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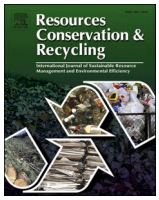

Full length article

What predicts and prevents source separation of household food waste? An application of the theory of planned behavior

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ABSTRACT

Food waste is a growing global issue with widespread environmental, economic, and social impacts. Households are both a major driver of waste generation and a key enabler of solutions such as source reduction and composting. In the U.S., household food waste is still predominantly landfilled, motivating this study to understand the beliefs, experiences, and barriers that individuals face when deciding whether to source separate household food waste as a precursor to landfill diversion. To understand these factors, the theory of planned behavior was applied using data collected via a survey of New York State residents and analyzed using structural equation modeling. Results indicate that attitude, subjective norm, and perceived behavioral control are all significantly and positively associated with the intent to separate household food waste. However, respondents also expressed significant concern that food waste separation would lead to odor, pests, and messiness in the home, ultimately resulting in a distinct "yuck factor" construct that had a significant negative association with behavioral intent. These concerns were particularly strong for individuals who had no past experience separating food waste. These findings suggest several potential interventions, including education on how to separate food waste and expansion of curbside collection systems to address consumers' unwillingness to handle waste or clean collection containers.

1. Introduction

Food waste is the single-largest material stream landfilled each year in the United States (U.S. EPA, 2018). The downstream impacts of discarded food include the release of greenhouse gases that contribute to climate change and the loss of nutritional and economic value contained in the wasted food (ReFED, 2016; Schanes et al., 2018). Although food is wasted at all points of its supply chain, households play a particularly important role. The residential sector accounts for about 40% of total food wasted in the U.S. (ReFED, 2016), equivalent to over 25 million tons discarded each year (U.S. EPA, 2018). As such, households should also be a major facet of food waste management solutions that first aim to reduce wasted food generation and then to divert unavoidable food waste away from landfills and into value-retention pathways (Babbitt 2017).

A broad body of literature has identified ways to reduce the amount of wasted food generated in households, including meal planning ahead of grocery shopping (Principato et al., 2020), increasing use of foods with cosmetic defects (de Hooge et al., 2017), and extending the useful life of food through proper storage (van der Werf et al., 2019). In addition, educating individuals about the meaning of food date labels could prevent confusion and the discard of food that is still good (Neff et al., 2015; van der Werf et al., 2019). Suggested interventions to reduce household food waste include awareness, technology, managing leftovers, size-portioning, storage, packaging, food risk, policy, regulation, and educational campaigns, which have been the predominant strategy deployed so far (Hebrok and Boks, 2017). In two studies, food literacy messaging campaigns were found to strengthen individuals' perceived behavioral control and decrease household food waste by about 30% (van der Werf et al., 2021; Wharton et al., 2021).

However, even with aggressive waste prevention and reduction strategies, some food waste will still be generated, due to the presence of inedible parts (e.g., bones, trimmings) and due to consumer opinions that some food waste is necessary to make meals taste fresh and good (Qi and Roe, 2016). Consequently, alternative management options are still required to divert wasted food from landfills. Such options available to households include composting, vermicomposting, or backyard digestion systems (Bortolotti et al., 2018; Curtis et al., 2013), which

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require space and user knowledge but could typically be operated in the privacy of the household (Loan et al., 2019). Recently, however, a new option has emerged for households: services that collect food waste from the residence or accept waste at drop-off locations and then centrally manage the resource recovery processes. These services are often called community composting (Yepsen, 2015) or residential organics collection programs (Geislar, 2017), and may operate as municipal programs paid for by taxes, non-profit community programs, or private, commercial services paid for by the resident.

However, success of these programs depends on consumer participation, namely through source separating food from other household waste. For example, New York City launched curbside collection and drop-off programs in 2011, but ultimately had to halt expansion due to lack of participation (Champeny, 2018). Research shows that structural barriers to separating food waste at home include a lack of available space (Gellynck et al., 2011) and lack of knowledge about handling compost (Tonglet et al., 2004). Barriers to participating in local household food waste collection programs include distance to drop-off locations (González-Torre and Adenso-Díaz, 2005), being unaware of existing compost drop-off bins (Sussman and Gifford, 2013), and people's perception of time available in their schedules to dedicate to handling food waste (Wu et al., 2019). Individuals are also concerned that the price of participating in organics collection programs will cost more than they can afford (Refsgaard and Magnussen, 2009).

Beyond structural challenges, individuals may hold deeper beliefs that influence their decision to engage in food waste separation or collection programs. For example, some individuals report negative feelings and emotions if food waste collection containers are perceived to be unhygienic and unsightly (Curtis et al., 2013). Another issue is the concern about what others will think about the behavior (Geislar, 2017; Refsgaard and Magnussen, 2009), like fear of being labeled a "nutty green" by neighbors and friends (Curtis et al., 2013) or getting other members of the household on board with the activity (Goldsmith and Goldsmith, 2011). Even individuals that hold pro-environmental beliefs may not ultimately choose the most environmentally preferred food waste option (Vittuari et al., 2018), but may be influenced by other factors, such as existing waste management habits in the home or access to facilities and resources to handle the waste (Quested et al., 2013).

To increase participation in food waste separation and landfill diversion, a greater understanding is required of the underlying structural and personal barriers that households face and the enablers that can motivate behavioral change. Individuals' behaviors result from a chain of intention informed by their attitude, the social influence they experience, and their knowledge and personal ability to perform the behavior (Ajzen, 1991). At the root of this chain are the internal beliefs people hold about the behavior in question: "Peoples' intentions and behaviors follow reasonably and consistently from their beliefs no matter how these beliefs were formed" (Ajzen 2015, p.127). Understanding these beliefs provides greater insight into interventions likely to change behavior (Ajzen et al., 2011). For example, education alone may be insufficient to motivate an individual to recycle materials (de Leeuw et al., 2014), but targeted interventions, such as providing convenient recycling bins, may increase participation because they address fundamental concerns about inconvenience (Bernstad, 2014).

The theory of planned behavior (TPB) provides a framework to identify and understand the beliefs that inform an individual's behavior. The theory predicts behavior from intention, which is preceded by three constructs: attitude, "the degree to which performance of the behavior is favorable or unfavorable"; subjective norms, "the perceived social pressure to perform or not to perform the behavior"; and perceived behavioral control, peoples' "perceived ease or difficulty of performing the behavior" (Ajzen, 1991, p. 188). These core constructs are assessed by measuring an individual's underlying behavioral beliefs, injunctive and descriptive norm beliefs, and control beliefs, respectively. The TPB has been applied to study a wide array of waste management behaviors and to design intervention strategies. For example, research has shown that subjective norms, convenience, awareness of consequences (Khan et al., 2019) and knowledge (Tonglet et al., 2004) positively influence recycling intention. As a result, interventions such as communicating information about types of recycling containers, the type of waste for each container, and providing a convenient drop-off location are shown to improve household waste sorting (Rousta et al., 2016).

The TPB has also been applied to study food waste behaviors, with much of this work specifically focused on interventions that can prevent or reduce wasted food generation. For example, perceived behavioral control was the main predictor of consumption of dairy products that are past their due date but still good (Schmidt, 2019). Attitude, personal norms (Neubig et al., 2020), and subjective norms (Heidari et al., 2020) were shown to motivate household food waste reduction. Further, the core TPB model can be extended to include additional constructs relevant to the behavior. For example, concerns over health risks negatively influence food waste reduction because people choose to avoid the risk associated with eating leftovers or food past its use-by date (Barone et al., 2019). On the other hand, individuals' experiences and habits related to food waste play a role in informing their attitude and perceived behavioral control of food waste reduction, thus indirectly influencing future intentions (Riverso et al., 2017). For example, a low frequency of food disposal combined with a low volume of food waste generated in the past correlate with intent to reduce food waste in the future (Russell et al., 2017).

While the TPB has been used successfully for understanding food waste prevention and reduction, it has seen less frequent application to behaviors related to diverting food waste from landfills. For example, the TPB has been used to study home composting (Edgerton et al., 2009; Taylor and Todd, 1995), but not all of the preceding behaviors involved in source separating food from other household waste. TPB applied to source separation has thus far analyzed cases in China (Xu et al., 2017; Yuan et al., 2016), Vietnam (Nguyen et al., 2015), Iran (Babazadeh et al., 2018), and Malaysia (Ghani et al., 2013). The method has not yet been used to analyze this behavior in the U.S., and findings cannot be generalized because infrastructure, norms, and policy differences vary from one region to the next and have varied influence on human behavior (Ajzen, 1991).

Applying the TPB model to food waste separation may also require expansion to include beliefs that are unique to this behavior. Unlike other forms of recycling, separating food waste requires individuals to handle a material they may believe to have a strong odor or to attract pests (Benyam et al., 2020; Edgerton et al., 2009; Tonglet et al., 2004). Whether this "ick factor" (Pai et al., 2019) is a deterrent to household food waste source separation has not been fully studied. Further, decisions surrounding food are likely to involve moral norms (Graham-Rowe et al., 2015), or feelings of obligation and guilt, which may not be as relevant to other types of recycling behaviors (Khan et al., 2019; Tonglet et al., 2004). Moral norms were found to influence Chinese residents' attitudes towards kitchen waste separation (Yuan et al., 2016), but have not been fully studied in other regional contexts. Furthermore, because past behavior is expected to influence future behavior (Ajzen, 2002), it has been included in extended TPB models to predict household waste source separation (Xu et al., 2017), but a comparison between consumers with and without food waste separation experience has yet to be made. Overall, it is unclear how these issues individually and collectively inform individuals' intention to source separate household food waste.

To fill these knowledge gaps, this study applies the TPB to investigate household food waste source separation and to identify the important underlying beliefs that drive the intention to perform this behavior, using New York State (NYS) as a case study. In NYS, more than $1 billion is spent every year to manage solid waste, 18% of which is food waste (Brown 2017). In New York City alone, residences are estimated to contribute 54% to total food waste generation (Hoover and Moreno, 2017), but low residential participation in separation programs has stymied collection and composting initiatives (Collins, 2018). While

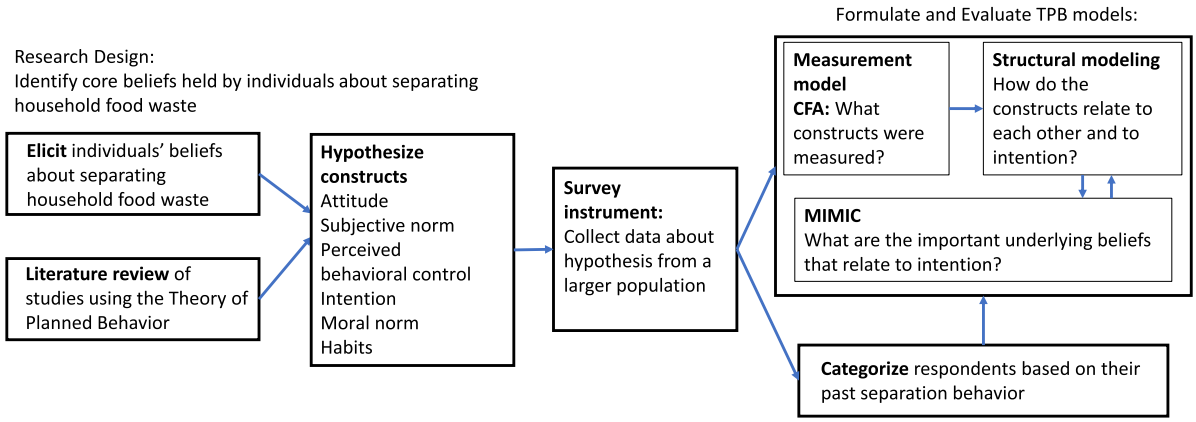

Fig. 1. An overview of the methodological process implemented in this study to apply the TPB to household food waste source separation.

NYS may not represent the full spectrum of food waste systems across the entire U.S., it does provide an effective case study as a region characterized by a diverse array of socioeconomic demographics and food production and consumption systems spread across both urban and rural regions. Confining the study to a single state also controls for anticipated variability in state-level food waste policy and infrastructure, which were anticipated to play a role in informing respondents' underlying beliefs (Babbitt et al., 2021).

The study addresses three main research objectives: 1) to determine the TPB constructs that explain consumers' intent to separate food from other household waste, as a first step towards landfill diversion; 2) to identify the underlying beliefs about food waste separation that may be leveraged to change behavior; and 3) to compare how beliefs and intentions differ between individuals with and without experience separating food waste. Ultimately, the outcomes of this study will inform the design of intervention strategies, business models, and education and policy initiatives that may increase consumer participation in sustainable food waste solutions.

2. Methods

The goal of this study was to apply the TPB following the expectancy-value approach (Ajzen, 1991) to determine the factors and beliefs that influence individuals' intention to separate household food waste. The focus on behavioral intention as the dependent variable was largely based on the difficulty associated with directly measuring food waste separation behaviors. Food waste separation is not directly observable, as an action that happens within private homes, and consumers' self-reported measurements related to food are often inaccurate (Quested et al., 2020). While a gap between stated intention and realized behavior is likely to exist, this approach can provide needed information about household food waste separation barriers and enablers, upon which behavioral interventions can be designed and tested by more direct observations.

The methods entailed research design based on literature review and interview-based elicitation, data collection by consumer survey, and data analysis to formulate and evaluate TPB models using confirmatory factor analysis (CFA) and structural equation modeling (SEM) (Fig. 1). Because this research involved human subjects, the interview and survey instruments, protocols, and informed consent processes were reviewed and approved by the RIT Institutional Review Board. Each step is described further in the following sections.

2.1. Research design

The TPB consists of the core constructs of attitude, subjective norm, and perceived behavioral control, which are independent variables expected to influence behavioral intention, the dependent variable. The model includes four underlying belief categories that correlate with independent variables (Ajzen, 2019): attitude is informed by behavioral beliefs, "the subjective probability that the behavior will produce a given outcome or experience;" subjective norm is informed by both injunctive and descriptive norm beliefs, which represent "the perceived behavioral expectations of important referent individuals or groups;" and perceived behavioral control is informed by control beliefs, "the perceived presence of factors that may facilitate or impede performance of a behavior." According to the expectancy value approach, each individual belief is composed of two parts: the expectancy, or the likelihood that the belief will occur, and the value, or assessment of how much that belief impacts the decision to perform the behavior in question (Ajzen, 2006).

The approach to measure these beliefs was based jointly on literature review of past TPB studies, where the behaviors and constructs analyzed could be reasonably extended to food waste separation (as discussed below) and elicitation interviews, to identify and explore any concepts not yet represented in existing literature. The elicitation process consisted of a series of semi-structured interviews (full protocol provided in the S.I.) that were designed according to Montoya's framework (Montoya, 2016). Respondents were recruited at community-focused events (e.g., farmers markets) in Rochester, NY, targeting parts of the community served by a curbside composting program, and via snowball sampling. Respondents were all over 18 years of age, with direct knowledge of household food waste decisions, and included individuals who participated in curbside composting, those that composted at home, and those that did not separate food waste. A total of 14 interviews were recorded, each lasting 10-to 30-minutes. Interviews were transcribed using Happy Scribe™ software and then analyzed line by line with NVivo 12™ software, first through open coding (Strauss and Corbin, 1990), and then according to thematic analysis (Braun and Clarke, 2006). The coding was performed by one researcher, with review and decisions on the use of coding findings made by three researchers.

While interview findings could not be generalized broadly, due to the limited sample size and composition, the identified themes were used to confirm and expand beliefs and constructs found in related literature on food (Russell et al., 2017) or waste management behaviors (Kumar, 2019). For example, individuals expressed concerns about being too busy to separate and the amount of knowledge required to compost separated food waste (perceived behavioral control; Edgerton et al., 2009; Heidari et al., 2018; Nguyen et al., 2015; Wang et al., 2021) and indicated that their behaviors were influenced by the views and actions of other members of their household (subjective norm; Yuan et al., 2016; Zhang et al., 2015). Respondents also discussed their attitudes towards food waste separation primarily in terms of a desire to reduce harm to the environment (Kumar, 2019; van der Werf et al., 2019) or as "a good thing to do" (Khan et al., 2019; Tonglet et al., 2004). These sentiments most closely relate to the instrumental aspect of attitude, which assesses

Table 1
Hypothesized constructs, beliefs, and measures based on the literature review and elicitation interview findings.

Hypothesized Construct	Construct Measurement Definition	Reflective and Formative Measures
Attitude	An individual's attitude towards separating household food waste	Reflective Measures: Evaluation of separation as bad/good, worthless/worthwhile, unpleasant/pleasant, waste of time/good use of time Behavioral Belief Formative Measures: Potential to reduce environmental harm, landfilled trash, trash cost
Subjective norms	An individual's perception of social pressure to separate household food waste	Reflective Measures: People important to me approve, separate their own food waste, think it's a good thing to do Injunctive and Descriptive Norm Beliefs Formative Measures: Family, friend, neighbor approval; Family, friend, neighbor actions
Perceived behavioral control	An individual's perception of whether or not they have control and the ability to separate household food waste	Reflective Measures: Control of the decision to separate, control over and ability to separate Control Beliefs Formative Measures: Time, space, knowledge and costs of separating; Availability of pick-up and drop-off services; Ability to compost and use compost material; Arguments and support within household; Cleaning required *Potential for pests, odor, and messiness
Intention	An individual's intention to separate household food waste in the next year	Reflective Measures: Frequency, degree, and determination in planned food waste separation
Moral norms	An individual's perception of moral obligation to separate household food waste	Reflective Measures: Benefits future generations, Right thing to do, Reduces guilt, Duty of a responsible citizen
Habits	Other behaviors individuals practice which may be related to separating household food waste	Reflective Measures: Gardening, Visiting farmers' markets, Purchasing green cleaning products, Giving money to charity, Eating a vegetarian diet, Driving a hybrid or electric vehicle, Recycling electronics or other household materials

*Interview findings suggested that concerns about pests, odor, and messiness due to food waste separation would be control beliefs; this table reflects that hypothesis, although it was later modified as discussed in the Results.

perceived outcomes or consequences, rather than the experiential aspect, which relates to the experiences performing the behavior (Ajzen and Driver, 1991; Ajzen and Fishbein, 2005; Wan et al., 2017). Further, when respondents discussed the experience of food waste separation, they most commonly raised issues of ability. For example, individuals mentioned concerns about odor, messiness, and pest attraction as factors that would prevent them from starting to separate food waste, echoing past studies on household waste (Sidique et al., 2010; Taylor and Todd, 1995). Therefore, these beliefs were hypothesized to inform perceived behavioral controls, although that was later disproven by the analysis.

Jointly, the literature review and interviews also identified additional factors relevant to source separation behaviors but not fully captured by core TPB constructs. These factors included moral norms, or a person's sense of obligation to separate household food waste (Botetzagias et al., 2015), experience with curbside recycling of other household materials (Abdelradi, 2018), and household habits related to food, gardening, and natural living (Edgerton et al., 2009; Khan et al., 2019; Kumar, 2019). The literature review was also used to confirm measurement items and scales used in past TPB studies (Ajzen, 2015; de Leeuw et al., 2015; Russell et al., 2017) and operationalize the elicitation interview themes into a survey instrument (Tonglet et al., 2004), as described in the following section. Collectively, the outcomes from the research design (see Appendix) formed the hypotheses that attitude, subjective norm, perceived behavioral control, moral norm, and habits would be the primary constructs informing intention, and the core constructs (attitude, subjective norm, and perceived behavioral control) would each be informed by several important beliefs (Table 1).

2.2. Survey instrument

A survey was developed to gather data to test the hypothesis that the TPB can be used to predict intention to separate household food waste and to identify important underlying beliefs. The survey questions followed the target, action, context, and time (TACT) approach (Ajzen, 2006), in which each question asks the target (NYS resident) about the action (source separating food waste) in a specific context (the household) and time (the next 12 months). Respondents were also asked about their past experiences and practices separating household food waste (in the past 12 months). For each TPB construct, the survey included at least three questions intended to be reflective indicators (direct measurements) (Kline, 2016) and at least three sets of formative indicators (beliefs leading to the formation of the constructs) with questions assessing both expectancy and value (Ajzen, 1991; de Leeuw et al., 2015; Morais et al., 2017).

Following established practices in TPB methodology (Ajzen, 2006, 1991), we implemented validated measurements and scales identified from literature review (see Appendix). Direct measures for intention and perceived behavioral control were assessed on unipolar, 5-point scales (Heidari et al., 2018; Ghani et al., 2013). Subjective norm utilized 7-point bipolar adjective scales (Huffman et al., 2014). Attitude followed the TPB questionnaire protocol (Ajzen, 2006), using 7-point, semantic differential adjective scales of good/bad (Russell et al., 2017), worthless/worthwhile (Graham-Rowe et al., 2015), unpleasant/pleasant (Ajzen, 2006) and waste of time/good use of time (Tonglet et al., 2004). Expectancy was assessed on 5-point unipolar scales of likelihood (Ajzen, 2015; Gao et al., 2017; Tonglet et al., 2004) and importance (de Leeuw et al., 2015). Value was assessed on 7-point bipolar scales (de Leeuw et al., 2015) to capture the potential for beliefs to prevent or hinder a behavior (negative) or enable or increase it (positive) (Ajzen and Fishbein, 2008).

The survey instrument (see Oehman, 2022 for full text) organized these measurements into six distinct sections that presented questions in a logical order with page divisions and a variety of question wordings, formats, scale anchors, and response set randomizations intended to mitigate common method biases (Podsakoff et al., 2003). Respondents were provided with definitions of key concepts to mitigate ambiguity; for example, specifying that household food waste referred to "any food that is thrown out rather than eaten (things like banana peels, meat trimmings, bones, coffee grounds, old spinach, uneaten leftovers, or plate scrapings)." In addition to the measurements discussed above, respondents were also provided with free text options for open-ended responses and were asked to select three adjectives, from a list of 10 options, that they strongly associated with household food waste separation. The survey also captured standard demographic data, such as age and education level, as well as situational factors, such as owning or renting a home.

The survey was designed and distributed via the Qualtrics platform during September and October 2020, after several months of instrument testing with the general public and implementing feedback about clarity and experience. Qualtrics recruited participants who met the eligibility criteria of being residents of NYS aged 18 years and older. To provide a sample that was representative of state demographics, participant

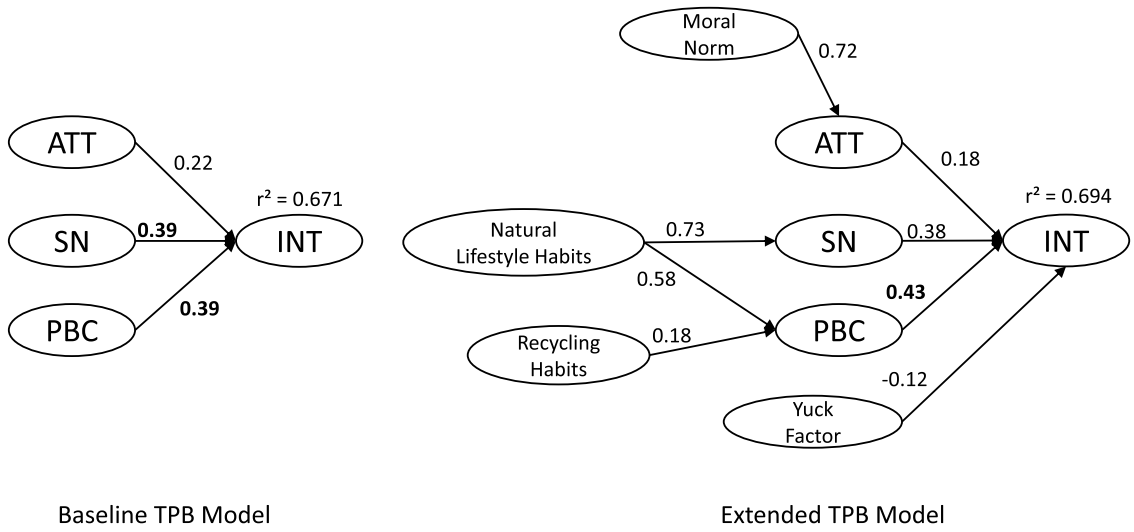

Fig. 2. Structural models represented the Baseline (left) and Extended (right) TPB models. ATT = attitude, SN = subjective norm, PBC = perceived behavioral control, INT = intention, MN = moral norm; NLH = natural living habits; RH = recycling habits; YF = yuck factor. The values shown on each line are the standardized beta coefficients, or the correlations between the latent variables. The r-squared value for intention was 0.671 in the baseline model and 0.694 for the extended model. All structural relationships shown are significant at $p < 0.05$ (insignificant structural relationships are omitted). The bold type indicates the highest correlation with intention. Covariances between error terms are not pictured.

recruitment was continued until quotas approximating the reported 2019 NYS population were met (see Appendix) (US Census Bureau, 2019). In parallel, opportunistic sampling by web and social media distribution was carried out to capture additional respondents not affiliated with an Internet panel. A total of 544 reliable responses were received from the Qualtrics panel, and 105 responses were received from opportunistic sampling. The final sample size ($n = 649$) included only those respondents who passed consistency and quality checks, which flagged respondents who "straight-lined" answers across at least three matrices in a row (Vanette, 2018) or straight-lined the matrix of past behavior questions in such a way that would lead to impossible outcomes (e.g., both discarding and separating all of their food waste; see the S.I. for more details). No instances of missing data were found in the finalized data set for the variables required for subsequent analysis.

2.3. Formulating and evaluating TPB models

The efficacy of using the TPB model was evaluated through analysis of survey data in two major steps: first confirming the hypothesized constructs through a confirmatory factor analysis (CFA) and then testing the TPB structural model, including both a baseline and an extended version, to establish relationships between constructs and behavioral intention. A multiple indicators multiple causes (MIMIC) model was used to determine the most important beliefs that underlie the constructs, which were then used to discuss potential interventions. All data analysis and modeling were carried out in RStudio (RStudio Team, 2020) R version 1.3.1093, using custom scripts and the following packages: lavaan (Roseel, 2012), dplyr (Wickham et al., 2020b), tidyr (Wickham, 2020), ggplot2 (Wickham et al., 2020a), RColorBrewer (Neuwirth, 2014), MVN (Korkmaz et al., 2014), psych (Revelle, 2020), semTools (Jorgensen et al., 2022), and the variance inflation factor function from the car package (Fox and Weisber, 2019). All survey data and model scripts are provided online via figshare (Oehman, 2022).

2.3.1. Measurement model

A confirmatory factor analysis (CFA) (Brown, 2006; Finch and French, 2015) was performed to test the items measured based on the hypothesized constructs according to the TPB (Table 1). CFA is used because the data are being tested according to a well-defined theory (TPB), grounded in empirical evidence, which specifies the items and latent variables (Brown, 2006). The initial hypotheses, based on the TPB and literature review, were that attitude, subjective norm, perceived behavioral control, moral norm, and habits would be the primary constructs informing intention. The compatibility of each survey question and adequacy of these hypotheses were assessed through several steps of a CFA: test for multicollinearity and normality, define the constructs per hypothesis, evaluate factor loadings, remove factors and redefine constructs based on subsequent loadings (Kumar, 2019), evaluate convergent and discriminant validity, and test for adequate goodness of fit statistics in the final CFA (Brown 2006).

Multicollinearity was evaluated by calculating the variance inflation factor (vif) according to Kline's method; all vifs were less than 10, indicating no multicollinearity was detected (Kline, 2016). The CFA used maximum likelihood estimation, which assumes normally distributed data, but robust estimators can be used for data that do not meet the condition of normality (Finch and French, 2015; Kline, 2016). All of the expectancy-value products and construct survey questions were tested for normality using Mardia's test (Finch and French, 2015; Korkmaz et al., 2014) in RStudio via the mvn function from the "MVN" package. All data were found to be non-normal with skew and kurtosis, and therefore, the robust estimator maximum likelihood with Satorra-Bentler correction (Satorra and Bentler, 2011), mlm, was used for the subsequent analysis (Finch and French, 2015). Harman's single factor test (Harman, 1976) was used to test for common method bias by pooling all latent variable items into a single factor and verifying that the explained variance (0.35) did not account for the majority of the covariance among items (i.e., was less than 0.5).

The CFA factor loadings for each hypothesized construct were evaluated using the following criteria: (1) a loading above a cutoff of 0.4 (Hair et al., 2010; Morais et al., 2018), (2) significance at $p < 0.05$, and (3) consistency in loadings (Kumar, 2019). One question intended to measure attitude (ATT) did not meet these criteria and was subsequently removed, possibly because this item was oriented more towards the experiential dimension of attitude ("separating household food waste would be extremely unpleasant/extremely pleasant"), whereas other attitude measurements encompassed the instrumental dimension (Ajzen and Driver, 1991; Wan et al., 2017). Three statements related to habits were removed: NLH5, "following a vegetarian diet" and NLH6, "driving a hybrid or electric vehicle" were not statistically significant and NLH4, "give money to charity" had inconsistently low factor loading

Table 2
Fit statistics analyzed for the Baseline, Extended, and MIMIC TPB models, for the entire population (first three columns of results) and for the sub-populations divided based on food waste separation experience within the past year (last two columns of results).

Model description	Baseline model	Extended model	MIMIC model	Separators MIMIC model	Non-separators MIMIC model
R-squared of Intention	0.671	0.694	0.680	0.796	0.363
CFI (>0.9)	0.993	0.957	0.957	0.944	0.938
TLI (>0.9)	0.989	0.949	0.951	0.935	0.929
RMSEA (<0.08)	0.037 (p-value = 0.978)	0.052 (p-value = 0.211)	0.055 (p-value = 0.050)	0.064 (p-value = 0.004)	0.064 (p-value = 0.001)
SRMR (<0.08)	0.031	0.054	0.084	0.114	0.119

relative to other items. Further, the remaining questions related to habits ultimately divided across two factors, one that related to "green" or natural lifestyle habits and one that related more to habits of recycling other materials (see Results and Discussion).

Based on interview findings, one original hypothesis was that the beliefs about odor, pests, and messiness would inform the construct of perceived behavioral control, as respondents mentioned these issues in the context of their perceived ability to separate food waste. However, these beliefs were found to be insignificant as individual expectancy-value products informing either behavioral control or attitude (see Section 2.3.2), and were instead determined by CFA to be significant only as an independent latent construct. The construct was then termed "yuck factor" to represent individuals' negative disposition to the odor or unhygienic consequences of handling and separating household food waste.

As a result of CFA methods described here, the constructs used in the subsequent analysis included the core TPB constructs: attitude, subjective norm, perceived behavioral control, as well as the additional constructs of moral norm, natural lifestyle habits, recycling habits, and yuck factor. To ensure these constructs were measured well and distinctly from each other, all were evaluated for convergent validity and discriminant validity (Brown 2006; Kline 2016) using Chronbach's Alpha (Alpha), construct reliability (CR), and average variance extracted (AVE) (Kline, 2016). All results indicated that the constructs were measured adequately with Alpha values > 0.7, CR greater than 0.7, and AVE values greater than or equal to 0.5 (Kline, 2016, 1999) (see Appendix). Overall, the measurement model met the accepted goodness of fit criteria (Kline, 2016) to continue to the next step of structurally modeling the relationships between the constructs.

2.3.2. *Structural model*

Structural equation modeling (SEM) was used to test the hypothesized relationships between constructs confirmed by the CFA and the intention to separate household food waste. The SEM process followed three steps: (1) test the baseline and extended TPB models for their efficacy in predicting intention to source separate food waste, (2) determine the most important beliefs underlying the main constructs, and (3) determine differences in beliefs and structural relationships between respondents with and without prior experience separating household food waste. All steps of the SEM were carried out using custom script and the latent variable analysis (lavaan) package in RStudio. All models were evaluated according to the following fit statistics: comparative fit index (CFI), Tucker Lewis index (TLI), root mean square error of approximation (RMSEA) and standardized root mean square residuals (SRMR). The percent of variance in intention explained by the model is the R-squared value (x100). All standardized coefficients are reported.

First, the baseline model was assessed to evaluate the relationships between the core TPB constructs and intention according to the TPB (Ajzen, 1991). The baseline model achieved an adequate CLI and TLI score, but had RMSEA and SRMR values just above suggested thresholds. Inspection of the model's residuals indicated two absolute correlation residuals that were positive (suggesting an under-defined model) and exceeding 0.10 (Brown, 2006; Kline, 2016). High residuals were observed between two indicators of attitude: ATT1 (separating food waste is bad/good to do) and ATT2 (separating food waste is worthless/worthwhile) and between two indicators of perceived behavioral control: PBC1 (Is it your decision whether or not you separate food waste) and PBC2 (How much control do you have over separating food waste in your household). Theoretically, it stands to reason that common or interrelated factors jointly inform respondent beliefs about each set of these indicators and can explain shared error variance (Kline 2016; Leandro, 2012; Lam and Hsu, 2004). For example, the two attitude items both strongly align with the instrumental dimension of attitude (Ajzen and Driver, 1991; Wan et al., 2017) and the normative sentiments observed during elicitation interviews about food waste separation as a value-laden activity or a "good thing to do." Similarly, the actual act of separating food waste was described during interviews as requiring planning and decision making by a household 'champion,' which may explain the common underlying distributions observed in the two PBC terms.

Based on these rationale, covariances were added between the errors of the two attitude indicators and the two PBC indicators. To assess the implications of this approach, relative to other options (such as removing terms that may not be measured distinctly), model fit statistics were evaluated for multiple scenarios, including the baseline CFA and SEM with and without covariances and for the baseline model with the above mentioned ATT and PBC terms removed individually and jointly. This analysis determined that adding the covariance according to the theoretical rationale discussed above improved fit statistics to within suggested thresholds without changing the overarching structure of the TPB model (relative magnitude, direction, and significance of core constructs were unchanged). Removing terms in question from the model did not make substantial improvements to model fit statistics and was not supported by theoretic rationale noted in literature or interview findings. All of the evaluated fit statistics are provided in the online repository (Oehman, 2022).

Next, an extended model was built to include the additional constructs discussed above. The TPB allows for additional factors to be added to the model to increase the variance explained in intention, and also states that constructs such as experience may be background factors whose influence on intention may be mediated through the core constructs of attitude, subjective norm, or perceived behavioral control (Ajzen, 2012; Fishbein and Ajzen, 2010). The extended TPB literature review suggested several potential structural relationships wherein the additional constructs directly influenced intention (Barone et al., 2019; Graham-Rowe et al., 2014; Khan et al., 2019; Nguyen et al., 2015; Russell et al., 2017; Si et al., 2020; Wan et al., 2012; Wang et al., 2021; Xu et al., 2020) or their effect was mediated through the main constructs (attitude, subjective norm, and perceived behavioral control) (Heidari et al., 2018; Heiny et al., 2019; Kumar, 2019; Rathore and Sarmah, 2021; Wei et al., 2021; Xu et al., 2017; Yuan et al., 2016; Zhang et al., 2015).

Because the literature review provided a theoretical basis for both direct and mediated models, both approaches were evaluated based on fit statistics and the proportion of variance of intention explained by each model (Huh et al., 2009). This approach to model comparison is consistent with related TPB literature (e.g., Botetzagias et al., 2015; de Leeuw et al., 2015; Graham-Rowe et al., 2014; Heidari et al., 2020, 2018; Heiny et al., 2019; Wan et al., 2021; Xu et al., 2020). Covariances introduced in the baseline TPB were carried through the extended

model. Of the constructs added to the extended model, only yuck factor had a significant direct association with intention, a structure that was tested on the basis of past observations that negative emotions and disgust have a direct relationship with intention (Olsen 2001; Russell et al., 2017). Conversely, such negative emotions may also be thought to inform the experiential dimension of attitude (Wan et al., 2017), but yuck factor was insignificant when mediated by attitude. All of the other additional constructs were then tested as background factors mediated by the core TPB constructs (Heidari et al., 2020; Heiny et al., 2019). Of all models tested, the baseline and extended models with the best fit statistics and the highest predictions of intention, R-squared value (de Leeuw et al., 2015; Huh et al., 2009) were selected and discussed in the Results (see Oehman, 2022 for model comparisons).

Second, a Multiple Indicators Multiple Causes (MIMIC) model was developed to identify the most important beliefs underlying the core constructs of the TPB (Finch and French, 2015; Kline, 2016). MIMIC models are fitting when latent constructs are measured using reflective (direct) and formative indicators (belief expectancy-value products) (Borges et al., 2016). The expectancy-value product was calculated as a multiplicative composite of behavioral beliefs (b_i x e_i) where b_i is the behavioral belief about the expectancy of outcome (i) of the behavior, and e_i is the evaluation of the ith outcome (Ajzen, 2006, 1991; Morais et al., 2017). This same calculation was performed for each belief in the subsequent categories (descriptive norm beliefs, injunctive norm beliefs, and control beliefs).

Following the approach of Borges & Oude Lansink (2016) and Morais et al. (2017), three individual MIMIC models were tested to determine which behavioral, normative, and control beliefs (as expectancy-value products) had significant correlation (at $p < 0.05$) with ATT, SN, and PBC, respectively. In cases where a belief might theoretically associate with multiple belief categories, they were tested in each of the three individual models, but only retained for relationships that were significant (Borges and Oude Lansink, 2016; Morais et al., 2017). During this process, none of the beliefs related to odor, mess, pests, or container cleaning were found to significantly correlate to their theorized construct (PBC) or any other constructs. This motivated the evaluation of yuck factor as a standalone construct as discussed earlier.

Finally, the models described above were reformulated and tested for respondents that were divided into two groups: those with and without experience separating food waste in the past year (12 months preceding the survey) similar to the approach from Stöckli & Dorn (2021). This analysis was motivated by the understanding that past behaviors can influence individuals' beliefs and intention (Ajzen, 1991) and because of the opportunity presented by responses that were relatively evenly divided: 307 respondents were "separators" and 342 respondents were "non-separators" (see SI Section 2 for additional details on making this distinction). All of the above modeling steps (CFA, SEM, and MIMIC models) were repeated in the same ways described above, but applied independently to the two data subsets. The models exhibited acceptable goodness of fit statistics, except for the SRMR, which was high for both of the models. Investigation of the models' residuals revealed many underlying relationships between the expectancy-value belief products, which is perhaps unsurprising given the potential for interaction among individuals' beliefs (Ajzen, 1991) and between model constructs (La Barbera and Ajzen, 2020). These interactions were not explored here, both to avoid overspecification of the model and to focus on the primary goal of assessing utility of TPB for explaining food waste separation intent, but this remains an important area for future study.

In parallel, additional statistical analyses were carried out to test the significance of key differences between separators and non-separators. Wilcoxon rank-sum tests (Mann and Whitney, 1947; Wilcoxon, 1945) were used to determine statistical difference between the two groups in their responses to the statement, "I want to separate household food waste but there are reasons why I can't" and a question as to whether they owned or rented their home. The groups were also compared based on the choice of terms respondents strongly associate with household food waste separation and their responses to survey questions about whether specific control beliefs make it easier or harder to separate.

3. Results and discussion

The results presented here demonstrate the efficacy of using the TPB to predict intention to separate household food waste and establish the relationships between key beliefs that enable and hinder separation intent. Results also compare the underlying factors that vary between individuals with and without prior experience separating household food waste (Table 1). Discussion of these results focuses on opportunities to leverage beliefs and behaviors to increase participation in food waste diversion efforts.

3.1. Predicting intention to separate household food waste

The first goal of this study is to determine if the TPB model could predict individuals' intent to source separate household food waste. The baseline TPB model accounts for 67% of the variance in respondents' intention to separate (Fig. 2). All three of the base constructs – attitude (Alpha = 0.89, CR = 0.89, AVE = 0.74), subjective norm (Alpha = 0.89, CR = 0.89, AVE = 0.74), and perceived behavioral control (Alpha = 0.82, CR = 0.83, AVE = 0.62) – exhibited good fit and had a significant, positive correlation with intention. However, perceived behavioral control and subjective norm both had the highest correlation with intention ($\beta = 0.39$ for each), indicating that individuals' behavioral intention is equally linked to their perceived ability to carry out the act of separating food from the rest of their waste and to the social pressure they feel to engage in this behavior. These findings are consistent with other studies that have found the TPB to predict intention to reduce food waste (Russell et al., 2017), separate kitchen waste (Ghani et al., 2013; Yuan et al., 2016), and source separate municipal waste (Heidari et al., 2018).

However, other studies have found that food waste behaviors were strongly influenced by other constructs, including moral norm (Neubig et al., 2020; Yuan et al., 2016), environmental awareness (Graham-Rowe et al., 2015), and knowledge (Abdelradi, 2018), suggesting that an extended TPB model may offer additional explanatory power. Therefore, we also tested an expanded TPB model that included constructs and background factors verified by the CFA: moral norm, yuck factor, natural living habits, and recycling habits. The expanded model explained 69% of variance in intention, a slightly higher correlation than that of the baseline model (Table 2), but with slightly lower fit statistics. The extended model may provide further insight useful for informing solutions and interventions, as it establishes additional factors and relationships that could be leveraged to influence behavioral changes.

In the extended model, the construct of yuck factor has good fit (Alpha = 0.83, CR = 0.88, and AVE = 0.60) and a significant, negative correlation with intention to separate (β = -0.13). This construct captured beliefs that separating food waste will lead to a negative visceral experience or outcome, such as noxious odor, pest attraction, and messiness in the home. While these beliefs were originally theorized as influencing behavioral control, the results of the CFA and MIMIC model (see Section 2.3.1 and 2.3.2) showed a poor fit in that structure. These beliefs were also tested as determinants of attitude, particularly the measurement related to the pleasant or unpleasant experiences of separating food waste (ATT3), but were also found to be insignificant in that structure. However, future study is required to differentiate how beliefs related to disgust inform experiential dimensions of attitude (Wan et al., 2017) as opposed to behavioral controls or separate constructs that capture negative emotions (Olsen, 2001; Russell et al., 2017).

The importance of the "yuck factor" was consistent with views frequently raised during the elicitation interviews. For example, one

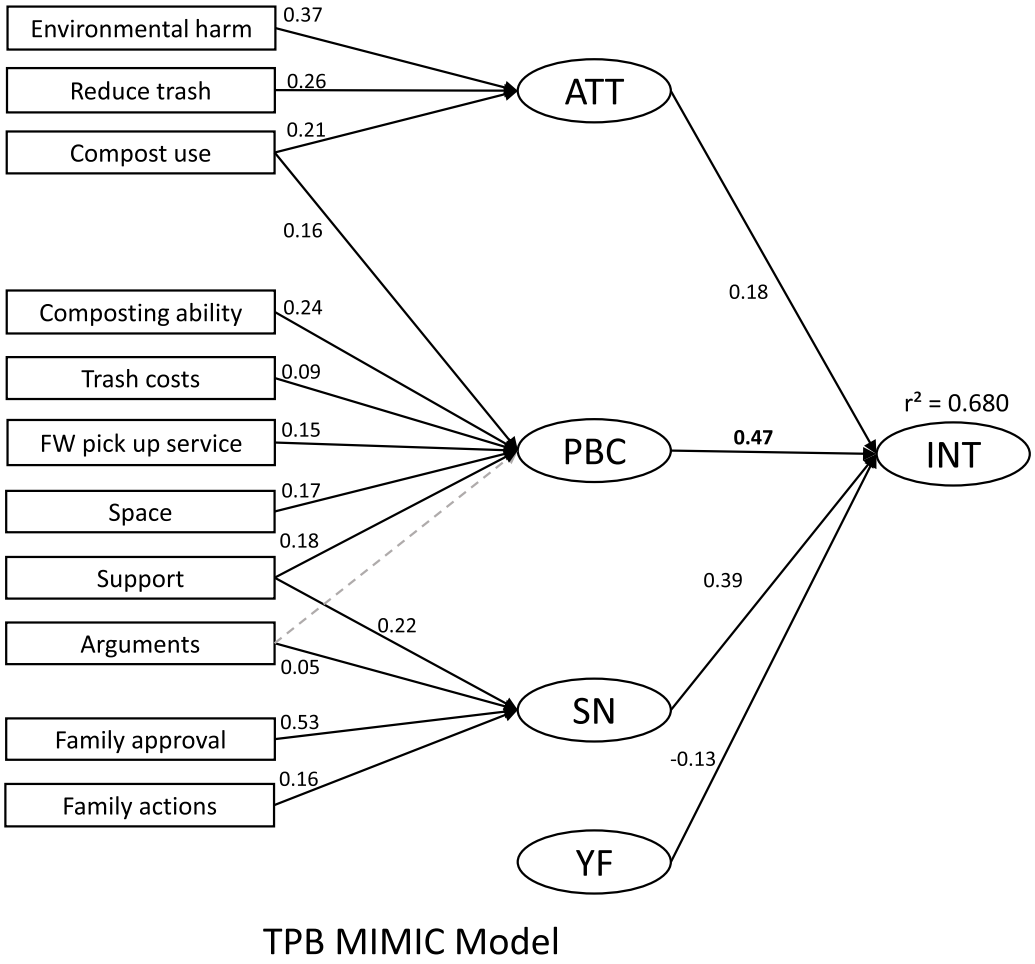

Fig. 3. The TPB MIMIC model highlighting individuals' important beliefs for each respective TPB construct. ATT = attitude, SN = subjective norm, PBC = perceived behavioral control, YF = yuck factor, INT = intention, FW = food waste. The values shown on each arrow indicate the standardized coefficients. Only those beliefs that were significant when tested against each individual construct were carried over to the integrated model shown here; some were then found to be insignificant for the integrated model and are shown here with a broken line. The bold type indicates the highest correlation with intention.

interviewee stated, "the odor was just too much" and another, "pricing is not what prevented us from doing it; it was probably habit and concern over smell." Past work has likewise documented that odor can be a major barrier to participation in curbside collection and organic waste diversion programs (Benyam et al., 2020; Pickering et al., 2020) and that potential for pest attraction may limit municipal recycling (Tonglet et al., 2004). One study assigned beliefs about the outcomes related to odor and bones from seafood consumption to "negative emotions" (Olsen, 2001), but the concept of yuck factor associated with household food waste goes beyond emotion and includes the added physical elements of dealing with food waste, such as physically handling food scraps or spoiled foods. Unappealing appearance, touch, smell, and taste are reasons people throw out food (Andrews et al., 2018) and find leftovers unappetizing (Evans, 2011). This study further adds to this literature by demonstrating how concerns that food waste is "gross" may be a barrier to broader participation in food waste separation and recycling efforts and by highlighting the need for future study to evaluate strategies to overcome these concerns.

The extended TPB model also determined that moral norm ($\beta = 0.72$, Alpha = 0.88, CR = 0.88, AVE = 0.67) is a background factor mediated by the construct of attitude. Respondents appeared to assign moral value to food waste separation due to feelings of obligation, guilt over sending food to landfill and potentially harming the environment, and a responsibility to recycle food waste as a way of benefiting future generations. Yet even with these strong underlying beliefs, the construct of moral norm did not have a significant direct correlation with intention. This finding is consistent with a comparable study on separating food waste in China, which also found that moral norm informed attitude but did not directly inform intent (Yuan et al., 2016). On the other hand, several studies dealing with food waste reduction have observed a much stronger link to moral norm as an activator of behavior changes that may lead to food waste prevention (Graham-Rowe et al., 2015; Neubig et al., 2020). These differences suggest that morality plays a different role influencing individuals depending on whether they are reducing or separating food waste. In fact, individuals may feel less guilty or responsible for wasting food if they know it is going to ultimately be diverted from the landfill (Qi and Roe, 2017).

The distinction between feeling guilt from wasting food and relieving guilt by separating food from the trash was echoed in the elicitation interviews. One respondent indicated, "I feel good about composting my food scraps instead of throwing them away" and another, "I think just knowing that we're not putting things in the landfill that we might have put in before makes me feel a little less guilty." Yet these feelings do not seem to be enough to overcome other barriers that consumers face, including behavioral controls and the yuck factor. One possible explanation is that feelings of morality are warring with feelings of disgust or unpleasantness as this conflict was noted in studies about individuals' attitudes and causes of food waste (Radzymińska et al., 2016), and safety concerns associated with generating food waste (Watson and Meah, 2012).

These issues are further informed by background factors related to individuals' lifestyles and experiences with other behaviors that may be connected to food waste separation. For example, one construct emerged, here termed "natural lifestyle habits," (Alpha = 0.72, CR = 0.73, AVE = 0.49) which included experience with food- and environmentally-related behaviors like gardening, buying foods at local farmer's markets, and purchasing green cleaning products. This emerged as a standalone construct that was mediated by both subjective

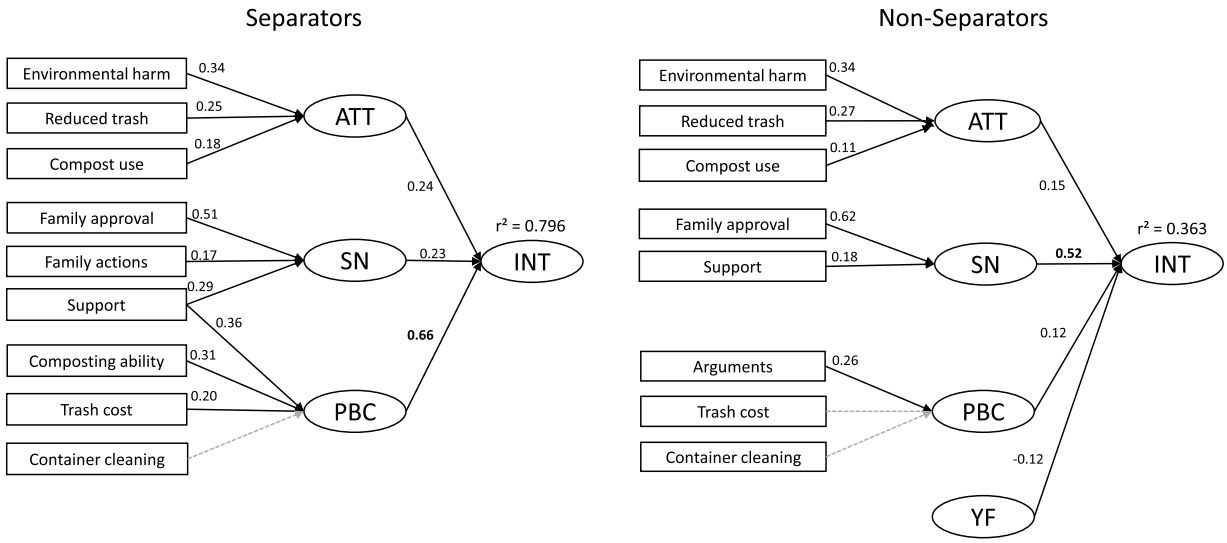

Fig. 4. The MIMIC models for household food waste separators (left) and non-separators (right). ATT = attitude, SN = subjective norm, PBC = perceived behavioral control, YF = yuck factor, INT = intention. The values shown on each arrow indicate the standardized coefficients. Only those beliefs that were significant when tested against each individual construct were carried over to the integrated model shown here; some were then found to be insignificant for the integrated model and are shown here with a broken line. The bold type indicates the highest correlation with intention.

norms ($\beta = 0.73$), and perceived behavioral control ($\beta = 0.58$), likely because of the social pressures that drive actions that form how individuals perceive themselves (Fishbein and Ajzen, 2010). Similarly, the expanded model also included the background factor of "recycling habits" (Alpha = 0.67, CR = 0.67, AVE = 0.51) which included past behavior of recycling both municipal household waste and electronic waste. Recycling habits was mediated by a small but significant correlation with perceived behavioral control ($\beta = 0.18$), suggesting that familiarity with other types of recycling may provide a sense of control and ability to carry out food waste separating, similar to a study that found individuals who participated in municipal waste recycling (glass, paper, and plastic) were less likely to waste food (Abdelradi, 2018) and that current food waste habits influence future intentions to reduce food waste (Riverso et al., 2017). Collectively, these habits may be considered "gateway behaviors" (Prochaska et al., 2008; Sheppard et al., 2012) that nudge people towards participating in similar activities through "positive spillover," which occurs when one pro-environmental behavior increases the likelihood people will perform another (Thomas and Sharp, 2013). For example, household recycling was found to be the initial behavior that motivated consumers to later adopt water and energy conservation behaviors (Berger, 1997). Following this example, food waste separation, collection, and recycling may be more easily adopted if modeled after the familiar curbside recycling pickup systems. Similarly, positive spillover can be encouraged by co-locating food waste educational activities or drop-off sites at farmers' markets, gardening events, or other locations focused on natural living and green products.

3.2. *Identifying underlying beliefs that influence food waste separation intent*

The core constructs comprising the TPB model were further investigated using a MIMIC model to identify the underlying beliefs most strongly associated with behavioral intention (Fig. 3). The TPB MIMIC model's fit statistics met all of the requirements (Table 2). These results show that the most important beliefs informing attitude are those that reflect individuals' concern for the environment and a desire to reduce waste disposal. This finding is consistent with past work linking environmental concerns with attitude regarding source separation of waste (Heidari et al., 2018), kitchen waste separation (Yuan et al., 2016), wasting food (Abdelradi, 2018), and other household waste separation (Nguyen et al., 2015). One challenge, however, is that these beliefs are linked with relatively intangible and uncertain future environmental outcomes, whereas beliefs about the cost, space required, messiness, or anticipated unpleasantness of handling food waste are immediate, tangible barriers that consumers may not be equipped to overcome.

The role of family and other household members also emerged as significant drivers of individuals' behavior. The beliefs with strongest correlations with subjective norm included having family approval for separating ($\beta = 0.53$) and knowing family members who already separate their own food waste ($\beta = 0.16$). We also asked survey respondents if they would have support within their household to separate food waste and if separating would lead to arguments in the home (which may not only be comprised of family members). A significant correlation was observed between household support and both subjective norm ($\beta = 0.22$) and perceived behavioral control ($\beta = 0.17$). In the elicitation interviews, participants often noted the challenge of unsupportive household members: "My family is kind of against it, they reluctantly cooperate" and "I want to do it, but it's my husband, he's not on board with the idea." Overall, the results confirm that individuals experience social pressure to perform a behavior when their respective "in-group" supports or also performs the behavior (Cialdini et al., 1990; Terry and Hogg, 1996). These findings suggest opportunities to leverage family relationships and household support, such as marketing household food waste separation as easy, convenient, fun, and feasible for any member of the household.

Many of the strongest correlations were observed for beliefs related to situational factors or food waste management infrastructure. In the MIMIC TPB model, the important beliefs informing perceived behavioral control are related to adequate space for composting, reducing household trash costs, and having access to a food waste pickup service (Fig. 2). These results suggest that emerging business models that collect food waste from homes can increase an individual's ability to separate food waste, particularly if space for home composting is limited (Layzer and Schulman, 2014). These services typically provide a collection container, handle the transportation and cleaning, and manage the food waste through composting or other processes, thus eliminating the practical barriers that may arise when setting up a home composting system, as well as the messiness and odor issues associated with cleaning a food waste collection container (Yepsen, 2015). In fact, 94% of respondents indicated that having a food waste service as defined in the study would make it easier for them to separate. The cost of such a service was tested as a control belief in the study, but was not significant

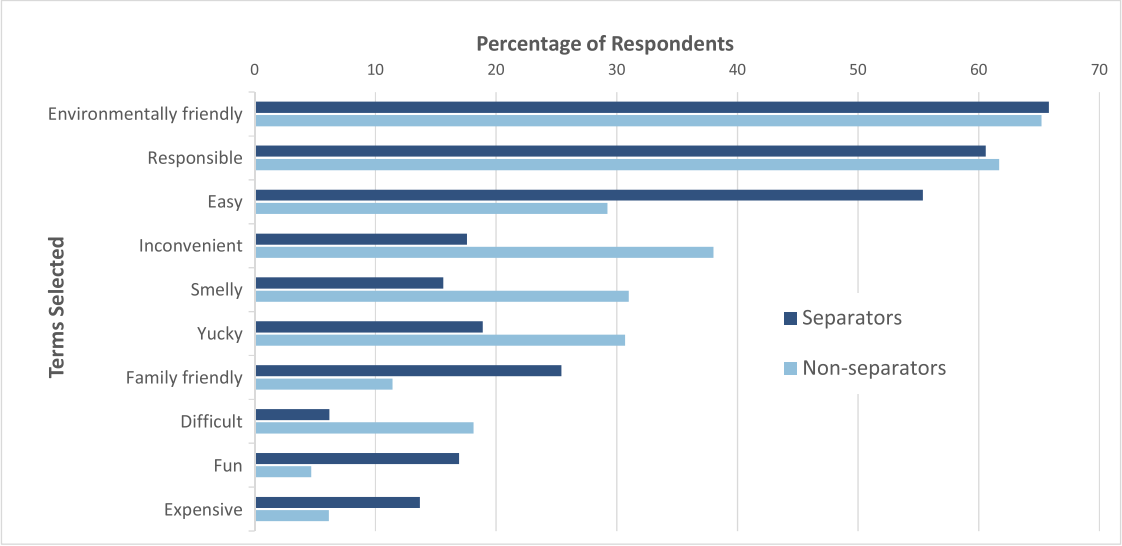

Fig. 5. The percentage of separators (dark bar) and non-separators (light bar) who selected each descriptive word to describe the idea of separating household food waste. Values reflect the percentage of respondents who selected the descriptor as one of three choices from a list of terms they might associate with food waste separation.

in the MIMIC model. Future work should specifically investigate consumer preferences regarding the cost to participate in these services relative to the perceived benefits.

3.3. *Underlying beliefs are different for separators and non-separators*

The survey analysis demonstrated that approximately half of respondents had routinely separated household food waste in the last 12 months. This natural division in the data provided an opportunity to explore how underlying beliefs and behavioral intentions vary between individuals with and without direct experience with food waste. Model construction and analysis were repeated separately for "separators" (n = 307) and "non-separators" (n = 342), resulting in two TPB MIMIC models for comparison (Fig. 4). The model for separators explained 80% of the variance in intent to separate, while the model for non-separators only explained about 40% of this variance.

One major distinction between these groups was a differing belief in their own ability to separate food waste. Separators have a strong sense of control over food waste separation, and perceived behavioral control is the main predictor of intention (β = 0.66). Having the ability to compost the separated food waste is the most important belief informing this construct for separators (β = 0.32). While the TPB model for non-separators only showed a small correlation of perceived behavioral control with intention (β = 0.12), this construct had relatively low explanatory power (r^2 = 0.06), suggesting that there may be other constructs or underlying beliefs not captured here that influence non-separators. These results also suggest that interactive effects that were not tested in the additive TPB model may be occurring. Recent work has shown that greater perceived behavioral control can strengthen the relationship between attitude and intention while lowering the relationship between subjective norm and intention (La Barbera and Ajzen, 2020, 2021). Separators exhibit stronger behavioral control and a stronger relationship between attitude and intention compared to non-separators.

To investigate non-separators' perspectives further, we evaluated the differences in responses between the two groups when asked to select terms they strongly associate with household food waste separation (Fig. 5). Non-separators described the act of separating as "inconvenient" or "difficult" twice as frequently as separators, who more commonly described it as "easy" and even "fun" (Fig. 5). Further, non-separators had much higher valuations of key control beliefs as making it harder to separate. For example, more non-separators indicated that cleaning a collection container and concerns about space, odor, pests, and messiness in the home (Fig. 6) would make separating a lot harder. These findings mirror a recycling study in the EU, which found that people who did not sort their waste were more concerned about convenience factors (Minelgaitė and Liobikienė, 2019).

Some initial comparisons may help provide additional interpretation on the differences between the two groups. When presented with the statement, "I want to separate, but there are reasons why I can't," non-separators indicated that this statement describes them significantly more when compared to those who had source separated food waste in the last year (Wilcoxon rank-sum test: w = 58,830, p-value = 0.0058, where w is the test statistic and the p-value indicates significance at alpha = 0.05). Thus, non-separators may face different barriers or factors outside of their control. For example, separators were significantly more likely to own their home, and non-separators were significantly more likely to rent (w = 60,266, p-value = 2.7E-6). Home ownership may allow separators to have more control over kitchen set-up to collect food scraps or access to outdoor areas that provide space for composting. These differences may also be a consequence of the size and space of the living quarters or the expected concentration of rentals in urban areas with less outdoor areas for composting.

Both separators and non-separators express a positive attitude towards food waste separation as informed by pro-environmental beliefs, but non-separators are far more likely to have negative feelings related to the "yuck factor." Notably, the yuck factor construct is only significant in the MIMIC model for non-separators (Fig. 4) and is negatively correlated with intent (β = -0.12). When selecting terms that describe household food waste separation, both groups frequently chose "environmentally friendly" and "responsible," but non-separators selected "yucky" and "smelly" about twice as frequently as separators (Fig. 5). Non-separators describe food waste separation as unpleasant at a significantly higher rate than separators (w = 31,731, p-value = 2.2E-16) and report that odor, pests, messiness and cleaning a food waste container would make separation more difficult (Fig. 6). Non-separators may either have a disproportionate expectation that the behavior is unhygienic because they have never directly experienced it or they have not yet found solutions to manage the challenges of odor, pest attraction and messiness, which separators may have overcome through time and experience.

Family is important to both separators and non-separators, but in

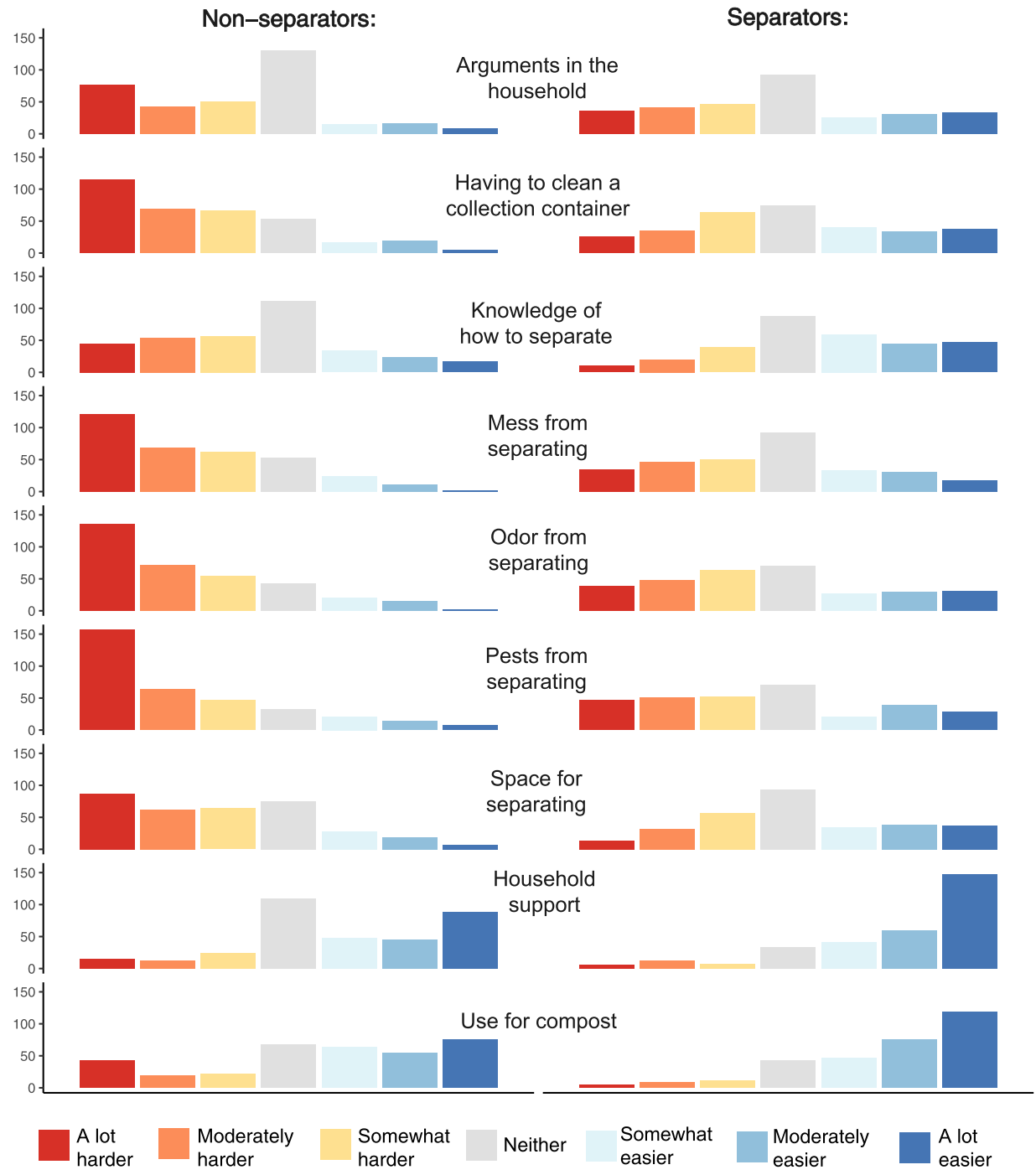

Fig. 6. A comparison between the control beliefs that separators and non-separators assess to make it easier or harder to separate household food waste. The y-axes represent the number of respondents who rated each control belief according to the descriptors shown on the x-axis. Wilcoxon rank-sum tests revealed statistically significant ($p < .05$) differences between separators and non-separators for all of the belief categories pictured above, except for "arguments in the household" ($p = 0.057$).

different ways. For both groups, subjective norm is largely influenced by family approval of separating ($\beta = 0.51$ for separators and $\beta = 0.62$ for non-separators) and having support in the home to separate ($\beta = 0.29$ for separators and $\beta = 0.18$ for non-separators). However, the belief about having family members who also separate food waste (family actions) is only important for separators ($\beta = 0.17$). Separators were significantly more likely to say that they would separate if their neighbors were doing the same ($w = 31{,}996$, p-value = 2.2E-16). This finding is consistent with past work that found that individual's involvement in waste separating behaviors could be encouraged by providing information about their neighbors' participation (Ghani et al., 2013). It may also be possible that non-separators know fewer people who actually separate their own food waste: 53% of non-separators reported that they do not have family who separates, and 20% said they don't know if their family separates or not. Since non-separators may desire to change their behavior but lack an example of how to do it, connecting with others who have this experience could provide compelling examples and share best practices and tactics to manage odor and pest challenges.

4. Implications and extensions

The purpose of this study was to use the TPB to identify the important factors and beliefs that inform individuals' intention to separate household food waste and understand the differences in beliefs held between separators and non-separators. The results point to three areas that might be leveraged to enable food waste separation for landfill diversion: education, business models, and policy. This section further interprets the findings in the context of these potential interventions.

4.1. Potential intervention strategies

Results demonstrate that actions, opinions, and support of family and household members play an important role in shaping an individual's intention to source separate household food waste. Some respondents emphasized their children as inspirations or catalysts for separating food waste, with one interview subject noting "my kids compost at school, so we do it at home." In fact, households with children in the home were significantly more likely to have source separated household food waste in the past year ($w = 62{,}677$, $p = 3.55\text{E-}14$). Thus, educational interventions in primary and secondary schools may present an opportunity to indirectly influence households' food waste practices (Ohshima, 2013) by educating their children about food waste impacts and separation practices (Antón-Peset et al., 2021). Informal education may also play a role to convey the environmental benefits of food waste management as a means to foster participation in pro-environmental behaviors (Lemaire and Limbourg, 2019) as past work has documented correlations between educational efforts and behavior (Aschemann-Witzel et al., 2015). However, education alone is not enough to help people overcome barriers to perform a behavior (Wilson, 1996), rather, informal knowledge sharing through face-to-face interactions (Bernstad et al., 2013) and word-of-mouth (Qi and Roe, 2016), either in person or online (Goldsmith and Goldsmith, 2011; Wharton et al., 2021), may be more effective in increasing engagement and participation. Leveraging these communication practices, while at the same time engaging family and household members, could help non-separators learn methods to overcome perceived nuisances, like pests and odor.

Results also suggest that the availability of food waste pick-up services may facilitate source separation by increasing individuals' perceived ability to handle wasted food (Fig. 3). Residential food waste collection programs remove the responsibility of downstream management of the food waste from the individual and may overcome the beliefs that separation will lead to odor, mess, pests, or having to clean a collection container, all of which are significantly higher for those who do not currently separate food waste (Fig. 6). These programs may also address some of the structural barriers noted earlier, like concern over space for separating and ability to separate in a rental. Thus, there is an opportunity for new circular business models that provide a convenient way for consumers to divert waste from landfill, while at the same time recovering the resources contained in wasted food (OECD, 2018), and creating added value within a community (Bocken et al., 2021). These services, offered by municipal programs and private companies, are available throughout NYS and nationally (CompostNow, 2021). Food waste services are relatively new business models and have a wide array of operational modalities (Yepsen, 2015). Ongoing research is needed to understand how these businesses can contribute towards a circular economy (Närvänen et al., 2021) and if and how their service models are likely to help individuals overcome participation barriers for household food waste separation.

Such services may also enhance consumer participation if they simultaneously provide feedback about environmental outcomes of landfill diversion. Here, we show that pro-environmental beliefs contribute to individuals' positive attitudes (Fig. 3), but suggest that these may not be sufficient to overcome practical barriers of handling food waste. Thus, the method and form of conveying information should go beyond environmental messaging. Types of consumer feedback that have been successful at increasing participation in waste management schemes include economic rewards (Xu et al., 2018), technology feedback (i.e. smart bins, bin-cams, and fridge-cams) (Bandyopadhyay and Dalvi, 2017; Comber and Thieme, 2013; Ganglbauer et al., 2013; Lim et al., 2017), and gamification (Soma et al., 2020). Social group feedback, also called norm messaging (Sintov et al., 2019; Thomas and Sharp, 2013), has been effective to motivate consumers to participate in energy saving behavior (Allcott, 2011). This technique may be extensible to food waste behavior if consumers can see how their separation behavior compares to that of their neighbors. Food waste pick-up services may ultimately turn what has previously been a private behavior (home composting) into a more a visible behavior by putting food waste collection containers at curbside for pick up or facilitating drop-off at high visibility locations. Future research should investigate how food waste businesses communicate to consumers and what types of feedback strategies, if any, are most successful.

Circular business models, like food waste pick-up services, have the potential to meet consumer and community food waste management needs, but cost may also be a factor (Fig. 3). Past work has shown that the net cost of residential food waste services will significantly decline once a certain density of participation in a city or neighborhood is achieved (Armington and Chen, 2018). But overcoming the initial economic hurdles may require government investment or policy support. Currently, however, the majority of policy efforts in the U.S. do not cover residential food waste management. For example, policies including organic waste recovery mandates and landfill bans have been enacted in several states, but these typically only require compliance by large commercial and institutional food waste generators (Broad Leib et al., 2018). However, such policies may indirectly benefit residential service through expansion of transportation and treatment infrastructure that ultimately reduces costs of landfill diversion pathways for households as well. For example, state investment in food waste infrastructure (Shahid and Hittinger, 2021) may reduce costs of currently inefficient hauling and collection systems (ReFED, 2016) and remove regulatory barriers that stunt the growth of businesses and programs targeting household food waste (Pai et al., 2019). However, more research is required as the impact of government mandates on residential food waste collection and management programs in the U.S. has not been widely studied.

4.2. Limitations and future work

One limitation to the use of the TPB model is the focus on measuring behavioral intention rather than assessing the behavior itself, although this approach is typically necessary due to the time and difficulty involved in directly measuring certain behaviors (Ajzen, 1991). Intention is the first precursor to behavior, and here we do see a significant, positive correlation between self-reported separation behavior in the last 12 months and intention to separate food waste in the next year ($\beta = 0.89$). However, precedent and intention do not guarantee that the behavior will actually be implemented in the future (Sheeran, 2002). Ideally, longitudinal studies would subsequently be conducted to directly assess household food waste separation before and after the implementation of proposed intervention strategies. Further, the results suggest a need for more study specifically focused on individuals with no past experience separating food waste to identify beliefs and barriers not yet captured here. The R-squared value for perceived behavioral control for non-separators was small, with only one significant underlying belief, suggesting that there are additional or more varied beliefs that inform these individuals' sense of control or ability to separate.

This study investigates the beliefs and factors influencing individuals' intention to separate in a specific region of the U.S., a scope selected to control for regional variability in food waste infrastructure and policy, which may influence how consumers view or experience source separation. However, by focusing on one state, even one as large and as geographically and culturally diverse as NYS, the findings may

not be fully generalizable to other regions. Additionally, while efforts were made to mitigate and detect common method biases, some uncertainty is introduced by using questionnaire data collected from common raters, which may have been a factor in common item content across some indicators of attitude and perceived behavior control. While this was addressed here by adding error covariance terms within the model, questionnaire instruments can be further improved with greater knowledge of food waste management behaviors and beliefs to better measure items that distinctly inform the TPB constructs. In addition, survey respondents were recruited through a panel in to fulfill demographic quotas to match reported 2019 NYS percentages (for ethnicity, gender, and age), but opportunistic sampling also took place via social media platforms, which led to a small subset of data that skewed slightly higher than the NYS distribution for non-Hispanic white adults and females and respondents with college education. Future work can extend this analysis to evaluate the beliefs and factors influencing individuals' separation intention in other geographical areas with different policy, infrastructure, and demographics.

5. Conclusion

Landfilled food waste creates a wide array of social, economic, and environmental impacts that may be mitigated by alternate management pathways. However, landfill diversion hinges on consumer willingness to source separate food waste that can then be recovered either by home composting or by businesses who collect and handle wastes for them. The TPB models presented here provide new insight into individuals' underlying beliefs and the factors that may ultimately help or hinder household food waste separation. The TPB model was found to predict intention to separate household food waste, and provide additional insight by adding the new construct of yuck factor (the unhygienic challenges of food waste separation) and the background factors of moral norm and natural living and recycling habits. When investigating underlying beliefs that inform these constructs, results show that individuals express positive attitudes and a desire for the pro-environmental benefits of food waste separation, but also face situational barriers that limit their perceived practical ability to participate in this behavior.

Barriers to food waste separation include structural issues, such as lack of knowledge or space for food waste collection containers, as well as more personal concerns, such as the belief that food waste will lead to odor or pests in their home or arguments among household members. Those individuals with experience separating food waste had a significantly higher sense of control and ability to perform this behavior, suggesting that they have developed strategies to overcome the so-called "yuck factor" or have realized these concerns are not as bad as non-separators may fear. Overcoming these barriers will require intervention strategies that expand knowledge on how to effectively source separate household food waste and the benefits of doing so as well as efforts to expand policy and infrastructure to increase collection services and reduce costs of participating. The recent emergence of business and municipal services that provide household food waste pick-up in the U.S. provide a compelling opportunity to study if these strategies can meaningfully engage consumers in landfill diversion solutions.

CRediT authorship contribution statement

Jessica M. Oehman: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft. **Callie W. Babbitt:** Conceptualization, Writing – review & editing, Funding acquisition. **Carli Flynn:** Conceptualization, Methodology, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

All data and codes are publicly available on an open access repository (figshare) that is cited within the paper (Oehman, 2022).

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.resconrec.2022.106492.

Appendix

Table A1
Representative interview quotes, literature sources, and survey questions that ultimately defined the hypothesized latent variables.

Interview Quotes	Construct	Literature	Survey Question
"But just in general it was just something that we thought was a good thing to do."	Attitude	Barone et al., 2019; Greaves et al., 2013; Kumar, 2019; Russell et al., 2017	ATT1: Separating HFW is…extremely bad/extremely good to do ATT2: Separating HFW is…extremely worthless/extremely worthwhile *ATT3: The activity of separating household food waste is…extremely unpleasant/extremely pleasant ATT4: Separating HFW is…a complete waste of time/a completely good use of time
"My family is kind of against it. They reluctantly cooperate."	Subjective Norm	Barone et al., 2019; de Leeuw et al., 2015; Nguyen et al., 2015	SN1: People important to me…approve of separating HFW (strongly disagree to strongly agree) SN2: People important to me…separate their own HFW (strongly disagree to strongly agree) SN3: People important to me…think separating HFW is a good thing to do (strongly disagree to strongly agree)

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Table A1 (*continued*)

Interview Quotes	Construct	Literature	Survey Question
"I didn't want to manage the compost myself." "I didn't feel like I had the mental or actual time to invest in the cheaper option." "My wife and I would talk about it first."	Perceived behavioral control	Barone et al., 2019; de Leeuw et al., 2015; Khan et al., 2019; Russell et al., 2017	PBC1: Is it your decision whether or not you separate HFW in the next 12 months? (not my decision to completely my decision) PBC2: How much control do you have over separating the food waste in your household? (no control to complete control) PBC3: Do you have the ability to separate your HFW? (No to completely)
"The intention would be there, the ability to execute I'm not sure."	Intention	Barone et al., 2019; de Leeuw et al., 2015; Heidari et al., 2018	INT1: How often do you plan to separate in the next 12 months? (never to always) INT2: How much of your HFW do you plan to separate in the next 12 months? (none to all of it) INT3: I am determined to separate HFW in the next 12 months (does not describe me, completely describes me)
"I think just knowing that we're not putting things in the landfill that we might have put in a landfill before. And it also makes me feel a little less guilty. I do have some food waste.	Moral Norm	Kumar, 2019; Si et al., 2020; Tonglet et al., 2004	MN1: Separating HFW will benefit future generations (strongly disagree to strongly agree) MN2: Separating HFW is the right thing to do (strongly disagree to strongly agree) MN3: Separating HFW reduces guilt (strongly disagree to strongly agree) MN4: Separating HFW is the duty of a responsible citizen (strongly disagree to strongly agree)
"We would pick those up at the farmer's market and use them in our own garden." "I'm a fairly avid gardener" "We are heavy duty recyclers." "We have one here for newspaper papers and the other one for plastic and metal and glass and I do that faithfully." "We recycle everything we possibly can."	Natural Lifestyle Habits, Recycling Habits	Abdelradi, 2018; Edgerton et al., 2009	NLH1: I garden at my home (does not describe me to completely describes me) NLH2: I visit local farmers' markets (does not describe me to completely describes me) NLH3: I purchase green cleaning products (does not describe me to completely describes me) *NLH4: I give money to charity (does not describe me to completely describes me) *NLH5: I follow a vegetarian diet (does not describe me to completely describes me) *NLH6: I drive a hybrid or electric vehicle (does not describe me to completely describes me) **RH1: I recycle electronics (does not describe me to completely describes me) **RH2: I recycle items such as cans, bottles, paper, cardboard, or glass (does not describe me to completely describes me)

*Denotes survey questions that were removed from the respective construct during the CFA (see Section 2.0 Methods), and **Indicates survey questions that formed a separate construct during the CFA.

Table A2
Representative interview quotes, literature sources, and survey questions used to assess formative beliefs.

Interview Quote	Expectancy and Value Questions
"I don't know that I enjoy it, but it's important to me to feel like I'm not just sending things off to the landfill, I really hate that." "You know it feels somewhat expensive. It seems like a luxury to me to be able to have that kind of pick up except that we're saving money in that we're doing that every other week trash pickup.	**Behavioral Beliefs** (Responses given on a unipolar scale, 1= not likely to 5 = completely likely) Question: Separating household food waste would… reduce harm to the environment reduce the amount of trash sent to the landfill reduce my household trash costs **Behavioral Belief Evaluations** (Responses given on a bipolar scale, −3 = extremely unimportant to +3 = extremely important) Question: If the above outcomes happen, how important are they to you?
"I want to do it. But it's my husband." "After we started this my one friend started out. And a woman at work. And my niece is like 'I want to do that.'" "A neighbor a couple of neighbors really were pretty influential in our decision to take it on."	**Injunctive Norm Beliefs** (Responses given on a bipolar Scale, −3 = completely disapprove, +3 = completely approve) Question: In general, would the following people approve of you separating household food waste? Family, Friends, Neighbors **Injunctive Norm Motivation to Comply** (Responses given on a unipolar scale, 1 = not motivated, to 5 = completely motivated) Question: When it comes to separating household food waste are you motivated to do what people think you should?
"My son is really good about it. My daughter not so much. She'll do it if I ask her." "It was a mix of independent discovery and then also knowing that other people were using the service." "A neighbor, a couple of neighbors really were pretty influential in our decision to take it on."	**Descriptive Norm Beliefs** (Responses given on a bipolar scale −3 = definitely do not, to +3 = definitely do) Question: In general, do people in the following groups separate their own household food waste? Family, Friends, Neighbors **Descriptive Norm Motivation to Comply** (Responses given on a unipolar scale, 1 = not motivated to 5 = completely motivated) Question: When it comes to separating household food waste, are you

(*continued on next page*)

Table A2 (*continued*)

Interview Quote	Expectancy and Value Questions
	motivated to do what these people do? Family, Friends, Neighbors
"I guess just not feeling like time-wise it was going to be feasible to do what it took to have a good DIY option." "I thought yeah that's a good idea but I don't have room in my backyard for something like this." "Ok so it's a bit of kind of like a learning curve for composting." "I guess I have one friend that has been kind of like oh yeah this is a good option, I'm glad you have this kind of thing. It hasn't made her decide to do it because of financial constraints but she's in favor of it." "I like the convenience of having someone take it. The convenience factor of having someone pick it up was huge for me." "Pricing is not what prevented us from doing it, it was probably habit and concern over smell."	**Perceived Behavioral Control Beliefs** (Responses given on a unipolar scale, 1 = not likely to 5 = completely likely) Question: Do you think these situations are likely to occur in the next 12 months? I will be too busy to separate food waste I will have enough space in my home to separate food waste I will have sufficient knowledge of how to separate food waste It will cost me money to separate A food waste pick up service will be available to me A food waste drop-off location will be available There would be arguments in my household about separating People in my household would be supportive of separating I would have to clean out a collection container I have the ability to compost food waste I will have a use for the compost (in a garden for example) *The food waste would cause an unpleasant odor in my home *The food waste would attract pests such as insects, rodents, or other animals *The food waste would cause my kitchen to be messy **Perceived Behavioral Control Powers** (Responses given on a bipolar scale, -3 = a lot harder to +3 = a lot easier) Do these situations make it easier or harder to separate household food waste?

*Indicates the three control belief questions which ultimately formed the yuck factor (YF) construct.
Literature used here: Abdelradi, 2018; de Leeuw et al., 2015; Greaves et al., 2013; Heidari et al., 2018; Huffman et al., 2014; Ghani et al., 2013; Khan et al., 2019; Mak et al., 2018; Minelgaitė and Liobikienė, 2019; Nguyen et al., 2015; Russell et al., 2017; Sidique et al., 2010; Tonglet et al., 2004; Wang et al., 2016; Yuan et al., 2016.

Table A3
The Chronbach's alpha (Alpha), average variance extracted (AVE) and construct reliability (CR) of each latent variable as defined as a result of the CFA. NLH was kept because when rounded the AVE value meets the 0.5 cutoff. ATT = attitude, SN = subjective norm, PBC = perceived behavioral control, INT = intention, MN = moral norm; NLH = natural living habits; RH = recycling habits; YF = yuck factor.

	ATT	SN	PBC	INT	MN	NLH	RH	YF
Alpha >0.7	0.89	0.89	0.82	0.95	0.88	0.72	0.67	0.83
AVE >0.5	0.74	0.74	0.62	0.86	0.67	0.49	0.51	0.60
CR >0.7	0.89	0.89	0.83	0.95	0.88	0.73	0.67	0.88

Table A4
Discriminant validity of the latent variables as defined as a result of the CFA. The bold numbers on the diagonal are the AVE. Below the diagonal are the correlations between the latent variables (r). Above the diagonal (italicized) are the squared correlations (r^2) of the latent variables. In accordance with Kline's recommendations (Kline, 2016), the r^2 values should be less than the AVE to achieve discriminant validity. The variables here reflect adequate discriminant validity. ATT = attitude, SN = subjective norm, PBC = perceived behavioral control, INT = intention, MN = moral norm; NLH = natural living habits; RH = recycling habits; YF = yuck factor.

	ATT	SN	PBC	INT	MN	NLH	RH	YF
ATT	**0.75**	*0.21*	*0.12*	*0.27*	*0.61*	*0.14*	*0.21*	*0.04*
SN	0.46	**0.74**	*0.19*	*0.50*	*0.36*	*0.08*	*0.08*	*0.02*
PBC	0.35	0.43	**0.62**	*0.30*	*0.18*	*0.17*	*0.17*	*0.01*
INT	0.52	0.71	0.55	**0.86**	*0.33*	*0.09*	*0.09*	*0.08*
MN	0.78	0.60	0.43	0.57	**0.67**	*0.23*	*0.23*	*0.02*
NLH	0.37	0.59	0.41	0.64	0.45	**0.49**	*0.12*	*0.02*
RH	0.46	0.28	0.42	0.30	0.48	0.35	**0.51**	*0.00*
YF	-0.20	-0.15	-0.12	-0.28	-0.15	-0.14	-0.07	**0.60**

Table A5
The demographic statistics for the survey data, compared to 2019 NYS statistics where appropriate. The total sample size was $n = 649$. The data in the NYS column are from (Duffin, 2021; US Census Bureau 2015, 2019, 2020).

Demographic	Number of Respondents	Percent of Respondents	Percent in NYS
Ethnicity	**n**	**%**	**NYS%**
Non-Hispanic White	435	67.4	62
Non-Hispanic Black	67	10.4	12
Hispanic, Latinx, or Spanish Origin	94	14.6	17
Asian	28	4.3	5
American Indian or Alaska Native	5	0.8	1
Other	16	1.9	2
Prefer not to answer	4	0.6	NA
Gender	**n**	**%**	**NYS%**
Female	370	57	48.6

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Table A5 (*continued*)

Demographic	Number of Respondents	Percent of Respondents	Percent in NYS
Male	272	42	51.4
Prefer not to answer	7	1.0	NA
Age	**n**	**%**	**NYS%**
18–24	71	10.9	11.4
25–34	104	16.0	18.5
35–44	116	17.9	15.8
45–54	127	19.6	16.0
55–64	118	18.2	17.0
65+	113	17.4	21.3
Income	**n**	**%**	**NYS%**
Less than $19,999	64	9.9	18.1
$20,000-$39,999	106	16.4	17.7
$40,000-$59,999	68	10.5	14.7
$60,000-$74,999	61	9.4	9.3
$75,000-$99,999	89	13.8	11.9
$100,000-$149,999	95	14.7	14.4
More than $150,000	128	19.8	14.0
Prefer not to disclose	38	5.4	NA
Education	**n**	**%**	**NYS%**
Less than high school degree	12	1.8	6.6
High school degree or equivalent	132	20.3	25.8
Associates (2 yr degree)	83	12.8	8.8
Bachelor's (4 yr degree)	181	27.9	21.2
Graduate degree	221	34.1	16.6
Other	20	3.1	NA

Table A6
Additional demographics collected in this survey.

Respondent Information	Number of Respondents	Percent of Respondents
Residence Type	**n**	**%**
Owned by you or someone in your household	453	70
Rented by you	190	29
Other	6	1
Children in the household	**n**	**%**
Yes	284	43.8
Sometimes	25	3.9
No	338	52.1

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