landfills worldwide (United Nations, 2023) posing a serious threat to environmental, social, and personal wellbeing. In an effort to address this issue, governments globally support recycling campaigns, and encourage consumers to mindfully separate recyclables from non-recyclable waste. While policymakers unanimously recognize the necessity of implementing efficient recycling systems to reduce the volume of discarded goods sent to landfills, there is a lack of consensus on a standardized recycling system. In certain regions (for example, several parts of Italy), consumers receive instructions to meticulously sort their household garbage into specific categories like *paper*, *plastic*, *metal*, *glass*, and *general waste*. Conversely, in other regions (for example, the UK or the US), consumers are only required to separate items into recyclable and non-recyclable bins. Other regions have adopted recycling systems that fall between these two extremes. Given the heterogeneity in these systems, it is important to understand what is their relative effectiveness in terms of maximizing recycling by reducing unnecessary waste, such as discarding items that would be recyclable into general waste.

This research aims to answer this question by testing whether recycling systems that require consumers to categorize more narrowly (e.g., by separating recyclable goods into *paper, plastic, metal,* and *glass*) versus more broadly (e.g., by including all recyclable items in one category) influences people's tendency to waste and to recycle.

2. Theoretical Background

Prior research has identified several factors that can increase consumers' propensity to recycle, thereby reducing household waste. These factors include loss- versus gain-framed messages (White, MacDonnell, & Dahl, 2011), the extent to which a product's original form has been distorted during the consumption process (Trudel & Argo, 2013; Trudel, Argo, & Meng, 2016b), its relation to one's identity (Trudel, Argo, & Meng, 2016a), its past usage (Kamleitner, Thürridl, & Martin, 2019), or its potential future use (Winterich, Nenkov, & Gonzales, 2019). While these factors are effective, their impact is potentially limited as they do not directly affect the recycling system itself, but rather individual products or consumers (Chater & Loewenstein, 2022). Existing research that adopts a more systemic focus primarily examined whether simply offering the option to recycle, irrespective of its degree of categorization, influences resource usage (Catlin & Wang, 2013; Giebelhausen, Chun, Cronin

Jr., & Hult, 2016; Ma et al., 2019; Sun & Trudel, 2017; Van Doorn & Kurz, 2021). However, another crucial factor is always activated when consumers engage with a recycling system: the extent to which consumers need to categorize discarded goods. The central focus of this work is the underexplored question of how much the complexity of a recycling system affects how people dispose of goods. Here we define the complexity of the recycling system as the extent to which consumers categorize discarded goods either narrowly (e.g., by separating recyclable goods into *paper*, *plastic*, *metal*, and *glass*—higher complexity) or broadly (e.g., by including all recyclables items in one category—lower complexity).

To answer our research question, we build upon prior work on categorization. Previous studies on cognitive reasoning and accurate object descriptions (Ülkümen, Chakravarti, & Morwitz, 2010; Kruger & Evans, 2004; Savitsky et al., 2005) suggest that more complex categorization systems (those with a higher number of categories) make people's cognitive processes more accurate. Therefore, we predict that a narrower categorization of the recycling option—prompting consumers to categorize waste items into a higher number of categories (e.g., *paper*, *plastic*, *metal*, and *glass*)—encourages more accurate sorting. This enhanced accuracy is likely to result in fewer errors when deciding whether an item is recyclable or not. In contrast, a broader categorization—prompting consumers to categorize goods into fewer categories (e.g., merging all recyclable items into *recyclables*)—might lead to less accurate sorting, incentivizing the incorrect allocation of recyclable items to the trash, ultimately increasing waste.

Earlier studies also indicate that the likelihood of an event occurring tends to rise when the potential outcomes are divided into numerous categories as opposed to a limited set of alternatives (Isaac & Brough, 2014). Consequently, a greater number of bins could lead individuals to overestimate the degree to which items should be classified as recyclable by erroneously putting more non-recyclable items into the recyclables bin(s) —a bias that we define as *overzealous recycling*. We test our propositions across a series of preregistered studies: After inquiring about consumers' general preference for recycling systems with different degrees of complexity (Study 1), we tested the effect of the complexity of the recycling system (broad vs. narrow) on people's tendency to waste and recycle (Study 2), and an intervention to mitigate such recycling errors (Study 3).

3. Methods

Study 1

Study 1 aimed to assess consumers' preferences for three recycling systems of varying complexity (two, three, or six bins). Participants (N = 150, 65% females, M_{age} = 42.45, SD = 14.44; https://aspredicted.org/XWQ_H84) evaluated these systems within-subjects, imagining they had to use them to dispose of their household garbage. The two-bins system featured *recyclables* and *general waste*, the three-bins system included *recyclables*, *composting*, and *general waste*, and the six-bins system featured *paper*, *plastic*, *metal*, *glass*, *composting*, and *general waste* categories.

The three recycling systems were presented in random order. Participants rated each system based on four aspects. The first aspect (our focal dependent variable) was consumers' preference for the recycling system ("How favorably would you view the introduction of this recycling system in the area where you live?" 1 = I would be very much against; 7 = I would be very much in favor). Then participants rated the predicted acceptance of the recycling system in the community where they lived ("How favorably would other people in your area view the introduction of this recycling system?" 1 = They would be very much against; 7 = They would be very much in favor); the perceived effectiveness of the recycling system: "To what extent do you think this recycling system could help increase the amount of waste recycled in your area?" (1 = It would not help at all, 7 = It would help very much). Lastly, we asked participants whether a recycling system is in place in their area (yes, no) and its similarity with the three systems they rated, by asking them to identify which one was most similar to the system in use where they live (1 = 2 bins, 2 = 3 bins, 3 = 6 bins, 4 = Other – please specify).

Results. A repeated measures ANOVA showed a significant effect of recycling system complexity on consumer preference ($F(2, 298) = 48.72$, $p < .001$). Participants favored the three-bins system (M = 5.97, SD = 1.25) over the two-bins system (M = 5.41, SD = 1.87, $t(149) = 3.41$, $p < .001$) and the six-bins system (M = 4.15, SD = 2.04, t (149) = 10.81, $p <$ .001). The two latter systems also differed significantly ($t(149) = 5.54$, $p < .001$), indicating a general preference for recycling systems with fewer categories. Similarly, participants predicted higher community acceptance for the two-bins (M = 5.51, SD = 1.52) compared to the six-bins system (M = 3.41, SD = 1.67, $t(149) = 11.85$, $p < .001$) and for three-bins system (M = 5.43, SD = 1.29) compared to the six-bins system ($t(149) = 13.63$, $p < .001$), but no difference was observed between the three-bins system and the two-bins system ($t(149) = .60$,

p = .548). Additionally, the six-bins system (M = 4.19, SD = 2.03) was perceived as less effective than the two-bins system (M = 4.95, SD = 1.93, $t(149)$ = -3.24, $p < .001$), and the three-bins system (M = 5.35, SD = 1.56, $t(149)$ = -6.34, $p < .001$). The three-bins system was also rated as more effective than the two-bins system ($t(149)$ = -2.38, p = .018). All these results hold also when controlling for familiarity.

Discussion: Consumers have a general preference for recycling systems that ask them to categorize in fewer vs. more categories. They also expect others to accept the former systems more easily and perceive them as more effective than the latter. These effects hold also when controlling for consumers' familiarity with the different systems. Despite greater preference for recycling systems with fewer categories, in Studies 2-3 we will show that they are not always optimal at incentivizing recycling behavior.

Study 2

Study 2 (N = 189, 22% females, M_{age} = 21.56, SD = 1.94; https://aspredicted.org/CHM_T83), examined how the complexity of a recycling system (broad vs. narrow categorization) influences recycling behavior. The study was conducted using a university subject pool and to determine whether the items were disposed of correctly, we relied on the recycling guidelines of the neighbourhood where the study was conducted. We predicted that a narrow categorization (5 bins), compared to a broad categorization (2 bins), would reduce participants' tendency to waste, computed as the number of recyclable items erroneously allocated to the general waste bin.

Participants imagined that after moving to a new apartment they had to dispose of the garbage by dragging and dropping the different items one-at-a-time into the bins provided in a naturalistic task (see Appendix). The garbage included 25 items (20 recyclables, 5 non-recyclables in both systems). Participants were randomly assigned to either a broad categorization condition where the bins available were *recyclables* and *general waste*, or a narrow categorization, where the bins were *paper*, *plastic*, *metal*, *glass*, and *general waste*. The order of the items and of the bins was randomized. In both conditions we specified that paper-, plastic-, metal-, and glass-based items are recyclables so that the level of knowledge was comparable across conditions.

Our focal dependent variable was *tendency to waste*, which we computed as the number of recyclable items that had been erroneously allocated to the general waste bin. Additionally, we preregistered three other potential errors: *overzealous recycling* (i.e., the number of non-recyclable items put into the recyclables bin(s)), and a *recycling contamination error* as the

number of recyclables that ended up in the wrong bin (in the broad condition, the latter matching tendency to waste), and *error in recycling* as the sum of three errors above.

Exploratory variables included six measures collected after the recycling task: effort ("How effortful was disposing of the garbage?" 1 = not effortful at all, 7 = very effortful; time spent on the sorting task (in seconds); confidence ("How confident were you that you were disposing of the garbage correctly?" 1 = not confident at all, 7 = very confident); perceived impact of recycling behaviour ("To what extent do you think you have done something good for the environment?" 1 = very little, 7 = a lot); perception of waste produced ("How much general waste do you think you have produced?" 1 = very little, 7 = a lot); and perceived effectiveness of recycling ("How much of the disposed materials (everything that did not go in the general waste bin) do you think will be recycled?" 7-point slider scale: percentage of recycled material 0 – 100). We also measured whether a recycling system was in place where participants lived (Yes = 1 vs. No = 0) and familiarity with the recycling system featured in the experimental task (7-point scale: not at all - very much). Lastly, participants indicated whether the recycling system in use where they lived required sorting items into fewer, the same number, or more categories (7-point scale: 1 = less, 4 = same number, 7 = more categories).

Results. An independent sample t-test showed that tendency to waste decreases as the complexity of the recycling system increases ($t(187) = -3.81$, $p < .001$). Specifically, tendency to waste was lower in the narrow condition ($M = 3.21$, $SD = 2.36$) than in the broad ($M = 5.10$, $SD = 4.21$). However, in the narrow categorization ($M = 4.21$, $SD = .97$) overzealous recycling was higher compared to the broad categorization ($M = 3.20$, $SD = 1.47$, $t(187) = 5.58$, $p < .001$). The recycling contamination error did not differ between broad and narrow categorization systems ($p = .47$), and the overall error in recycling was also not significantly different ($p = .120$). Participants' confidence ($p = .221$), perceived impact of the recycling behaviour ($p = .516$), perception of the waste produced ($p = .948$) and effectiveness of the recycling system ($p = .889$) did not differ across conditions. The narrow categorization was perceived as more effortful than the broad ($p = .032$) and participants also spent more time completing the task ($p < .001$). In addition, people were more familiar with the broad categorization system than with the narrow categorization ($p < .001$). Results hold when controlling for familiarity with the recycling system.

Discussion. The results of Study 2 indicate that as the categorization system gets narrower (i.e., with more categories), people tend to waste less. However, a narrow categorization is

associated with an increase in overzealous recycling. The current study demonstrates that systems with narrower categories are perceived as more effortful, and the time required to dispose of the items is also higher. The fact that the perceived impact on recycling behavior does not differ across conditions suggests that the differences observed in the tendency to waste cannot be attributed to tokenism (i.e., greater entitlement to waste due to the narrower categorization, Sun & Trudel, 2017; Ma et al. 2019). Interestingly, despite a substantial difference in wasted recyclable resources, participants do not feel like they wasted more. We conducted a direct replication of this study on the participant pool of a Dutch University, and observed results consistent with the ones reported here.

Study 3

Study 3 (N = 800, 52% females, M_{age} = 43.3, SD = 14.07; https://aspredicted.org/WL4_WW7) aimed to i) replicate the effect of complexity of a recycling system on tendency to waste and overzealous recycling observed in previous studies, ii) test an intervention to mitigate the second error in the narrow categorization condition, by providing participants the option to consult recycling guidelines.

The study uses a 2 (broad vs. narrow categorization) by 2 (intervention vs. control) between-subjects design. We predicted an interaction between the complexity of the recycling system and the intervention, such that in absence of recycling guidelines, overzealous recycling would be higher in the narrow than in the broad categorization (replicating the results of prior studies). However, we expected this difference to be reduced when participants had the option to consult the recycling guidelines.

Participants were provided with the same scenario and the same stimuli of Study 2. The recycling guidelines that participants could consult when such possibility was offered are reported in the Appendix. In contrast to Study 2, where the act of dragging-and-dropping was used to simulate disposal more realistically, we replaced it with multiple-choice questions. We computed overzealous recycling and tendency to waste as in Study 2 and we also collected the same exploratory variables.

Results. On average, participants consulted the guidelines the same number of times in both recycling systems when such possibility was available (M_{broad} = 3.95, SD = 2.97, M_{narrow} = 3.42, SD = 3.25, $t(400) = 1.62$, $p = .106$), suggesting that neither system prompted people to consult the guidelines more often. A 2 (recycling system: broad vs. narrow) x 2 (intervention: guidelines vs. control) ANOVA on overzealous recycling revealed significant

main effects of recycling system (M_{broad} = 2.23, *SD* = 1.20 ; M_{narrow} = 3.51, *SD* = 1.45; $F(1, 798) = 209.03$, $p < .001$), of the intervention (M_{broad} = 3.28, *SD* = 1.35; M_{narrow} = 2.46, *SD* = 1.49; $F(1, 798) = 84.49$, $p < .001$), and a significant interaction ($F(1, 798) = 10.95$, $p < .001$), such that the effect of categorization on overzealous recycling replicated in the control condition (M_{broad} = 2.49, *SD* = 1.16; M_{narrow} = 4.07, *SD* = 1.01; $F(1, 798) = 157.44$, $p < .001$), but it was attenuated when the possibility to consult the recycling guidelines was offered (M_{broad} =1.97, *SD* = 1.18; M_{narrow} = 2.96, *SD* = 1.59; $F(1, 798) = 62.30$, $p < .001$). Examining tendency to waste, a 2x2 ANOVA revealed significant main effects of recycling system, (M_{broad} =3.53, *SD* = 3.00; M_{narrow} =2.16, *SD* = 2.02, $F(1, 798) = 69.99$, $p < .001$), of the intervention (M_{broad} = 3.86, *SD* = 2.79; M_{narrow} =1.83, *SD* = 2.05*;* $F(1, 798) = 154.23$, $p < .001$), and most importantly, a significant interaction ($F(1, 798) = 22.32$, $p < .001$), such that in the control condition, people wasted more in the broad than in the narrow condition, replicating prior results (M_{broad} = 4.94, *SD* = 2.93*;* M_{narrow} = 2.79, *SD* =2.17*;* $F(1, 798) = 85.47$, $p < .001$), whereas such effect was attenuated in presence of possibility to consult the guidelines (M_{broad} = 2.12, *SD* = 2.36; M_{narrow} =1.53, *SD* = 1.64; $F(1, 798) = 6.65$, $p < .001$). In this study we did not observe a difference in effort between the two systems ($p = .349$), but the narrow categorization compared to broad increased participants' confidence ($p = .020$), and their perceived impact of the recycling behaviour ($p = .042$), while it did not affect the perception of the waste produced ($p = .320$) and of effectiveness of the recycling system ($p = .345$).

Discussion. Study 3 replicated prior findings and additionally demonstrated that offering the option to consult the recycling guidelines reduces the gap between the two systems on both overzealous recycling and tendency to waste. The results of this study also suggest that the benefits of recycling systems with narrow categorizations are minimized the moment easily accessible recycling guidelines can be consulted.

4. Conclusions

A series of preregistered experiments provide consistent evidence that, despite being consumers' most preferred option, a broader categorization of a recycling system leads people to inaccurately allocate more recyclable items into the general waste, ultimately landfilling items that could have potentially been given a new life. However, we also show that a narrower categorization leads people to erroneously recycle more non-recyclable items and therefore contaminate the recycling supply chain. We propose that providing easily accessible

recycling guidelines is a readily implementable and scalable intervention to mitigate the magnitude of both errors and enhance the efficiency of recycling across different categorization systems.

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6. Appendix

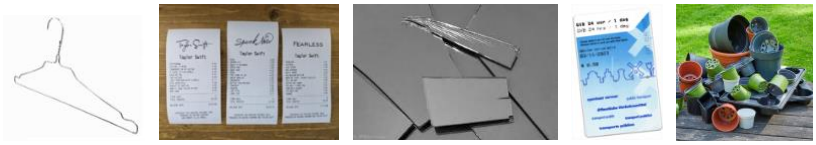
6.1 Stimuli used in Studies 2 and 3.

Paper-based: 

Plastic-based: 

Metal-based: 

Glass-based: 

General waste: 

6.2 Recycling guidelines provided in Study 3.