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Space oddity: How context matters in waste-sorting behavior

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Abstract

The circular economy gives a prominent role to recycling, entailing the general implementation of waste sorting in private, semi-public, and public locations. Previous literature has extensively explored the psychological and contextual antecedents of waste-sorting behavior, but mainly with a focus on one specific setting, without considering how the sorting location might moderate the influence of these antecedents. To investigate this research question, we develop a dual-route model of waste-sorting behavior based on an integrated TPB-NAM framework. To test this model, we used a survey based on self-reported data considering three successive locations (i.e., home, university and on the way to university) from the same 296 French college students and analyzed it using structural equation modeling with partial least squares (PLS-SEM). Although both psychological and contextual routes influence waste sorting, we show that their relative importance differs across locations. Furthermore, at university and on the way to university, the contextual route influences the psychological one. These results highlight why individuals' self-reported waste-sorting behavior may vary across locations and call on academics to replicate pro-environmental behavior models across all relevant contexts before recommending public policies to promote them.

***Keywords*:** Waste-sorting behavior, Spaces, Contextual factors, Facilitating conditions, Anticipated guilt, TPB-NAM.

Introduction

EU Directive 2008/98/EC on waste laid down measures to prevent or reduce the adverse impacts of waste generation and management. Since then, EU waste management policies have placed significant emphasis on recycling, leading to a near doubling of sorting residues between 2010 and 2022 in the EU and an increase in the collection of recyclable products (EEA, 2024a). The European Environment Agency (EEA, 2024b) emphasizes that "*policies proven successful in reducing landfilling include landfill bans and taxes, and incentives for recycling and recycling infrastructure.*"

Recycling refers to the entire process by which used materials are sorted, reconditioned, and reused. It aims to alleviate the strain on natural resources by reducing the demand for new raw materials that can be replaced by used materials, thereby decreasing waste quantities (Zomeren & Tosti, 2017). Additionally, it reduces energy consumption and the volume of greenhouse gases emitted during the production of new goods (Kaza et al., 2018). However, recycling necessitates rigorous waste separation (Goh et al., 2022). Without sorting, recycling becomes more challenging, and in some cases, even impossible. For instance, paper cannot be recycled if it is mixed with putrescible waste. The earlier sorting and separation occur, the easier and cheaper the process becomes, resulting in less recyclable material being lost.

Sorting is even more important at the household level. In 2022, households represented 24% of EU waste generation excluding major mineral waste, and this proportion is tending to increase, as household waste generation has risen by 10.6% compared with 2004, while overall waste generation in the EU has risen by only 2% (Eurostat, 2022). The systematic participation of ordinary citizens in sorting, all the time, everywhere, is therefore crucial for the effectiveness of recycling policies (Schultz et al., 1995; Knickmeyer, 2020). This raises the question of how context influences individuals' waste-sorting behavior.

While there is a considerable body of literature on individuals' waste-sorting behavior, most of it focuses on identifying its antecedents (i.e., theoretical constructs such as norms, attitudes, and intentions) in specific locations, whether domestic, hence private, or organizational, hence semi-public. The domestic space has attracted the most attention (Tudor et al., 2008). Other, smaller streams of the literature focus on waste sorting at work (e.g., Lee et al., 1995; Yuriev et al., 2018) or at university (e.g., Kelly et al., 2006; Bailey et al., 2015). In this literature, waste-sorting behavior is seemingly assumed to operate similarly across contexts, at home, at work and at university. Individuals would draw everywhere on the same

awareness regarding the consequences of recycling and the same social norms, and should thus feel the same motivation for sorting (Smith & O'Sullivan, 2012). And indeed, a significant correlation between recycling at home and at work suggests the existence of self-consistency spillovers (Lee et al., 1995; Tudor et al., 2007).

Yet, the specific influence of context in waste-sorting behavior has attracted too little attention and a few studies suggest that individuals sort differently in different spaces. For Whitmarsh et al. (2018), individuals report a higher proportion of waste recycled at home (67%) than in the workplace (39%) and on holiday (38%). This could result from differences both in terms of facilitating conditions and social exposure. To explain such "space oddities", it is necessary to study the same individuals' waste-sorting behavior in different spaces. To the best of our knowledge, very few research papers have attempted this so far. Tudor et al. (2007) explored the correlations between the determinants of waste-sorting behavior in the 'home' and 'work' settings, but they did not explain how these determinants correlate with waste-sorting behavior in the two settings. Whitmarsh et al. (2018) identified the drivers that predict researchers' waste-sorting behavior at home (i.e., perceived behavioral control - PBC, knowledge, attitude), at work (i.e., pro-environmental identity), and on holiday (i.e., PBC, recycling facilities, personal norms), but did not explore how the sorting location might moderate the influence of these drivers on waste-sorting behavior.

To investigate this specific research question, we first develop a dual-route model of waste-sorting behavior that incorporates variables from the Norm Activation Model (NAM) beyond the classic variables of the Theory of Planned Behavior (TPB). This sheds light on the psychological mechanisms at play, notably on the role of anticipated guilt, which has been shown to influence sorting (Elgaaied, 2012). To test our dual-route model, we carried out a survey based on self-reported data considering three successive locations (i.e., home, university, on the way to university) from the same 296 French college students. We used structural equation modeling with partial least squares (PLS-SEM) and a multi-group structural analysis with permutation tests, instead of stepwise regression analyses for each context, which made it possible to examine differences in paths across locations.

By testing our dual-route model in three different locations and showing that the relative importance of the paths varies across them, we demonstrate that waste sorting cannot be explained by a single model but requires context-specific models depending on spatial settings. This represents an important theoretical contribution, as it underscores the need to account for location-specific characteristics when analyzing pro-environmental behaviors. In other words,

conceptual models of pro-environmental behaviors should be validated across multiple relevant contexts rather than being restricted to a single setting.

We advance this contribution by providing improved internal and external validity compared with previous research. With respect to internal validity, we examine how social science students self-report their waste-sorting behavior across three locations (i.e., home, university, on the way to university), thereby controlling for age and for the types of waste likely to be sorted, which are fairly similar across contexts (e.g., recyclable packaging such as bottles and cans, paper, cardboard, tissues, or organic waste such as peelings and leftovers). Regarding external validity, we extend prior research by including two additional contexts beyond the home, i.e., university (a semi-public space) and commuting to university (a public space), which strengthens the generalizability of existing findings on waste-sorting behavior[1].

The remainder of the paper is organized as follows. First, we review the main theories proposed in the literature to explain waste-sorting behavior and the spatial influences on pro-environmental behaviors. Next, we introduce our conceptual model and describe the methodology, which relies on self-reported online data. We then present the results obtained through structural equation modeling using PLS-SEM. Finally, we discuss the findings and conclude.

Literature review

Academics have devoted substantial effort to understanding and explaining pro-environmental behavior (Steg & De Groot, 2019) as it is a prerequisite for developing appropriate and effective policies to address pollution and promote sustainable development. A significant body of literature has specifically focused on explaining waste-sorting behavior.

Explaining waste-sorting behavior

Given the wide range of factors found to influence waste-sorting behavior, including attitudes, beliefs, norms, values, environmental concerns, knowledge, awareness, education, socio-

[1] The literature distinguishes between private and public pro-environmental behaviors in three different ways. In the first view, private behaviors suggest individual actions in the private sphere, at home for instance, whereas public behaviors are collective and closer to advocacy behavior (e.g., petitioning, public voicing, volunteering) by citizens in the public sphere (e.g., Stern, 2000). In the second view, the distinction between private and public behaviors depends on the visibility of the behavior (Francey & Bergmüller, 2012), and this leads to a focus on reputational effects (Bateson et al., 2006). In the third view, the distinction is based on the spaces where the behavior takes place and their relative openness to the public. They can be considered as public spaces (e.g., streets, parks, bus stations), private spaces (e.g., the home), or semi-public spaces (e.g., universities, restaurants). Semi-public spaces operate as a buffer zone between public and private spaces. They are common spaces for some individuals, while excluding others. Our research adopts this third view.

demographic characteristics, etc., coherent models are essential to provide a framework for explaining individuals' decisions to engage in it. The TPB is certainly the most frequently used model to explain waste recycling (Mannetti et al., 2004; Geiger et al., 2019). According to this model, intention to perform a behavior depends on the attitude towards the behavior, the perceived social pressure to perform the behavior, namely the subjective or social norm, and the PBC (Ajzen, 1991, p.181/188). Intention then results in behavior. However, the effectiveness of the TPB to predict pro-environmental behaviors has raised increasing concerns (Yuriev et al., 2020). In particular, the TPB is argued to be too "rational," putting too much emphasis on the consciously-controlled aspects of human information processing and decision-making, without considering personal habits or household routines, nor affective states and emotions (Conner & Armitage, 1998).

Following Ajzen's (2011) invitation, some authors have proposed more complex versions of the TPB, notably by integrating components of the NAM (Chen & Tung, 2010; Botetzagias et al., 2015; Setiawan et al., 2020). In the NAM, behavior is shaped by an individual's personal moral obligation, which operates through a process of norm activation (Schwartz, 1977; Bamberg & Möser, 2007; Onwezen et al., 2013). Personal norms arise when individuals are both aware that their actions have tangible consequences and feel responsible for those outcomes (Chan & Bishop, 2013; Manstead, 2000). Unlike social norms, they do not rely on the threat of sanctions. For instance, altruistic behaviors are driven by personal norms when individuals recognize the impact of their actions on others' well-being and assume responsibility for these effects. The underlying motivation is thus a perceived moral duty, which may originate in social norms but becomes internalized over time. Accordingly, in the NAM, personal norms mediate the link between social norms and behavioral intention (Thøgersen, 2006).

The TPB and the NAM typically explain individual sorting behavior based on stable personal characteristics. While they are useful for accounting for general sorting intentions, they are less effective in explaining specific sorting actions (Grassias, 2025). To address this limitation, it is necessary to consider the context of decision-making and incorporate more automatic, non-deliberative mechanisms.

Introducing contextual factors

Individuals tend to rely on similar beliefs about recycling, as well as comparable social and personal norms, when sorting at home and in the workplace. One might therefore expect their

motivation to engage in waste sorting to remain consistent across settings (Smith & O'Sullivan, 2012). Empirical evidence partly supports this view: several studies report significant correlations between recycling at home and at work (Tudor et al., 2007, 2008). Yet other research shows that individuals are more likely to sort waste at home than in alternative contexts, such as the workplace or during holidays (Barr et al., 2010; Whitmarsh et al., 2018). To account for these "space oddities", previous studies have highlighted the role of contextual factors (Geiger et al., 2019, 2022), notably time (e.g., waste collection frequency; Ölander & Thøgersen, 1995; Barr, 2007) and space (e.g., availability of storage for recyclables at home; Hornik et al., 1995; Timlett & Williams, 2011). Such contextual variables may exert a direct influence on waste-sorting behavior (Zhang et al., 2019; Matiiuk & Liobikienė, 2021), whereas within the TPB they are generally treated as indirect drivers operating through PBC. As De Young (1989, p. 350) aptly notes, "*the issue, in fact, is not why one ought to recycle, but rather how one is to carry out the activity.*"

From this perspective, relatively few studies have examined waste sorting through the lens of habit formation (Knussen & Yule, 2008). Monnot et al. (2014), for example, investigated how consumers develop logistical strategies to manage household waste daily. Once established, these strategies may trigger waste-sorting behavior automatically, consistent with dual-system theory (Kahneman, 2011), which distinguishes between two modes of cognitive processing: System 1, characterized by fast, intuitive, and effortless thinking, and System 2, marked by slow, deliberate, and effortful reasoning. The extent to which sorting habits engage System 1 in routine decision-making is likely to vary across contexts (Grassias, 2025). Hence, individuals may be less inclined to sort waste in settings that fail to support the development or activation of habits, such as while on holiday or when faced with unfamiliar waste types.

Accordingly, space-related contextual factors, both in terms of facilitating conditions and social exposure, may significantly influence waste sorting (Lo et al., 2012). At work, for example, organizational factors such as managerial support, colleagues' attitudes, and internal culture have been shown to shape behavior but are irrelevant in domestic settings (Yuriev et al., 2018). In public or holiday contexts, brightly colored recycling bins may serve as more salient and effective cues than at home (Lin et al., 2016). Conversely, the monetary cost of sorting may weigh heavily in households but not in workplaces (Lee et al., 1995; Whitmarsh et al., 2018). Yet, because most studies on waste sorting examine antecedents within a single setting, either domestic, hence private, or organizational, hence semi-public, the role of space-related contextual factors has been largely overlooked (Reniou et al., 2026).

Tudor et al. (2007) were the first to compare the determinants of waste-sorting behavior between the 'home' and 'work' settings, but they neither measured contextual factors in these environments nor examined whether their influence varied between them. Whitmarsh et al. (2018) advanced this line of inquiry by exploring waste-sorting behaviors at home, at work, and on holiday. They conducted interviews with university researchers, whose waste practices largely depend on location, and identified antecedents influencing behavior across the three contexts. However, they did not assess whether location moderates the impact of these antecedents. Moreover, their study did not control for waste type, respondent age, or the role of habit formation, all of which have been shown to shape sorting behavior (Lakshmi et al., 2022).

The aim of the present research is to fill this gap by better understanding how the location might moderate the influence of the antecedents of waste-sorting behavior. The next section introduces the conceptual framework guiding this analysis across three distinct settings.

Conceptual model

The conceptual model we develop aims to investigate how the location moderates the influence of the antecedents of waste-sorting behavior. Specifically, the model is designed to account for variation in the same individuals' sorting behavior across three spatial contexts, which differ in their degree of public accessibility: a private space (i.e., the home), a semi-public space (i.e., the university) and a public space (i.e., the commute to and from university). Drawing on existing literature, the model integrates both rational and emotional psychological factors to explain waste-sorting behavior, while explicitly incorporating space-related contextual variables. Furthermore, it considers how facilitating conditions influence motivational processes.

We build on Onwezen et al. (2013), who propose an integrated NAM-TPB framework in which personal norms, reflecting moral convictions, shape individuals' anticipation of future emotions. In this framework, the TPB provides the rational foundation while incorporating NAM-related motives, thereby enhancing predictive power. Bamberg and Möser (2007) highlight the mediating role of emotional reactions, particularly guilt, when social and personal norms interact: internal attributions evoke guilt, which in turn fosters a sense of moral obligation to offset environmentally irresponsible behavior. Similarly, Carrus et al. (2008) show that anticipated guilt mediates the effect of personal norms on pro-environmental behavior. More recently, Elgaaied (2012) confirmed that anticipated guilt is a central determinant of

recycling intentions, with the strongest explanatory power observed when guilt mediates the relationship between personal norms and behavior.

Given our focus on different settings, facilitating conditions play an important role in the conceptual model we propose. First, consistent with Ertz et al. (2017), who show that favorable contextual perceptions are positively related to PBC, we expect facilitating conditions to shape PBC. Littleford et al. (2014) further demonstrate that having physical control over one's environment directly strengthens PBC, suggesting that this effect may vary across locations. Beyond PBC, we also anticipate a direct influence of facilitating conditions on waste-sorting behavior, in line with prior evidence (e.g., Knussen et al., 2004; Monnot et al., 2014; Varotto & Spagnolli, 2017). Finally, drawing on Steg and Vlek (2009), we assume that the impact of contextual factors on behavior may be mediated by anticipated guilt.

Following Chan and Bishop (2013), who show that a TPB model substituting personal norms for attitude accounts for greater variance in recycling intention and behavior, we replace attitude with personal norms. Moreover, Goh et al. (2022) demonstrate that awareness of environmental consequences, together with social norms, contributes to the formation of personal norms, as individuals internalize shared understandings of what is good or bad, right or wrong.

In the end, our model is structured along two complementary routes as shown in Figure 1: a psychological route and a more contextual route that emphasizes facilitating conditions while also incorporating PBC. These two routes are assumed to be interdependent. Facilitating conditions may, for example, influence anticipated guilt: individuals are likely to feel more guilty about not recycling when waste collection facilities are readily available. Unlike the TPB but consistent with the NAM, our model does not include behavioral intentions. Prior studies suggest that intentions are weak predictors once awareness of consequences and facilitating conditions (Holland et al., 2006; Yuriev et al., 2020) or personal norms are accounted for, which supports their exclusion in an integrated TPB–NAM framework.

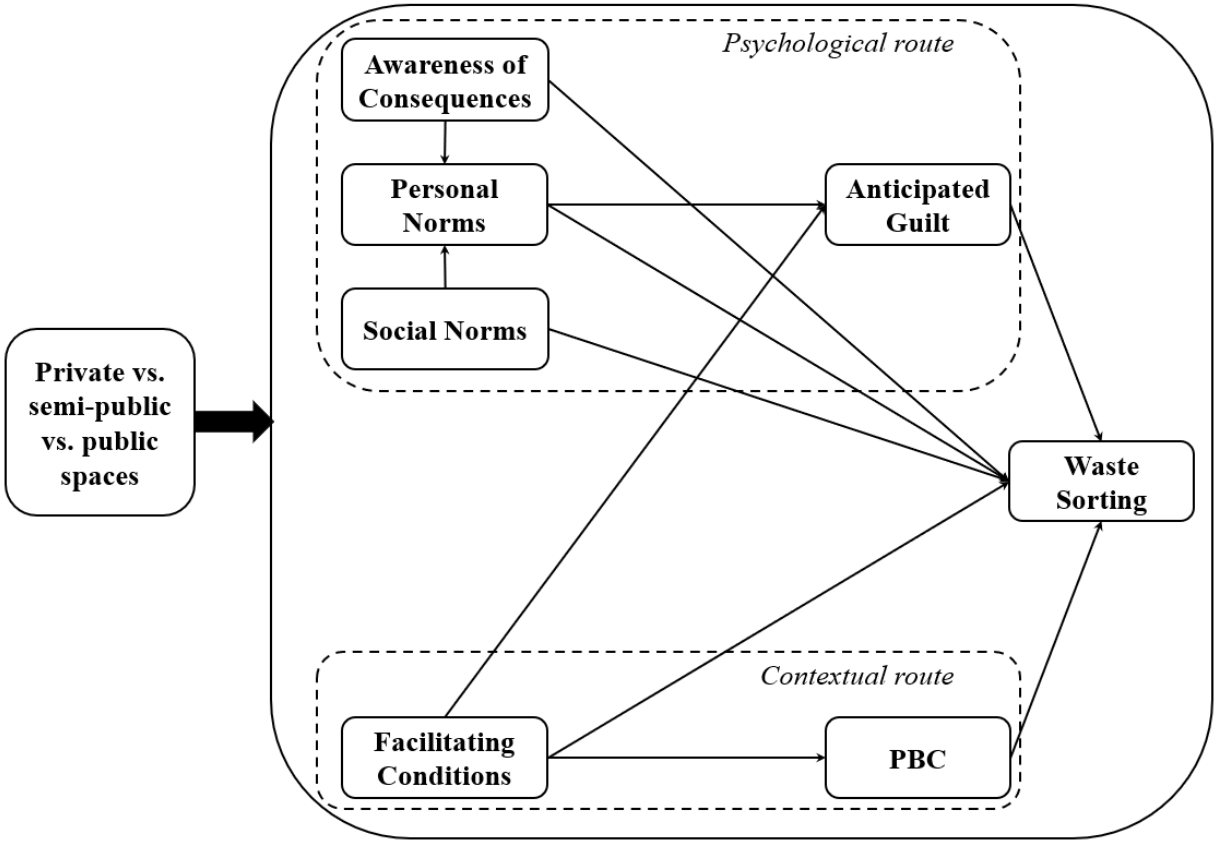


Fig. 1. Conceptual model.

Given that public, semi-public, and private spaces differ in terms of visibility and individual control (Ergun & Kulkul, 2019), we expect the relationship between the two routes to vary by context. Waste sorting in private spaces is typically less visible to others but more controllable for the individual, as familiarity with facilitating conditions (Littleford et al., 2014; Reniou et al., 2026) can make the practice easier. Conversely, the absence of social exposure may reduce anticipated guilt and thereby discourage waste sorting (Baumeister et al., 1994; Parkinson & Illingworth, 2009), as altruistic behaviors are sometimes motivated primarily by the desire to alleviate guilt (Feigin et al., 2014). Although recycling facilities in public and semi-public spaces have expanded over the past decade, individual control remains limited, and behavior in these contexts may be more strongly shaped by social norms. This effect is likely to be amplified in workplaces or educational settings, where social ties with colleagues and peers are particularly influential (Brooks, 2007). Taken together, these insights suggest that the relative importance of the antecedents of waste sorting varies across spatial contexts.

Methodology

We carried out an online survey on Qualtrics to test our conceptual model across three different locations, including a private space, a semi-public space and a public space. approved by the research ethics committee of Université Paris Dauphine – PSL (FF/KB – 20231222/01) and was transparently presented as a study on individual waste sorting, in accordance with the committee's requirements.

Participants

Data were collected from 394 first-year college students in social science at two French universities, in exchange for their participation in a lottery (i.e., 40 Kadeos vouchers worth €20 were up for grabs, which represented about a 1 in 10 chance of winning one). Students were invited by email to participate in the online survey at a time that suited them best. After confirming their informed consent, participants were asked to consider three successive recycling settings (at home, at university, on their way to university) and to answer the same set of questions for each recycling setting. As is usually the case in France, the two universities do not offer on-campus accommodation, so their students all have to make their own way to campus with different modes of transit to campus (e.g., walking, bus, metro). As previously explained, surveying students in social science offers better control than previous research over the kind of waste likely to be sorted, as fairly similar types of personal waste are likely to be sorted in the three locations, including recyclable packaging (e.g., bottles, cans), paper, cardboard, tissues or organic waste (e.g., peelings, leftovers from meals). Moreover, the three locations presented to students, i.e., their home, their university (where they spend most of their time), and the route between the two, are all familiar environments. We therefore assume that students are likely to have already developed habits related to waste sorting in each of these settings.

Measures

In line with previous research (Whitmarsh et al., 2018), all constructs were measured three times, once for each recycling setting. This approach enables strict control over individual-level variability when comparing the estimated model across the three recycling contexts, but it also increases the cognitive load for participants. To mitigate this, we prioritized short scales and successfully limited the response time (median = 15 minutes). The settings were presented in random order to prevent potential order effects. The questions concerned waste-sorting behavior, anticipated guilt, perceived behavioral control, facilitating conditions, personal norms, social norms, and awareness of consequences. Waste sorting was self-reported and

measured by a single item ("*When you have to throw away something that could be sorted for recycling, you put it in a recycling bin, even if that means keeping the item concerned until you find one"*) on a 5-point scale (*never – rarely – about half the time – usually – always*). This measure deliberately targeted a relatively extreme sorting behavior in order to avoid a social desirability answer. Most of the other items were adapted from established questionnaires and used 7-point Likert scales (see Table 1). The adequacy of the measurement model was evaluated using loadings and composite reliability. The elimination of 98 respondents who did not complete the questionnaire resulted in a final sample of 296 respondents (average age = 18.5, SD = .88, 66% female).

Table 1. Measurement items, reliability statistics and mean score.

Constructs	Measurement items	Loadings	Composite reliability	Mean	Std dev.
Waste sorting	When you have to throw away something that could be sorted for recycling, you put it in a recycling bin, even if that means keeping the item concerned until you find one			3.27	1.33
Anticipated guilt (Parguel et al., 2022)	At the thought of throwing away something that could be sorted for recycling:				
	AG1: I feel hesitant	.903	.931	5.11	1.79
	AG2: I feel uncomfortable	.890		4.88	1.86
	AG3: I don't feel anything at all (reverse)	.826		5.23	1.89
	AG4: I feel guilty	.893		4.74	1.89
PBC (Amireault et al., 2008)	Thanks to recycling bins:				
	PBC1: I can sort my waste more effectively	.890	.921	5.36	1.71
	PBC2: It's very easy to sort my waste properly	.908		5.45	1.65
	PBC3: I'm confident that sorting my waste will be effective	.875		5.21	1.75
Facilitating conditions (ad hoc)	FC1: I always know where to find recycling bins	.921	.924	3.91	2.42
	FC2: Recycling bins are easily accessible	.911		4.33	2.20
	FC3: There are recycling bins everywhere	.854		3.32	2.01
Personal norms (Kronrod et al., 2012)	PN1: Recycling my waste is very important to me	.926	.922	5.88	1.37
	PN2: Recycling my waste is a priority for me	.924		4.84	1.63
Social norms (Venkatesh and Bala, 2008)	SN1: My family and friends think I should sort my waste	.957	.956	5.09	1.81
	SN2: In general, my family and friends support waste sorting	.956		5.10	1.82
Awareness of consequences (ad hoc)	AW1: Waste sorting is important to fight pollution	.914	.917	6.24	1.21
	AW2: Waste sorting mitigates our impact on the planet	.926		6.21	1.22

With a mean score of 3.27 (out of 5), the item measuring waste sorting does not appear to be affected by social desirability. This mean of 3.27 results from different scores for different locations: 2.55 for sorting on the way to university, indicating that, on average, people sort less than half of the time in this context, 3.20 at university and 4.08 at home ($F_{(2,885)}$=126.37,

p<.001). Contrast tests show that our respondents sort their waste less on the way to university than when at university ($F_{(1,885)}$=45.05, p<.001), and less at university than at home ($F_{(1,885)}$=83.26, p<.001). Thus, data reflects some inconsistency in waste sorting across spaces.

Analysis

We used XLSTAT-PLSPM software to test the conceptual model and examine potential differences in the path coefficients across the different scenarios. PLS-SEM is beneficial since it only requires a minimum of 100 observations, even when the model is complex relative to the sample size (Chin, 1998; Hair et al., 2022). Moreover, it provides results even if the data deviate from a normal distribution (Shen et al., 2016), which was the case for individuals' awareness of consequences, as could be expected. In our case, a sample of 296 subjects allows the detection of small effect sizes (f^2 of .05) with a power of .80 and an alpha of .05 (Cohen, 1988).

As the respondents' university did not influence any of the constructs, we pooled the data. We controlled for gender when a bivariate relationship with one of the constructs was observed, which was the case for waste sorting, anticipated guilt, and personal norms.

Results

The following section discusses the reliability and validity of the measurement model in all three locations. Then the accuracy of the structural model is assessed, and the results are given. Lastly, the permutation tests of differences in the structural paths between them are presented.

Measurement model

To make sure the indicators for each construct measure what they are intended to measure, tests for convergent and discriminant validity were conducted on three sub-samples consisting of the responses for each location. This confirmed that the measures functioned adequately in all the data before making multi-group comparisons. Construct reliability was assessed by examining the indicators loadings: all are significant and exceed the recommended threshold of 0.708, as displayed in Table 1 (Hair et al., 2022). Moreover, the squared value of the indicator loadings always exceeds 0.5, confirming indicator reliability. Internal consistency reliability was assessed using Jöreskog's (1971) composite reliability (CR) and convergent validity using the average variance extracted (AVE). As displayed in Table 2, all the estimated indices are above the threshold of 0.6 for CR and 0.5 for AVE (Bagozzi & Yi, 1988). Finally, we tested the

discriminant validity of the construct items by looking at the cross-loadings, and found that all PLS item-to-construct loadings are greater than the cross-loadings (Gefen & Straub, 2005), and each correlation is lower than the square root of the AVEs of the two correlated variables (Fornell & Larcker, 1981). Together, these tests support the discriminant validity of the constructs across the three sub-samples.

Table 2. Results of the measurement model for the three sub-samples.

		At home			At university			On the way to university		
Latent variable	Items	Load.	AVE	CR	Load.	AVE	CR	Load.	AVE	CR
Anticipated guilt	AG1	.899	.734	.916	.896	.777	.933	.876	.766	.929
	AG2	.869			.894			.886		
	AG3	.802			.823			.844		
	AG4	.855			.911			.894		
PBC	PBC1	.869	.791	.918	.903	.804	.924	.878	.764	.907
	PBC2	.903			.904			.895		
	PBC3	.895			.882			.848		
Facilitating conditions	FC1	.895	.694	.870	.888	.806	.926	.912	.781	.916
	FC2	.880			.906			.871		
	FC3	.712			.900			.868		
Personal norms	PN1	.893	.852	.924	.900	.853	.924	.898	.853	.924
	PN2	.951			.947			.948		
Social norms	SN1	.947	.900	.947	.952	.902	.949	.962	.921	.959
	SN2	.950			.948			.957		
Awareness of consequences	AW1	.926	.858	.921	.895	.818	.900	.917	.854	.921
	AW2	.899			.914			.931		

Structural model

The structural model evaluates the significance of the 48 hypothesized paths in our conceptual model, with 16 paths estimated for each location. The goodness-of-fit statistics for both the internal and external models are very high across the three sub-samples, confirming that the model fits the data well (above .92 for the internal model and above .99 for the external model). The first panel of Table 3 reports the estimated coefficients for each sorting location, based on bootstrapping with 1000 resampling iterations. Of the 48 possible paths, 36 are statistically significant and align with the expected direction. Notably, the variance explained in the endogenous constructs is consistently higher at home ($.29<R^2<.46$) than at the university

(.22<R^2<.42) or during commuting (.11<R^2<.37). Figure 2 displays the significant path coefficients in all three locations.

Table 3. Results of the structural model and multigroup permutation tests[1].

	Structural model						Multigroup permutation test (only significant differences are reported)		
Paths	At home (1)		At university (2)		On the way to university (3)		1≠2	1≠3	2≠3
	β	t	β	t	β	t	Differences		
DV: Waste sorting	R^2=.44		R^2=.31		R^2=.33				
Gender	.03	.54	-.04	-.72	.00	.05			
Anticipated guilt	.13	2.08*	.16	2.53*	.42	6.88***		.29***	.26***
PBC	.17	2.57*	.18	2.76**	.06	1.00			
Facilitating conditions	.19	3.06**	.29	4.54***	.23	4.36***			
Personal norms	.15	2.71**	.19	3.00**	.04	.69			
Social norms	.28	4.66***	.03	.54	.03	.54	.20*,†	.25***	
Awareness of consequences	-.16	-3.03**	.02	.10	.02	.32			
DV: Anticipated guilt	R^2=.45		R^2=.42		R^2=.37				
Gender	.19	4.20***	.16	3.41**	.20	4.14***			
Facilitating conditions	.06	1.16	.10	2.13*	.12	2.41*			
Personal norms	.35	6.61***	.44	8.76***	.39	7.37***			
Social norms	.28	5.09***	.13	2.57*	.15	2.71**			
Awareness of consequences	.07	1.46	.15	3.03**	.01	1.873			
DV: PBC	R^2=.46		R^2=.38		R^2=.11				
Facilitating conditions	.68	15.91***	.62	13.49***	.33	5.97***		.35***	.29***
DV: Personal norms	R^2=.29		R^2=.22		R^2=.23				
Gender	.14	2.71**	.16	3.11**	.17	3.24**			
Social norms	.34	6.28***	.33	5.93***	.34	6.06***			
Awareness of consequences	.26	4.88***	.17	3.1**	.18	3.25**			

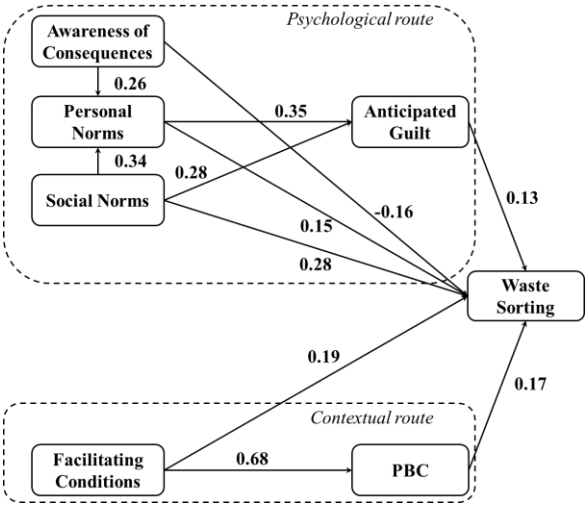
Notes: [1] *** p<.001, ** p<.01, * p<.05, † not significant after FDR correction.

The analyses reveal a few similarities across spaces. Along the psychological route, awareness of consequences and social norms both have a positive influence on personal norms about the importance and priority of waste recycling (.17≤β≤.34, *p*<.01). In return, personal norms, in combination with social norms, positively influence anticipated guilt (.13≤β≤.44, *p*<.05), which positively transfers to waste sorting (.13≤β≤.42, *p*<.05). Along the contextual route, facilitating conditions directly influence both PBC (.33≤β≤.68, *p*<.001) and waste sorting (.19≤β≤.29, *p*<.01). Lastly, in all our spaces, gender is a significant antecedent of personal norms and anticipated guilt (.14≤β≤.20, *p*<.01).

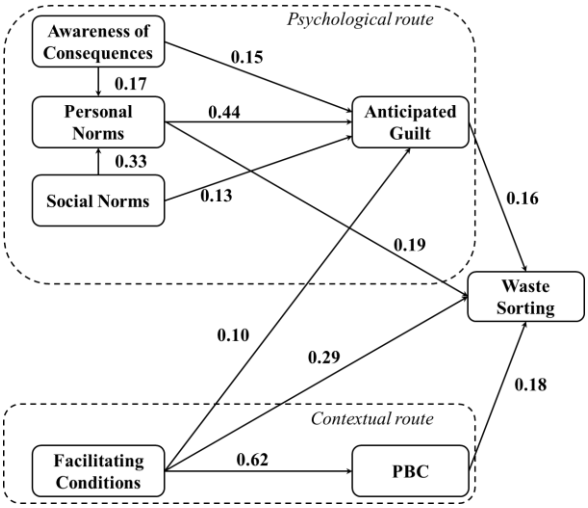
Some factors play a different role in different places. Along the psychological route, the influence of awareness of consequences on anticipated guilt and waste sorting varies

extensively: it is significantly positive on anticipated guilt, but only at university (β=.15, p<.01), and significantly negative on waste sorting, but only at home (β=-.16, p<.01). Waste sorting is also positively impacted by personal norms at home and at university (.15≤β≤.19, p<.05), and directly influenced by social norms, but only at home (β=.28, p<.001). Along the contextual route, facilitating conditions positively influence anticipated guilt, but only when students are away from home, and the coefficients are small (.10≤β≤.12, p<.05), while PBC significantly impacts waste sorting at home and at university, but not on the way to university.

At home



At university



On the way to university

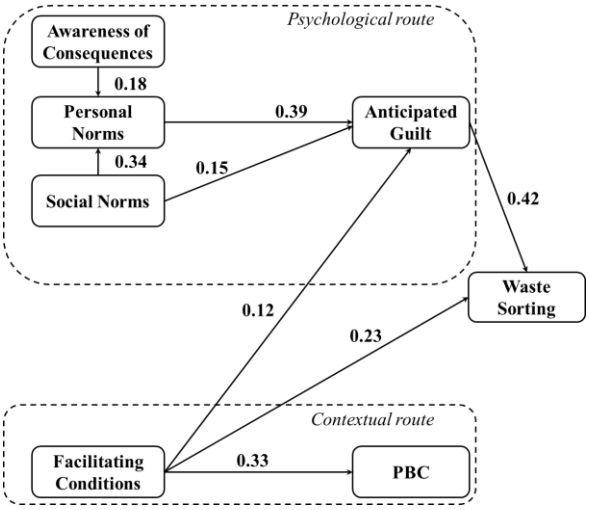


Fig. 2. Significant path coefficients.

Multigroup permutation tests

Multigroup permutation test analyses were applied to all the paths in the conceptual model (Chin & Dibbern, 2009). Given that multigroup comparisons may increase the risk of inflated false positives, we applied a False Discovery Rate (FDR) adjustment (Benjamini & Hochberg, 1995) to control for multiple comparisons. The final three columns of Table 3 report significant differences. After the FDR adjustment, no significant differences appear between private and semi-public spaces, suggesting that semi-public spaces may operate more like private than public ones, a result that differs from the findings of the structural model.

Going further, three path coefficients significantly differ across the three locations. Interestingly, the path coefficient from facilitating conditions to PBC is significantly lower for waste sorting on the way to university than for waste sorting at home or at university (diff=.35, $p<.001$ and .29, $p<.001$). Conversely, the path coefficient from anticipated guilt to waste sorting is significantly higher on the way to university than at home or at university (diff=.29, $p<.001$ and .26, $p<.001$). Also, the path coefficient from social norms to waste sorting is significantly higher at home than on the way to university (diff=.25, $p<.001$).

To summarize these differences more clearly: in public spaces, facilitating conditions do not influence waste-sorting behavior through PBC, as might be expected. Instead, they exert an indirect effect by influencing anticipated guilt, which emerges as a particularly strong driver of waste sorting in these settings. This suggests that when individuals encounter public environments with more limited or ambiguous sorting infrastructure, the emotional cost of failing to act appropriately becomes a key source of motivation. In contrast, in private spaces, such as the home, social norms play a significantly greater role in shaping behavior than in public contexts. This may reflect the stronger presence of habitual practices, peer or familial expectations, and a clearer sense of accountability in private settings.

Discussion

Theoretical contributions

In this research, we test a model of waste sorting based on an integrated TPB-NAM framework. Our results confirm Whitmarsh et al.'s (2018) conclusion that waste-sorting behavior varies across locations, but we extend their design by exerting tighter control over participants' age and ensuring comparable types of waste across settings. A key contribution of our research is the inclusion of a public space, alongside private and semi-public contexts, which enables the

analysis of the same individuals' waste-sorting behaviors in three distinct environments within a single day. Employing multi-group structural equation modeling with permutation tests, we identify significant differences in path coefficients across locations (even though the permutation test somewhat tempers the structural estimates), highlighting that spatial context moderates the influence of the antecedents of waste-sorting behavior. In doing so, we offer a more robust assessment, both internally and externally, of the factors shaping inconsistencies in waste sorting across everyday environments.

Our findings outline specific insights. In line with Kraft et al.'s (2005) suggestion that the role of PBC as a predictor of intention to recycle may be overestimated, and the role of emotion underestimated, we show that anticipated guilt appears to have the strongest influence on waste sorting in a public space, where PBC and social norms have no influence at all. We thus shed light on the crucial influence of moral emotions in individuals' everyday pro-environmental behaviors (e.g., Wang & Wu, 2016; Hurst & Sintov, 2022), especially when behaviors are visible to others. Turning to the antecedents of the anticipated guilt, in public spaces, when recycling bins are available and known, negative emotional levers are also reinforced. Conversely, the absence or remoteness of recycling bins can reduce anticipated guilt. Lastly, our results corroborate the influence of social norms and personal norms on anticipated guilt when controlling for one another. As such, our findings contribute to the growing body of literature that emphasizes the role of "green emotions" in pro-environmental behaviors. They support the need for a model that integrates rational and emotional determinants to better understand these behaviors. Specifically, we find that the desire to avoid anticipated guilt (Peloza et al., 2013) appears as a powerful green emotion motivating waste sorting when controlling for the TPB variables, something not done previously by Elgaaied (2012). Turning now to PBC, its weakest influence on the way to university may stem from the shared use of recycling bins in public spaces by numerous individuals: the perceived effectiveness of individual waste-sorting efforts may be reduced by such dependence, which could discourage from sorting in public spaces (Berlin et al., 2025). At the other end of the continuum, the home is a fully private space with codified social norms that are powerful drivers of waste sorting, compared to university or on the way from home to university. This suggests that the expectations of the individual's social reference group relate primarily to waste sorting at home. In semi-public or public spaces, the estimation of the structural model shows that social norms only influence waste sorting through anticipated guilt. As such, social norms appear to exercise influence both with (in public or semi-public spaces) and without (at home) social exposure.

At a higher level, our findings further underscore the importance of accounting for location-specific characteristics when examining certain pro-environmental behaviors, such as waste sorting, which must often be enacted across diverse settings. Each location is associated with a distinct explanatory model of behavior. For instance, our results show that anticipated guilt exerts the strongest influence on waste sorting in public spaces, whereas PBC and social norms have no significant effect in this context. In contrast, the home, as a fully private environment characterized by well-established social norms, emerges as a setting in which these norms serve as particularly strong predictors of sorting behavior, more so than in public spaces such as the journey between home and campus. In conclusion, our results suggest that it is essential to identify relevant location characteristics including the degrees of exposure to others, privacy, and control to produce the desired pro-environmental behavior. As such, it extends previous research on the influence of place-related variables (i.e., neighborhood ties, community attachment, local identity) on waste-recycling intention at home (Pei, 2019) to other places. As a general rule, the more private the space where waste sorting takes place, the more the antecedents of the TPB are significant. An integrated TPB-NAM model is therefore relevant when seeking to explain pro-environmental behaviors in public spaces.

Practical implications

The findings of this research offer valuable insights for multiple stakeholders involved in promoting waste-sorting behaviors, including local authorities, public space managers, universities, policymakers, and communication strategists. Drawing from the distinct psychological and contextual drivers identified across different settings (home, university, and public spaces), we outline the following recommendations.

Regarding structural strategies, our results highlight the critical importance of facilitating conditions across all locations. These conditions influence behavior not only directly, by making sorting more physically feasible, but also indirectly, by heightening users' anticipated guilt at the idea of failing to sort their waste in public or semi-public spaces. To act on this, urban planners, local authorities, and public space managers should improve the physical conditions for sorting. Concretely, they must ensure that recycling bins are present in sufficient numbers and strategically placed in highly frequented areas such as hallways, cafeterias, universities, streets, public squares, and transit hubs. The bins should be clearly visible, intuitively designed, and easy to use, for example, with open or foot-operated lids that require no physical contact, and with standardized color codes and signage to reduce confusion about

what belongs where. They should also be clean and functional to avoid weakening the social norm. Such infrastructure improvements can strengthen the perception that waste sorting is a widely shared and expected social norm, not only in the private sphere, such as the home, but also in public and semi-public environments, which would ultimately activate anticipated guilt at the idea of not sorting, hence sorting.

Informational strategies can complement these structural efforts. Public awareness campaigns should emphasize the idea that sorting waste is a normal, expected behavior that applies 'everywhere and at all times,' as Knickmeyer (2020) suggests. These messages are especially relevant for individuals who may lack access to enabling infrastructure (Girardon et al., 2022). This could be done in universities in particular, as in any educational institutions more generally, which could run regular, consistent and targeted communication campaigns to remind both students and staff of the importance of waste sorting. Such institutional campaigns should be embedded into annual onboarding procedures and repeated regularly to maintain their salience and effectiveness. They could include visual reminders such as posters, stickers, or digital displays near decision-making points (e.g., next to bins). Engaging students in promoting sorting norms, for example through student ambassadors, sustainability clubs, or academic projects, could also contribute to reinforcing waste sorting as part of an institutional culture.

As waste sorting in public spaces is mostly driven by anticipated guilt, not by social norms or perceived behavioral control, public campaign designers could harness anticipated guilt to develop emotionally and identity-based messaging. Emphasizing that public (and also semi-public) spaces are shared environments may foster a sense of collective ownership, thereby extending private-sphere social norms, such as those that guide household sorting, into public domains. Campaigns might also highlight discrepancies between behaviors across different contexts, for instance by reminding individuals that they sort their waste at home and prompting reflection on why they fail to do so in other places they regularly frequent, even when appropriate bins are available. Such messaging can induce mild cognitive dissonance, encouraging individuals to align their behavior across settings through the anticipation of guilt. That said, it is essential to use guilt constructively and ethically, particularly in public spaces where external monitoring is limited. Messages must also be aligned with the availability of infrastructure to avoid undermining credibility by promoting sorting in places where bins are missing or inadequate.

Finally, our recommendations extend to researchers as our findings underscore the importance of systematically accounting for spatial context in research focused on the

promotion of pro-environmental behaviors. Scholars should clearly distinguish between public, private, and semi-public spaces, as the psychological and contextual drivers of pro-environmental behaviors, such as social norms, anticipated guilt, and facilitating conditions, vary significantly across these settings. Importantly, treating sorting behavior as context-neutral risks obscuring key mechanisms that drive or inhibit action. Future research should also pay closer attention to gender differences, given the observed influence of gender on personal norms and anticipated guilt. By incorporating spatial and demographic variation into theoretical models and empirical analyses, researchers can more accurately identify the situational levers of sustainable behavior and provide nuanced, context-sensitive recommendations for policy and intervention design.

Limitations and further research

As with most empirical research endeavors, ours exhibits certain limitations. Firstly, we chose to measure self-reported behaviors instead of observing actual behaviors, which allowed us to "follow" the same (rather than distinct) subjects across three different locations and facilitated control over intra-individual variance, a control that previous studies conducted independently across disparate locations did not permit. Its potential disadvantage in terms of over-reporting was mitigated using anonymous and self-administered questionnaires (Kormos & Gifford, 2014). To improve internal validity, future research could consider *in situ* experiments to practically manipulate the degree of exposure to others or the perceived control on sorting quality to measure their influence on waste sorting.

Secondly, we employed a sample of French students in social science. While it is worthwhile to develop sorting routines among young people who are long-term recyclers (Islam et al., 2021), future research should aim to enhance the external validity of these findings by investigating populations with more heterogeneous levels of engagement and knowledge regarding waste sorting (e.g., older adults, individuals from rural areas, newly arrived international students) to provide a more comprehensive understanding of the factors that facilitate or hinder the adoption of sustainable practices across diverse contexts. In addition, replicating this research in different cultural settings would further strengthen the generalizability of the results.

Third, building on Bargh et al.'s (1996) framework of automatic social behavior, future research could explore how the activation of context-specific norms or stereotypes influences individuals' waste-sorting behavior across different locations. From this perspective, waste

sorting may be automatically shaped by the perceived social cues of a given environment, leading individuals to respond to implicit situational primes rather than consistently acting in a pro-environmental manner.

Finally, like most research using structural equation modeling, our results are based on correlational analyses and require more complex data collection protocols to reach definitive causal conclusions (Goh et al., 2022; Wang et al., 2023). For example, experiments testing the influence of facilitating conditions on anticipated guilt in different contexts would be particularly appropriate.

Conclusion

The “space oddity” we observe in waste sorting suggests that behaviors depend on the location where they take place. This has two important implications. First, academics should test their conceptual models of waste-sorting behaviors in not just one but all relevant locations. Second, public policymakers should not use models produced for the private sphere, which is the focus of a large part of the existing literature, to design policies to improve waste-sorting behaviors outside the home. To achieve a more circular economy, society needs to use the full potential of recyclable materials, and that requires understanding waste-sorting behavior everywhere.

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